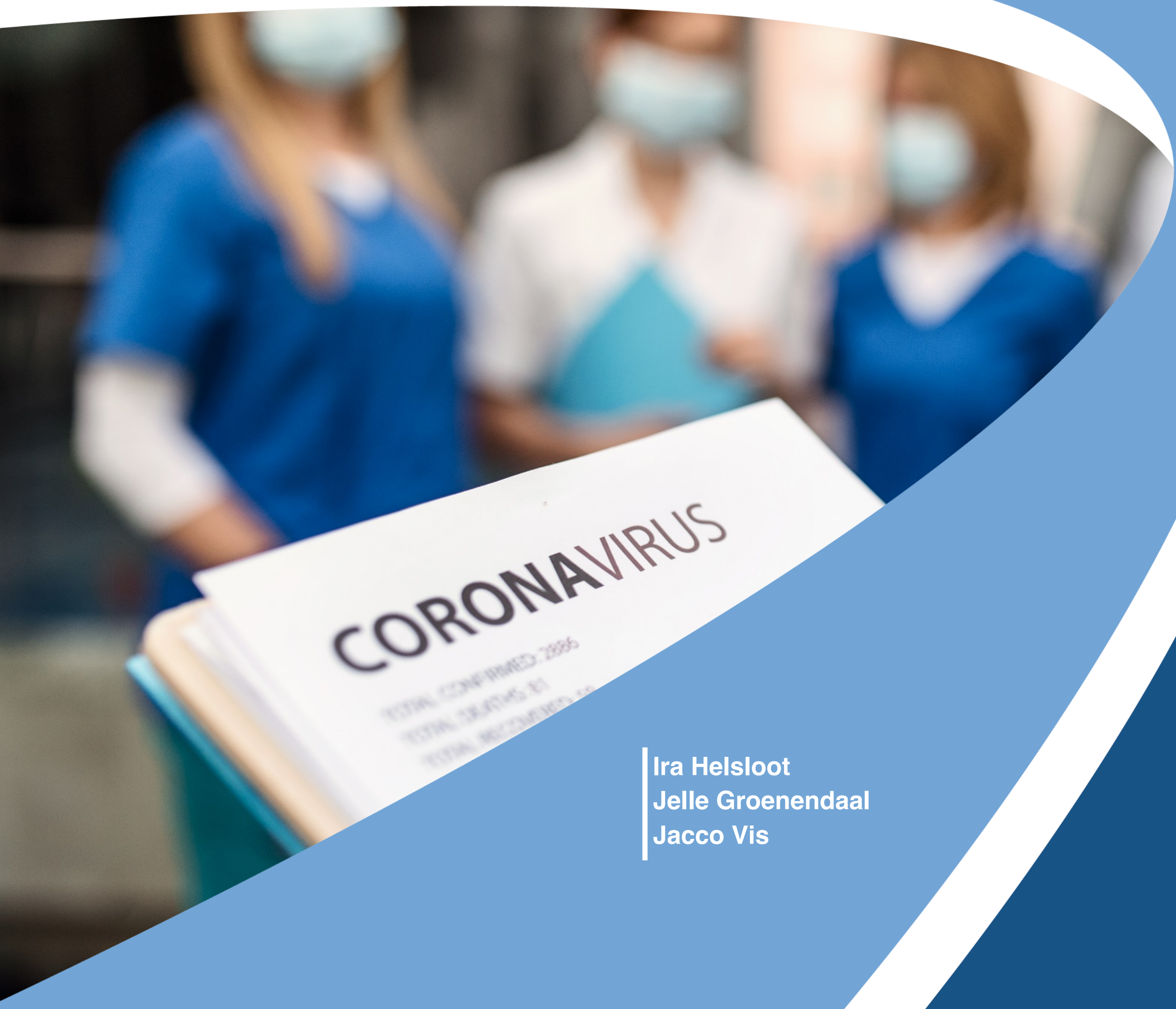
CrisisLab

What do we know about the coronavirus, up to this point, and what does this mean for events?



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Crisislab foundation is the research group supporting the chair on the governance of safety and security at the Radboud University Nijmegen. The objective of Crisislab is the development and distribution of knowledge in the areas of crisis management and safety governance. The core activity of Crisislab is empirically funded research on safety, because these days, facts are often lacking in making policy on and discussing risk and safety management. Based on this research, we advise authorities and businesses to arrive at reasonable and proportional safety policy. The exercises and courses we provide are aimed at dealing realistically with crisis mechanisms and with a resilient society.

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Version 24 August 2020

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1 Introduction

1.1 The beginning

On March 15, 2020 the Dutch Government decided to take severe measures to confront the new coronavirus (in medical terms the virus is called SARS-CoV-2; here, we will call it the coronavirus). Schools, childcare centres, sport and fitness clubs and bars and restaurants, among other businesses, had to close their doors on March 16.[1] Shortly before that date, companies were requested to ask their employees to work from home as much as possible and events and concert with over 100 visitors had been cancelled.

That the coronavirus was a potential threat for the public health at that time is not up for discussion. Based on the data communicated by the WHO at the time, it seemed a credible scenario that about 60% of the population would have been hit, without taking any measures, and the mortality risk would be 1%. This would have made it comparable to historic epidemics like the Spanish flu (1918) and the Hong Kong flu (1968). Based on this estimate, a response from the Dutch government would have been inevitable.

> *"In the most pessimistic scenario, which I do not espouse, if the new coronavirus infects 60% of the global population and 1% of the infected people die, that will translate into more than 40 million deaths globally, matching the 1918 influenza pandemic. The vast majority of this hecatomb would be people with limited life expectancies. That's in contract to 1918, when many young people died. One can only hope that, much like in 1918, life will continue. Conversely, with lockdowns of months, if not years, life largely stops, short-term and long-term consequences are entirely unknown and billions, not just millions, of lives may be eventually at stake."*[2]

Nearly five months after the proclamation of these severe measures, there is still very much unclear about the facts upon which the Dutch policy was based. The government says it consults the *Outbreak Management Team* (OMT). Contrary to the advice by the OMT, the minutes and the scientific records have not been made public.

Therefore, it comes as no surprise that more and more criticism is expressed against the measures and their proportionality in the public debate about the battle against the coronavirus. Politicians[3], scientists[4], health care workers[5] and opinionmakers[6] have all questioned – the scientific foundation of – the effectiveness of the measures or wonder if

[1] Rijksoverheid (2020).
[2] Skerrett (2020).
[3] Kieskamp (2020).
[4] NOS (2020a).
[5] Quekel (2020).
[6] NOS (2020b).

the negative effects of the measures are sufficiently considered. Also, the proportionality of the measures is questioned by some.[7]

It is clear that in the past five months, many scientific insights have been gained about the risk of the coronavirus, the way its spreads and the effects of the measures to fight it. Yet nothing is communicated by Dutch authorities about those facts and if these suit the Dutch policy or not.

For this reason, concert organiser Mojo has asked Crisislab to write down the facts as they are known in scientific literature at this moment, medio August 2020. Mojo is especially interested in their significance for indoor and outdoor events. Mojo has expressed as their starting point their wish to take measures (to prevent the spread of the coronavirus) that are related to the actual risk of the virus. Therefore, they want to have insight in this risk and how it relates to other daily risks.

1.2 Central and subsidiary questions

The central question of this report is the following:

> **What is known in scientific literature at this point in time about – the effects of the measures against – the transmission of the coronavirus and what is the meaning of this for the organisers of events?**

This central question will be discussed by looking at the following subsidiary questions:

1. What is known in scientific literature about the transmission and mortality[8] of the coronavirus?
   a. Infectivity of the virus.
   b. Primary routes of infection.
   c. Indoor versus outdoor transmission.
   d. Transmission through singing/cheering/dancing.
   e. Effect of sunlight/UV on coronavirus.
   f. Chance of dying (mortality).

2. What is known in literature about the effects of the measures against the spread of the coronavirus?
   a. Keeping a distance of 1.5 metre.
   b. Use of mouth masks.
   c. Ventilation inside.
   d. Use of UV.
   e. Cancelling events.

[7] Teeffelen (2020).
[8] This is the percentage of people dying after getting infected with the coronavirus.

3. How does the risk to contract corona relate to other daily risks?

The outcome of the answers to the central and subsidiary questions will be discussed in the Conclusion.

1.3 Delineation

The study is specifically focused on the new coronavirus (SARS-CoV-2). In this report we will only use ‘coronavirus’ for reasons of readability, but this should be read as ‘the new coronavirus’, for the sake of completeness.

In discussing scientific literature about the effects of the measures against the spread of the coronavirus, we have limited ourselves to five measures that could potentially have a substantial impact on the events industry. These measures are keeping a distance of 1.5 metres, using face masks, ventilation, UV radiation and cancelling events.

1.4 Approach of the study

Key in chapters 2 and 3 is the analysis of scientific literature about the – effectiveness of the measures against the – transmission of the coronavirus. We went to work as described below.

During the search for scientific literature we principally used two search engines: PubMed and Google Scholar. In each chapter we will indicate the search terms we used when looking for scientific literature. We have looked primarily for peer-reviewed papers. However, because the coronavirus is only known for some months, and because of the speed of relevant developments and advancing insights, we have chosen to not limit our selection to peer-reviewed articles, but also look at papers that were placed online, for example by Medrxiv[9], that haven’t yet been subjected to reviews by academic peers. If we would have limited ourselves to only use peer-reviewed papers, this would mean we wouldn’t have been able to use a lot of relevant and recent information, due to the fact they hadn’t been through the time-consuming process of a peer review. In the case of these papers, we explicitly added the term ‘not peer-reviewed’ in our footnotes. For references that do not have this addition, a peer review has taken place.

Besides using these two search engines, we have also found articles by tracing sources in the literature we found, a so-called cross-reference search, and by tips received from third parties.

The search for scientific literature was finished at the start of August 2020. This makes this report a sort of snapshot of the current state of coronavirus science. In view of the fast

[9] Medrxiv is a site where pre-prints of medical articles can be pre-published. This allows for a quick access of relevant knowledge. Articles that are pre-published here, have generally not been reviewed by peers, but do count as scientifically sound papers. This means they have been checked for plagiarism and can be cited.

development in scientific knowledge about the coronavirus, this report should ideally be kept up to date with current findings in scientific literature.

1.5 Reader's guide

This report has the following structure:

Chapter 2 describes the scientific literature about the transmission and mortality of the coronavirus.

Chapter 3 elaborates on the effects of the measures against the spread of the coronavirus found in scientific literature.

Chapter 4 tackles the infection risk of the coronavirus and places this in a broader perspective by comparing this risk with other daily risks.

Chapter 5 is the conclusion, where we summarize all our findings and the meaning of the previous Chapters for the events industry.

2 Scientific literature about the transmission and mortality of the coronavirus

This chapter describes the findings in scientific literature about the spread and the mortality of the coronavirus. Thus, this Chapter will answer subsidiary question 1.

2.1 Introduction

This Chapter explores scientific literature about the transmission and mortality (the number of infected people who die as a result) of the coronavirus.

In the first paragraph of this Chapter we elaborate on the infectivity of the virus.

Then the three routes of infection are explained, as described in literature: infection through direct contact with large drops, indirect contact with large drops (by touching large, infected surface areas) and transmission by air through droplets, the so-called aerosols. For each possible route of infection, we indicate the plausibility of the role of this route in the spread of the virus, based on scientific literature.

In the paragraphs 2.4 to 2.6 we discuss the three conditions needed to either increase or decrease the risk of infection: being indoors or outdoors, the influence of singing, cheering and dancing and, finally, the effect of sunlight and/or UV radiation on the coronavirus.

In the final paragraph (2.7) we look at the scientific literature about the mortality of the coronavirus.

2.1.1 Results of the search and selection strategy

In the table below, we indicate the search terms used for each paragraph.

Paragraph	Search terms used in PubMed & Google Scholar
2.2. **Infectiousness of the coronavirus**	'SARS reproduction'; 'SARS-CoV-2 reproduction'
2.3. Transmission of the coronavirus	'Transmission SARS'; 'Transmission SARS-CoV-2'; 'SARS spreading'; (since 2020)
2.4 Transmission inside versus outside	'Outdoor transmission SARS'; 'Outdoor transmission CoV-2'; 'indoor transmission SARS'; 'indoor transmission SARS-CoV-2' (since 2020)
2.5 Transmission by singing, dancing and cheering	'SARS CoV 2 + singing'; 'SARS CoV 2 + shouting'; 'SARS CoV 2 + dancing'; 'Covid-19 increased transmission'

2.6 Effect of sunlight and/or UV radiation on the coronavirus	'UV SARS'; 'UV SARS-CoV-2'; 'SARS UV irradiation'; SARS UV light' (since 2020)
2.7 Mortality of the coronavirus	'Mortality of Covid-19; 'Covid 19 + fatality rate'; 'SARS CoV 2 mortality'

We also used a number of papers that were found by checking the references of other articles and using tips of third parties.

2.2 Infectiousness of the coronavirus

The infectiousness of a virus is expressed with the so-called reproduction number. This number is indicated with the letter R and is the average number of people that is infected with the (corona)virus without taking measures like vaccines, working at home or closing schools. If, for example the reproduction number equals 3, this means that 1 infected person can infect 3 others.

The reproduction number is an estimate that can vary greatly for each location, age group and time period. It is calculated with the aid of models that take into account the time an infected person remains infectious, the probability of that person infecting others and the number of times that person is in contact with others.[10]

Estimating the reproduction number is difficult in the case of the coronavirus, because a great number of symptoms are relatively mild or cases are even asymptomatic. It is assumed that asymptomatic people or those with mild symptoms do not report as readily to health authorities, with the consequence that the health system has no clear view of the number of potentially infected people.[11] Therefore, it is important to realise that reproduction numbers are estimates where their reliability depends on the data and mathematic models that are used.

Reproduction number for the Netherlands

Since the outbreak of the coronavirus, the RIVM (the Dutch National Institute for Public Health and the Environment) keeps track of the reproduction number for the Netherlands. At the start of the outbreak in the Netherlands, the reproduction number was a little above 2 and decreased since March 2020 to below 1. Since the beginning of July 2020, R has risen to slightly above 1.[12]

Until June 11 the reproduction number was calculated by the RIVM based on the number of hospitalizations. When the number of hospitalizations went down, RIVM started using another method, based on the number of Covid-19 patients recorded by the GGDs (municipal health departments). If the rate of hospitalizations is low, as was the case at the time, R can differ greatly due to a single hospitalization more or less. The new method, however, also has its inherent limitations. The CPR corona test has a false positive rate of about 2%.[13] If the number of actual infections in the population is low, this can lead to an overestimate of R. Because of the

[10] Flaxman et al. (2020); Martellucci et al. (2020).
[11] Flaxman et al. (2020).
[12] RIVM (2020b).
[13] Zeichhardt & Kammel (2020).

use of various methods to calculate R, and because the infection rate after June 11 is significantly lower, the R number before and after June 11 cannot be compared.

In a meta-analysis of 21 studies of the reproduction number of the coronavirus in January 2020, researchers come up with a number between 1.9 and 6.5. In 13 of these 21 studies a reproduction number between 2 and 3 is reported. According to the researchers these reproductive numbers are comparable with the SARS virus (SARS-CoV-1).[14] Our own inventory of reproduction numbers in literature (see table below) paints a similar picture.

Range of reproduction in several countries and periods			
Study	**Scope**	**Period (in 2020)**	**Reproduction number**
Joseph et al. (2020)	China	December (2019)-January	2.68 on average
Lai et al. (2020)	China	January	2.2-3.5
Liu et al. (2020)	China	January-February	3.28 on average
D'Arienzo & Coniglio (2020)	Italy	February-March	2.4-3.1
Laxminarayan et al. (2020)	India	March	2.0-3.0
Alleman et al. (2020)	Belgium	March	2.83
Rahman et al. (2020)	Middle East	March	3.76 on average
Fung et al. (2020)	Canada	April-May	About 1.0
Riley et al. (2020)	United Kingdom	May	0.57
Meskina (2020)	Russia	May	3.8 on average

Besides the reproduction number, researchers have also calculated the average risk of an infected person to contaminate another person in the same household. Based on four studies, the researchers have come to the conclusion that there is a 12% chance of an infected person infecting another person in the same household.[15] The studies on which this number is based, have been published relatively early in the outbreak. From a later study of Sekine et al., that was published more recently, where the rate of infection is determined based on the presence of a T-cell response,[16] it appears that a significant higher percentage of people in the same household had been infected than was previously thought.[17] This could indicate that the earlier estimate of 12% of household members getting infected, is a severe underestimate due to less advanced diagnostic methods.

2.3 Transmission of the coronavirus

In scientific literature, two theories about the transmission of the coronavirus can be found. The first theory supposes that the virus is *primarily* spread by direct and/or

[14] Park et al. (2020).
[15] Martellucci et al. (2020).
[16] The presence of a T-cell response indicates someone was infected with a virus.
[17] Sekine et al. (2020).

indirect contact with large drops, generated by talking, coughing, or sneezing. This theory has been dominant in scientific literature and is supported by both the WHO and RIVM.

The second, and upcoming, theory is that the virus is *primarily* spread by aerosols, meaning the smaller droplets generated by breathing, talking or coughing that remain airborne because of their relatively small weight. In the following paragraphs, both theories and their argumentation are discussed.

Please note that most people do not get ill instantly if they get in contact with coronavirus particles in large or small drops. The manner of people getting ill really depends on the *viral load*, that is to say the number of virus particles present in either the large or the small drops. The higher the viral load, the larger the chance of people getting ill and, probably, the more serious the progression of the disease. Up until now it is not known how large the minimal viral load – also called the infectious dose – should be to make someone ill.[18]

2.3.1 Transmission by direct contact with large drops

The dominant theory supposes that the virus spreads because people get into contact with larger drops (with a diameter exceeding 5 micrometre) of saliva that are expelled when an infected person talks, sneezes, coughs, or sings. This contact can be direct or indirect. Direct contact occurs when you are close to an infected person and drops laden with virus particles reach your mouth, nose or eyes. With indirect contact the infection takes place through touching a contaminated surface and subsequently rubbing the virus in your eyes, for example. For a contaminated object think of a doorknob, a glass, a computer mouse or a water tap.[19]

Several studies looking into corona clusters in China, Singapore and the US have indicated that the coronavirus is transmitted *primarily* by direct contact with larger drops.[20] However, these studies could not exclude that indirect contact and aerosols also played a role in spreading the virus.

2.3.2 Transmission through indirect contact with large drops

Scientific research suggests that contamination with the coronavirus through indirect contact with larger drops, or *fomite transmission,* is theoretically possible, for example if someone touches a contaminated object like a doorknob and then rubs their eye.[21] So far, convincing evidence that this form of infection plays a role with the spread of the

[18] Heneghan et al. (2020).
[19] Prather et al. (2020).
[20] Pung et al. (2020); Ghinai (2020); Huang et al. (2020); Kakimoto et al. (2020).
[21] Castaño et al. (2020); Zhang (2020); Wei et al. (2020); Pung et al. (2020).

coronavirus is lacking.[22] However, other researchers say that is highly unlikely that the virus is spread through contaminated surfaces.[23]

Evidence that transmission of the coronavirus through touching surfaces is possible has come from laboratory studies, among others, where it was shown that the virus is viable on various types of surfaces for some time.

A recent and much-quoted study has shown that coronavirus particles remain active until 72 hours after applying them on plastic or surgical steel, even though the quantity of virus particles had diminished significantly.[24] In a Chinese study, also in laboratory setting, it was also shown that the coronavirus remained active on surfaces and under various circumstances (such as high or low temperatures).[25] A study in India showed that the coronavirus can survive for some hours or a number of days, depending on the different surfaces.[26] However, it should be noted that all these studies were carried out in a laboratory setting and it has rightly been noted that these findings are not altogether valid outside of a lab.[27]

RIVM not consistent about risk of infection by touching surfaces

On the RIVM website there are two contradictory statements about the chance to get infected by touching surfaces: *"Chances appear slim that the new coronavirus is spread via packages or surfaces (from a door to a supermarket cart). Although it has been shown in a laboratory that this is possible, but this was with ideal conditions that you will seldom meet. The most important message remains limit the chances as much as possible and wash your hands regularly."*[28]

A bit further down the web page it says: *"Can the new coronavirus spread through glassware or tableware? Getting infected with a bacteria or virus through surfaces is possible. However, at this moment the chance that you will use a glass that was used by someone excreting the virus is small. People with symptoms must stay at home. The chance that you will get the virus by drinking from a glass that was used by someone showing no symptoms yet does have the virus, is small yet present. In order to minimize this risk as much as possible, it is important that glassware is cleaned thoroughly. The same goes for tableware and cutlery."*[29]

Even outside laboratories, researchers have found virus material on various surfaces. In a Canadian study researchers found coronavirus particles in the toilet and on the doorknobs of a hospital, for example.[30] Other studies, carried out in hospitals, found coronavirus particles on surfaces like medical equipment, computer mice and doorknobs.[31] In another study researchers found virus particles on several surfaces in the cabins of a cruise ship,

[22] Goldman (2020); Allen & Marr (2020); Zhang (2020); WHO (2020).
[23] Goldman (2020).
[24] Van Doremalen et al. (2020).
[25] Chin et al. (2020); Liu et al. (2020), both not peer-reviewed.
[26] Suman et al. (2020).
[27] Goldman (2020).
[28] RIVM (2020h) (assessed at 22 July).
[29] RIVM (2020h) (assessed at 22 July).
[30] Santarpia et al. (2020), not peer-reviewed.
[31] Guo et al. (2020); Razzini et al. (2020).

even 17 days after the passengers had left the ship.[32] Whether people really got sick from being in contact with contaminated surfaces remains unclear. The problem with these studies is that it cannot be determined if the infection occurred through direct contact with an infected person or through indirect contact with the contaminated surface. Transmission by aerosols could also not be excluded.[33]

2.3.3 Transmission through the air (aerosols)

An alternative theory is that the virus is primarily spread through smaller drops (with a diameter smaller than or equalling 5 micrometre) that are transmitted with activities like breathing, talking, singing and coughing. These droplets are called aerosols and for that reason this theory is called the *aerosols theory*.[34] Other than the larger drops, aerosols remain airborne much longer.[35] For this reason the aerosols theory supposes that the coronavirus is *mainly* spread through the air.[36]

Until the present day it has not been scientifically proven that aerosols do play a large part in the transmission of the coronavirus.[37] At the other hand: at the moment there has not been gathered convincing evidence showing that the coronavirus is *not* spread primarily through droplets.[38]

Those adhering to the aerosols theory base their conviction on a number of scientific insights and results arguing for the theory. First, there are several studies show that virus particles (not necessarily the coronavirus) can be viable in aerosols, at least for a number of hours.[39] In hospitals in China and the U.S. for example, virus particles were found in the air.[40]

Critics of the aerosols theory (including the RIVM) do recognize that aerosols can contain virus particles. However, they are not convinced that aerosols can contain *sufficient* virus particles to infect people. They view the larger drops as the most important route for the spread of the infection: the bigger the drop, the larger the concentration of the virus and therefore, the larger the chance to get infected.[41]

RIVM suggests that aerosols play an insignificant role in the spread
"At this moment it is unclear if the droplets (aerosols) remaining airborne play a role in the spread of the new coronavirus. If they do play a role in the transmission, this is a less significant route than the larger drops [...] The most important argument for this is the reproduction number of the coronavirus. This number is a measurement for the number of people that can be infected by one

[32] Moriarty (2020).
[33] Ong et al. (2020).
[34] Papineni & Rosenthal (1997); Fennelly (2020); Setti et al. (2020).
[35] Hartmann et al. (2020).
[36] Allen & Marr (2020a, 2020b), 2020a not peer-reviewed; Fennelly (2020).
[37] Bourouiba et al. (2014); Kim et al. (2016).
[38] Morawska & Milton (2020); Fennelly (2020).
[39] Morawska et al. (2009); Van Doremalen et al. (2020); Xie et al. (2007); Morawska & Milton (2020).
[40] Fennelly (2020).
[41] Kohanski et al. (2020).

> *sick person if no precautions are taken. For the new coronavirus the reproduction number lies between 2 and 4. Diseases spreading through droplets that remain airborne for a significant time have a higher reproduction number. Some examples of these diseases are tuberculosis and measles. Someone with measles can infect about 17 persons (if no measures are taken).”* [42]

Secondly, there is a number of studies suggesting that aerosols were the most probable route for transmission, based on the infection pattern and the probability that the source and the victim were in contact, direct or indirect.[43] An often-quoted example is a study following an infection cluster in a Chinese restaurant, where the researchers used camera images to rule out direct contact between guests.[44] This could point to infection through aerosols, even more so because the restaurant was badly ventilated. Other studies also suggest that infection through aerosols are possible, such as virus outbreaks following singing in a choir[45], playing squash[46] or doing fitness.[47] However, these studies do not completely eliminate contamination through direct or indirect contact with larger drops.

> **The possible role of aerosols with the outbreak in the Skagit County Choir**
> Researchers studied a great outbreak in the *Skagit County Choir* in the state of Washington.[48] Of this choir 87% (n=52) of the choir members got infected following 2.5 hours of choir practice in a closed-off space. One choir member was responsible for the contamination. The researchers state: *“Choir practice attendees had multiple opportunities for droplet transmission from close contact or fomite transmission, and the act of singing itself might have contributed to SARS-CoV-2 transmission. Aerosol emission during speech has been correlated with loudness of vocalization, and certain persons, who release an order of magnitude more particles than their peers, have been referred to as super emitters and have been hypothesized to contribute to superspreading events. Members had an intense and prolonged exposure, singing while sitting 6-10 inches from one another, possibly emitting aerosols.”*

Thirdly, several studies claim that transmission through the air also played a role in earlier pandemics. Research found evidence, for example, that contamination through aerosols played a role in the spread of SARS-CoV-1, MERS, RSV and influenza.[49] It should be noted, however, that these studies did not rule out other routes of transmission.

And, finally: there has been some evidence that infected people without symptoms like coughing and sneezing have infected others. This is called asymptomatic transmission. It indirectly proves the aerosol theory, because large drops are mainly transmitted when infected people cough or sneeze. For asymptomatic transmission the route of aerosols is more probable, according to the researchers.[50] It should also be noted here that people

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[42] RIVM (2020h) (checked on July 2020).
[43] Miller et al. (2020), not peer-reviewed.
[44] Li et al. (2020), not peer-reviewed.
[45] Hamner (2020).
[46] Brlek et al. (2020).
[47] Jang et al. (2020).
[48] Hamner (2020).
[49] Yu et al. (2004); Olsen et al. (2003); Buonanno et al. (2020); Kulkarni et al. (2016); Nardell & Nathavitharana (2020).
[50] Fennelly (2020); Hijnen et al. (2020); Qian et al. (2020); beide not peer-reviewed; Allen & Marr (2020b).

without symptoms could have spread the virus with their hands (for instance after touching their eyes or nose).

2.3.4 Conclusion

How the coronavirus is exactly transmitted, is still being debated in academia. From literature, we can discern that transmission through direct contact with large drops in combination with transmission through the air (aerosols) is plausible. [51]

> *"Data are accumulating that severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID 19, is transmitted by both small and large particle aerosols. These data suggest that health-care workers should be protected from these potentially infectious aerosols when working in close proximity to patients."* [52]

The role of indirect contact with larger drops appears to be limited. Although theoretically possible, it is not likely that the virus transmits largely through people touching surfaces like shopping carts, doorknobs and handrails.

2.4 Indoor versus outdoor transmission

In scientific literature we have found clues that indicate that the chance to get infected indoors is (considerably) larger when compared to outdoor transmission.

The *first* piece of evidence comes from studies showing that great outbreaks, the so-called *super-spreading events,* nearly almost took place during indoor activities [53] Think of activities like choir singing, fitness, indoor sports, church visits, conferences or dancing.[54] Based on a meta-analysis of 67 studies of corona clusters in several countries, the researchers conclude:

> *"We found many examples of SARS-CoV-2 clusters linked to a wide range of mostly indoor settings. Few reports came from schools, many from households and an increasing number were reported in hospitals and elderly care settings across Europe."*[55]

Another striking example is a Chinese observational study following 318 outbreaks of the coronavirus with three or more cases of illness. The study concludes that nearly all infections took place in indoor spaces. Of the 318 outbreaks, the researchers only found one outbreak that seemed to have occurred during an outdoor activity. [56]

Using contact research, Japanese researchers studied 110 infections in 11 clusters in Japan. According to the researchers most infection clusters were located indoors, like a

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[51] Allen & Marr (2020a), not peer-reviewed.
[52] Fennelly (2020).
[53] Leclerc et al. (2020); Allen & Marr (2020b).
[54] Jang et al. (2020); Miller et al. (2020), not peer-reviewed; Shim et al. (2020); Nishiura et al. (2020), not peer-reviewed; Brlek et al. (2020); Shen et al. (2020), not peer-reviewed; Park et al. (2020); Pung et al. (2020).
[55] Leclerc et al. (2020).
[56] Qian et al. (2020), not peer-reviewed.

fitness school and a restaurant boat. The researchers estimate the chance to get infected indoors is almost 19 times higher than in an environment outdoors.[57]

Database with *super-spreading events* (not scientifically validated)
Koen Swinkels has started a database where data of *super-spreading events* are collected. This database records events where at least 5 persons are infected with the coronavirus. Data that are collected are the location of the event, the number of people getting infected, the type of activity and whether it took place indoors or outside. The data shows that the majority of super-spreading events took place in indoor spaces.[58]
Of the total number of 1,408 events collected so far, there are only 3 that can specifically be related to an outdoor activity. Although this database has not been validated by scientific research, it nevertheless gives an indication of the difference between the risk of getting infected indoors versus outdoors.

The *second* clue is that we have not been able to find research that demonstrates that the chance to get infected outside is large and/or plays a substantial role in the transmission of the coronavirus. At this point it should be noted that the absence of such research does not prove that people cannot be infected out of doors, but it is remarkable because a lot of research explicitly states that indoor spaces *do* hold a risk (and imply that being outside does so less or not at all).[59]

Chance to get infected in public transport seems small, but more research is needed
In the extensive analysis by Leclerc et al. (2020), it appears that public transport is not a source of infections. From the above-mentioned database by Koen Swinkels the same impression emerges only 0.5% of the total number of infections (N=1408) is possibly related to travelling with public transport. We should note at this point that travel by public transport had dwindled due to the intelligent lockdown in the Netherlands. Therefore, it is not entirely clear what the exact chance of transmission would be in public transport. This inconclusiveness certainly goes for a situation where public transport would be used to full capacity, such as during rush hour or events.

Both the 'direct and/or indirect contact with large drops' and the aerosols theory indicate that the chance of getting infected indoors could be much greater. In scientific literature, there are suggestions that aerosols with virus particles could easily accumulate in indoor spaces, especially when these are badly ventilated.[60] However, the amount of aerosols and virus particles needed to really infect people with the coronavirus remains unclear.[61] Contrariwise it is true that aerosols can dissipate easier in the air outside and for this reason, according to proponents of the aerosols theory, they are hardly dangerous outside. In addition, laboratory tests have shown that virus particles in aerosols respond aversely to sunlight or simulated sunlight. This is also a possible explanation why infections in

[57] Nishiura et al. (2020), not peer-reviewed.
[58] This database can be assessed at https://medium.com/@codecodekoen/covid-19-superspreading-events-database-4c0a7aa2342b
[59] Morawska & Cao (2020); Yao et al. (2020).
[60] Somsen et al. (2020); Nardell & Nathavitharana (2020); Kohanski et al. (2020) not peer-reviewed.
[61] WHO (2020b).

outside environments are reported less frequently in literature.[62] It is not known which of these factors (diffusion or sunlight) has the largest effect.

In the literature on aerosols a number of factors are mentioned that influence the risk of getting infected inside. These include the number of infected people inside this space, the presence ventilation, the duration of the stay indoors and the measures taken to prevent transmission in this space.[63]

Calculating transmission risk through the aerosols route, using the Wells-Riley method
On assignment by Mojo Concerts, *bba Binnenmilieu* has calculated the chance of visitors getting infected in various auditoriums through *the aerosol transmission route*, using the Wells-Riley formula. This method calculates the risk of infection by looking at a number of factors that are crucial for indoor transmission, according to Wells and Riley. These factors are the number of infected people inside the space, the viral emission of an infected person, the tidal volume, the duration of the exposure and the volume of fresh air supply. The starting point of the Wells-Riley formula is that the virus that is exhaled is spread evenly over the space and is accordingly diffused by ventilation. The Wells-Riley formula has been validated scientifically in studies with previous infectious diseases. And in the study of Miller (2020) into the Skagit Valley Choir this formula was also used. Additionally, the demands of the WHO set for ventilation in their guideline for infection prevention for naturally ventilated healthcare buildings are based on calculations with the Wells-Riley formula. Since the coronavirus is a relatively new type of virus, the input variables are still somewhat uncertain, and the results should be interpreted conservatively.[64]

2.5 Transmission through singing, dancing and cheering

From literature we see that certain activities make for a greater emission of virus particles. People coughing, singing and talking loud spread more virus particles (4-100 as much) than people breathing or talking normally.[65]

In an experiment, researchers looked at the amount of virus particles emitted by breathing, talking and coughing. From this study it appeared that breathing through the nose emits the smallest amount of virus particles: 23 virus particles per second on average. Breathing through the mouth emits 134 particles per second, and talking 195 per emission. By far the most particles are emitted by coughing, namely 13,709 particles per cough.[66]

From this study it also appears that with these three activities the vast majority of emitted particles is very small – 80% are smaller than 1 micrometre and 99.9% are smaller than 5 micrometres. During these activities aerosols are emitted mostly. The results about the

[62] Schuit et al. (2020).
[63] Morawska et al. (2020); Somsen et al. (2020); Li et al. (2020), not peer-reviewed; Morawska & Milton (2020).
[64] Beuker & Boerstra (2020), not peer-reviewed.
[65] Assadi (2020).
[66] Hartmann (2020) not peer-reviewed.

size of the particles correspond with the results of a study from 2009[67] (not about corona particles) and another study from 2020 about singing.[68] However, these differ with the results from two other studies from 2009 where larger particles were found mostly.[69] An investigation from 2011 demonstrated that cheering and yelling during sports matches (as well as playing a vuvuzela) mostly emits smaller particles (97%).[70]

The difference between the smaller and larger drops is relevant in this context because it has implications for the effect of preventive measures like distancing at 1.5 metres, ventilation and the use of face masks. Especially for face masks it seems they are less effective in filtering aerosols than larger drops.[71] In the next Chapter we will look into this further.

Super-spreaders: not every infected person emits the same amount of virus particles
In the studies cited above, it is noteworthy that a small number of people emits more particles than the average person. In some cases, even 10 to 20 as much as others. These persons appear to be so-called *super-spreaders*. In previous epidemics, like for instance the SARS-epidemic, the majority of people were infected by a limited number of individuals. In this context this is called the 20-80 rule. The majority of infections takes place by a small percentage of people.[72]

Researchers in Germany investigated the number of particles emitted when singing, professionally and relate these to breathing, talking and coughing. From this study it appears that with singing 4 to 100 times as many particles are emitted as with talking. It also appeared that singing higher and louder was associated with a larger emission of virus particles. So, this study confirms the hypothesis that singing causes a larger emission than talking.[73] This could partly explain the relatively large number of examples of choir practices where a great many of choir members were infected.[74]

Chance of infection when standing close together and shouting at outdoor festivals
Theoretically it would seem likely that the chance of infection through large drops is greater at outdoor events where people stand close together and shout at each other because of the loud music. However, we have not found a practical situation where such an event led to a corona cluster. It should be noted that the festival season in the Netherlands hadn't yet started. Still, there are no examples of events in other countries where it was proved beyond doubt that close-knit groups at events outside led to new outbreaks.

[67] Johnson & Morawska (2009).
[68] Mürbe et al. (2020) not peer-reviewed.
[69] Xie et al. (2020); Chao et al. (2009).
[70] Lai et al. (2011).
[71] Bowen (2010).
[72] Stein (2011).
[73] Mürbe et al. (2020), not peer-reviewed.
[74] O'Keefe (2020), not peer-reviewed.

2.6 Effect of sunlight and/or UV radiation on the coronavirus

In several experiments it was shown that real or simulated sunlight and/or UV radiation (both A and B) cause a quick decline of coronavirus particles in aerosols[75] and on surfaces.[76] This effect was also demonstrated with other infectious illnesses.[77] Finally, it has also been demonstrated in laboratories that UV-LED[78] and UV-C radiation[79] (which is not present in natural sunlight) can also neutralize coronavirus particles.

American researchers have investigated the influence of simulated sunlight and relative air humidity on virus particles in aerosols. Based on several laboratory experiments, the researchers state that sunlight (with levels of UV-A and UV-B comparable to natural sunlight) have a great effect on the virus. With the intensity of sunlight on a regular autumn day, 90% of the virus had been made inactive within 19 minutes. If the intensity is comparable to that of an average summer's day, this effect is reached within 8 minutes.[80]

Relationship between air humidity and spread of the coronavirus unclear
Researchers of the Centre for Evidence-Based Medicine at the University of Oxford have investigated the relationship between air humidity and the spread of the coronavirus. According to the researchers there are indications that certain weather conditions, such as humid air, can influence the transmission of the coronavirus. According to the researchers, there is no unambiguous or high-quality proof to demonstrate a causal relationship between air humidity and the transmission.[81]

Other American investigators studied the effect of sunlight on virus particles that were attached to steel. Based on their laboratory research, the researchers conclude that sunlight neutralizes the virus particles with a speed depending on the intensity of the sunlight. With an intensity of the sun on an average summer's day, 90% of the virus is inactive within 6.8 minutes. If the sun intensity is comparable to that of an average winter's day, this timeframe rises to 14.3 minutes.[82]

In a study carried out in Israel, the researchers wanted to know if it would be safer, corona-wise, to play a soccer match during the day or in the evening. To investigate this, the researchers left virus particles of a surrogate virus on the grass and a football for 90 minutes (the duration of a soccer match) to see how the virus developed on a sunny day. Subsequently, they repeated the same experiment at night. The researchers concluded that during the nightly experiment, 10% of the virus particles remained active, while in the simulation on the middle of the day almost all active virus particles had disappeared after 90 minutes. The researchers came to the conclusion that playing a soccer match

75 Schuit et al. (2020).
76 Ratnesar-Shumate (2020).
77 Schuit et al. (2020).
78 Inagaki et al. (2020), not peer-reviewed.
79 Walker & Ko (2007); Bianco et al. (2020), not peer-reviewed.
80 Schuit et al. (2020).
81 Spencer et al. (2020), not peer-reviewed.
82 Ratnesar-Shumate (2020).

during the day showed a much lower chance of getting infected with corona than during the night.[83]

Spanish investigators have pleaded for applying UV radiation to eradicate virus particles in the air or on surfaces, because of the positive effect of UV radiation on the eradication of coronavirus particles. As an example, they mention UV batteries in ventilation systems or special UV lamps.[84] We will discuss these further in the Chapter about the effect of the measures.

2.7 Mortality of the coronavirus

About the mortality of the coronavirus (this means the number of infected people who will actually die because of the virus) more and more has become known to science over time. Below, we will discuss the two ways to determine the mortality and the influence of several factors on the mortality rate.

Beforehand we would like to emphasize that, despite there being better data and methods available, there are still uncertainties regarding the reliability of the data and thus the true mortality of the virus.[85]

2.7.1 Confirmed fatality ratio CFR)

The CFR is a much-used unit in epidemiology to indicate the mortality of a virus. The CFR expresses the ratio of the people that died due to the virus versus the people that are infected. Crucial for this is establishing the presence of the virus in sick people by testing them, so the testing method is also important (see below).[86] Following the discovery of the coronavirus, the first studies showed a CFR surpassing 10%.[87] These high numbers could be explained by the limited number of cases that were considered: hospitalized patients (N=41 and N=99).

As more and more cases became known, and non-hospitalized Covid-19 patients were also counted in these studies, the estimated CFR quickly went down. From a large Chinese study into almost 45,000 confirmed patients, a CFR measuring 2.3% was found, where it appeared that the CFR varied strongly with each age group.[88] In this study, for patients between the ages of 70 and 79, for example, the CFR was 8%; and for the age group 80+ it was almost 15%.

Using CFR in a developing epidemic has a number of significant disadvantages. Mild or asymptomatic cases can only be detected with difficulty (people will not or do not get

[83] Kashtan, Fedorenko & Orevi. (2020), not peer-reviewed.
[84] Garcia de Abajo et al. (2020).
[85] All figures have a 95% certainty.
[86] Porta (2014).
[87] Huang et al. (2020); Chen, N. et al. (2020).
[88] Wu & McGoogan (2020).

tested) and are therefore not entered into the data. This situation is called under-ascertainment.[89] For Covid-19 the majority of infections are mild or asymptomatic.[90] Because of this a large part of the infections is not detected and will not be calculated into CFR. This leads to an overestimate of the CFR.[91] The rate of the CFR is therefore determined largely by the testing and registration policy of a country, rather than the true mortality of the virus. For this reason, the estimates of the CFR vary greatly, ranging from 1.38% to 15%. Therefore, many scientists feel the CFR is inadequate for expressing the mortality of the virus.[92] For this reason, the Centre for Evidence-Based Medicine in Oxford pleads for using the *Infection Fatality Rate* (IFR).[93]

Cruise ship 'Diamond Princess' unique testing environment, improves insight in CFR
Under-reporting, due to a limited testing capacity, was the reason that the first CFR estimates were high. An interesting case to illustrate this is that of the cruise ship Diamond Princess. On board one case of 'Diamond Princess'. Covid-19 was detected in one passenger and all passengers and crew were to remain in quarantine aboard the ship. Because this was a large but limited and closed-in population, almost all of the population could be tested. This meant the bias of under-ascertainment did not came into play but there was instead a reasonably high level of certainty about the number of confirmed cases. 3,063 people were tested on board, of which 619 people tested positive. Subsequently, researchers corrected for a delay in mortality, and the result was a CFR of 2.6%.[94] We should note here that the tests that were carried out here, checked for the presence of antibodies against the virus in the blood. There are many indications that there are other defence mechanisms against viruses at work in some people that render the coronavirus harmless.

2.7.2 Infection fatality rate (IFR)

The *infection fatality rate* is the ratio between all (estimated) infections versus the number of people dying as a consequence of these infections. Here the number of all infections is used, not just those that were confirmed by testing. One of the most famous studies into the IFR at the start of the outbreak, was the study of the Imperial College where an IFR of 1% was reported. This also meant that 82% of all people would get infected.[95] As more data became available, it became clear that both findings were a severe overestimate of reality (yet the starting points for prevention policy).

One of the first improved and much-quoted papers where the IFR was estimated, was carried out by Verity et al. Besides a CFR of 1.38%, they estimated an IFR for China of 0.66%.[96] Another study mentions IFR estimates for China, United Kingdom and India of 0.43, 0.55 and 0.20 respectively.[97] These various IFRs are explained by researchers by the

[89] Lipsitch et al. (2015); Battegay et al. (2020).
[90] Mizumoto et al. (2020); Bi et al. (2020); Pollan et al. (2020).
[91] Rajgor et al. (2020).
[92] Hauser et al. (2020).
[93] Streeck et al. (2020), not peer-reviewed.
[94] Russel et al. (2020).
[95] Ferguson et al. (2020).
[96] Verity et al. (2020).
[97] Wood et al. (2020).

demography of these countries. The studies were carried out on the basis of a statistical analysis, using corrected CFR data.

Ioannidis has executed a meta-study into 50 studies estimating an IFR based on the study of seroprevalence in the population.[98] The IFRs that were calculated here ranged from 0.01% to 1.63%. In areas where the number of deaths per million inhabitants surpassed 500 (the average number of deaths per million worldwide), the median IRF was 0.9%. In areas where the number of deaths per million was below the worldwide median, the IFR was 0.27%. If you look at areas where the population mortality is lower than the worldwide average, the median IFR was 0.10%. The IFR for people below 70 years ranges from 0.01% to 0.57%, with a median of 0.05%.

The previous suggests clearly that age plays an important role in determining the IFR. From Danish research, based on the study of antibodies in blood donors, an IFR of 0.0089% was found for persons between the ages of 17 and 69 (the age group that is allowed to donate blood in Denmark).[99]

Some notes for the use of the study for antibodies for determining the IFR

The use of research into antibodies has some limitations that can lead to either an under or an overestimation of the true number of infections and the IFR. A meta-analysis of Bobrovitz et al. into 73 studies demonstrates that none of these has a low risk of bias and about 43% has a high risk of bias.[100] An example: there could be an occurrence of cross-reactivity, where the body makes antibodies because of another virus infection. This can allow for false positive testing and an overestimate of the number of infections.[101] We know that this happened with the Zika and Dengue viruses.[102] A recent evaluation of the 'Roche' test shows that it has a very high rate of sensitivity (99.5%) with people with an infection determined in the lab and a 'specificity' of more than 99.8% . There was a possibly cross-reaction of only 4 of the 792 monsters.[103] This appears to limit the risk of false positive tests, and therefore an overestimate of the true number of infections. Yet with some tens of thousands of tests, the absolute number of false positives could very well be several hundreds.

However, there is a number of causes that could lead to an underestimate of the number of infected people and could therefore lead to an overestimate of the IFR. The *first* is that there are certain groups that have a higher risk of infection but are not proportionally represented in the studies for antibodies, for example if blood donors are studied. Examples of groups that can be underrepresented are: residents of care homes, homeless people, prisoners and ethnical minorities.[104] There have also been indications that people showing mild symptoms did not make detectable antibodies.[105] A study by Sekine et al., for instance, into people living with a corona patient that had no symptoms themselves, showed that 93% of them did have a positive

[98] Ioannidis (2020), not peer-reviewed.
[99] Erikstrup et al. (2020).
[100] Bobrovitz et al. (2020), not peer-reviewed.
[101] Kadkhoda (2020); Özcürümez et al. (2020).
[102] Sharp et al. (2020).
[103] Muench et al. (2020).
[104] Ioannidis (2020), not peer-reviewed. Perez-Saez et al. (2020).
[105] Yongchen (2020).

T-cell response but that 'only' 60% had antibodies in their blood.[106] This suggests that almost all of these people had been infected, but based on the antibody test, a conclusion could be that only 60% had been infected. In view of the large percentage of mild and asymptomatic cases, the number of infected people could be severely underestimated, wherefore the IFR, could be severely overestimated.[107]

The table below shows a brief overview of several meta studies arriving at an estimate of the IFR. They show a range of numbers. Some arrive at a very low IFR, when looked at people under the age of 70. Based on the level of complete populations, most estimates are within the range of 0.2% to 0.7%.

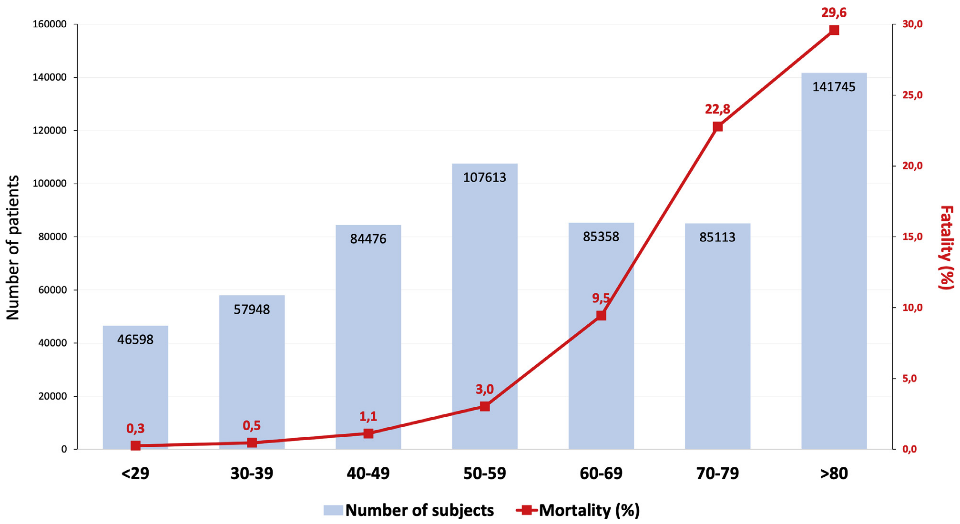
Title of de study	**Authors**	**Height of the IFR**
Estimation of SARS-CoV-2 infection fatality rate by real-time antibody screening of blood donors (antibodies)	Erikstrup et al. (2020)	0.0089% (for people below 70)
Infection fatality rate of SARS-CoV-2 infection in a German community with a super-spreading event (antibodies)	Streeck et al. (2020)	0.278%
COVID-19 and the difficulty of inferring epidemiological parameters from clinical data (modelling)	Wood, Wit, Fasiolo & Green. (2020)	0.20% India 0.43% China 0.55% United Kingdom
Estimating the infection and case fatality ratio for coronavirus disease (COVID-19) using age-adjusted data from the outbreak on the Diamond Princess cruise ship, February 2020	Russel et al. (2020)	0.6%
Estimates of the severity of coronavirus disease (modelling)	Verity et al. (2020)	0.66%
The infection fatality rate of COVID-19 inferred from seroprevalence data	Ioannidis (2020)	Ranges from 0.00 to 1.63%
Estimation of SARS-CoV-2 mortality during the early stages of an epidemic: a modelling study in Hubei, China and six regions in Europe (modelling)	Hauser et al. (2020)	Switzerland 0.5% Baden Wurttemberg, 0.7% Bavaria 0.8% Spain 1.0% Austria, 1.1% Lombardy 1.4% Hubei, China 2.5%

106 Sekine et al. (2020).
107 Perez-Saez et al. (2020), not peer-reviewed.

2.7.3 *Influence of age on mortality*

It has been ascertained beyond doubt that the mortality risk of COVID-19 correlates strongly with age. There is broad scientific consensus about this. This is also clear from the previous, where the CFR and the IFR were broken down into various age groups in a number of studies.

Bonanad et al. carried out a meta-study into all parameters available at the time, from China, Italy, Spain, United Kingdom and the state of New York (up until 7 May). This study covered more than 611,000 cases (looking at the CFR). There are great differences in CFR between the various countries. The lowest CFR is 3.1% in China, the highest 21%. However, we do want to remind the reader there are some reservations in using the CFR, as the differences between the countries can be explained to a large extent by the differences in testing policies. Still, what is true for all countries is that there is a significantly higher mortality risk for each age group as compared to the preceding cohort. The greatest difference is between the age group of 60 to 69-year-olds, as opposed to 50 to 59-year-olds.[108] In the figure below the CFR for all countries is represented. A Chinese study of Zhou et al. shows a significant rise in mortality risk in hospitals, of 1.1% per life-year.[109]



Source: Bonanad et al. (2020).

Ioannidis et al. carried out a meta-study into the risk of mortality of Covid-19 in 11 European countries and 12 American cities, where at least 800 Covid-19 deaths occurred. For this, they looked at the absolute risk of mortality for both groups and their relationships. This demonstrated that the absolute risk of mortality for people younger than 65 in the past months, was lowest in Canada, with 6 per million, and highest in New

[108] Bonanad et al. (2020).
[109] Zhou et al. (2020).

York City, with 246 per million.[110] In comparison with people of 65 and over, the absolute mortality risk in European countries for the group younger than 65 was 36 to 84 smaller than those of 65 and over (for The Netherlands this number was 69). In the United Kingdom and several American states this number ranged from 14 to 56. Just like in the Bonanad study, it becomes clear that there is a huge difference between various countries and regions. This difference can be explained partly by the huge strain on health care, as was the case in New York City and some states in America.[111] Another part of the explanation lies in the differences of testing policies and data collection. The researchers conclude that even in the epicentres of the outbreak, the risk for people under the age of 65 is very small.[112]

2.7.4 Influence of underlying medical conditions

Soon after the start of the epidemic, several Chinese studies showed that severe cases and hospitalizations correlated strongly with pre-existing medical conditions. In these studies, high blood pressure, diabetes and cardio-vascular disease reappeared each time as the most prominent underlying chronical illness.[113] American research later showed that (morbid) obesity strongly correlates with developing severe symptoms as well.[114] Even for young people with Covid-19, obesity is a risk factor for developing severe symptoms that can lead to hospitalization.[115] Obesity is a risk factor for more infectious diseases, by the way.[116]

British research, based on a study into 710 corona deaths, report that over 50% of the deceased had three or more underlying medical conditions. A little over 25% had two underlying medical conditions. Conversely, the chance to die from the coronavirus is minimal if underlying medical conditions are absent. The same British study shows that in 2.1% of deceased corona victims no underlying medical conditions were found.[117]

2.7.5 Conclusion

CFR is a unit used in epidemics to express the mortality of a virus. Because there are severe limitations for determining the CFR, the unit is unreliable to use for policy making. The IFR is a more reliable unit, although it also has its limitations. At first, the IFR was estimated at a high number of 1%. Since the availability of more and more reliable date, the estimated IFR was adjusted to a lower percentage. In most studies the estimated IFR

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110 This absolute risk is calculated by dividing the complete number of people in a certain age group by the total number of people who died of Covid-19 in that particular cohort.
111 European countries show a lower absolute risk for people of 65 and over. Spain scores 65 and therefore highest. The Netherlands has a risk of 20 per million.
112 Ioannidis et al. (2020), not peer-reviewed.
113 Zhou et al. (2020); Chen,T., et al. (2020); Yang et al. (2020); Richardson et al. (2020).
114 Kassir (2020); Finer et al. (2020).
115 Lighter et al. (2020).
116 Dietz & Santos-Burgoa (2020).
117 Hanlon et al. (2020).

appears to range from 0.2% to 1%, where the majority of the studies' estimates are nearer to 0.2% than to 1%.

There is a wide range of age groups in the Dutch population, where the risks for 65-year-olds and over are over ten times higher than for younger people (<65+). Of the severe Covid-19 cases, about 90% of the patients appeared to have at least one other chronical condition, of which high blood pressure, diabetes and obesity were most prevalent.[118]

It is important to stress that, although there clearly is a converging and downward pointing line, the mortality rate cannot be determined with absolute certainty. The data from the most quoted literature were collected for the most part at the starting phase of the epidemic. A lot of studies using more recent date are still in the peer-review process and/or make use of the study of antibodies to establish the IFR. As described in this Chapter, there is a number of limitations to using this type of testing, making it probable that antibody testing underestimates the number of infections and therefore overestimating the IFR.

2.8 Conclusion and significance for events

Scientific literature describes how the coronavirus is mainly transmitted by direct contact with large drops of saliva that is emitted 'straight forward' by infected people and possibly also through droplets (aerosols) that linger in the surrounding air for some time. With activities like singing, laughing and talking loudly, more large and small drops are emitted and therefore more coronavirus particles.

The literature we have studied, shows that the majority of infections take place indoors. The chance of getting infected outdoors is very small, according to the literature. Only one single case of an outside infection has been shown. Theoretically, it would appear that the risk of infection (through large drops) is greater at outdoor events where people stand close together and (because of the loud music) need to shout at each other. However, we have not found a researched practical situation where it appeared an event like that led to a corona cluster.

Transmission by touching contaminated surfaces is theoretically possible, says the literature, but does not play a role in the transmission of the virus in actual practice.

And, finally, visitors to events can also get infected on their way to and from the event. Based on the limited number of infections that occurred in public transport, however, we estimate this chance to be fairly limited. More research is needed however, to get a clearer picture.

At the beginning it was feared that the coronavirus was a virus with a very high mortality rate. At the moment the WHO called out a pandemic, the organization named the mortality

[118] Ioannidis (2020), not peer-reviewed.

risk of people infected with the coronavirus at 3.4%. Combined with a very high infection rate, expected at the time, this meant a very severe pandemic that was compared many times with the Spanish Flu from 1918 that cost the lives of 40 million people.

It soon appeared that this percentage was a severe overestimate of the true mortality, because at the starting phase of the pandemic hardly only severe cases were tested on Covid-19 and the vast majority of the infections are asymptomatic.

At this point in time, the mortality risk for people infected with the coronavirus is still highly variable, but for the entire population runs somewhere in the range of 0.2% to 1%, where the majority of studies arrives at a percentage that is closer to 0.2% than to 1%.

However, it is crucial to remember that there are large individual differences within the population for the risk of mortality. The median mortality risk is high because of elderly people with several medical conditions that have a considerably higher risk to die of Covid-19 if they get infected than young people.

Significance for indoor and outdoor events

All of the above suggests that:
- The chance to get infected at outdoor events is sufficiently small. Additional measures reducing the chance of infection do not appear necessary.
- The chance to get infected with the coronavirus at indoor events depends on a number of factors that include the number of infected individuals present and the duration of event but is nevertheless a real risk without additional measures.

3 Scientific literature about the effects of the measures against the transmission of the coronavirus

This Chapter elaborates on the results in scientific literature about the effects of the measures preventing the spread and mortality of the new coronavirus. This Chapter will answer sub-question 2.

3.1 Introduction

This Chapter elaborates on the findings in scientific literature about the effects of the five measures preventing the spread of the coronavirus. In paragraph 3.2 the social distance of 1.5 metres is discussed; in paragraph 3.3. the wearing of face masks; in paragraph 3.4 the use of adequate ventilation and the paragraphs 3.5 and 3.6 deal with the use of UV radiation and the cancellation of events respectively. In paragraph 3.7 the most significant results are summarized and then a conclusion is drawn as to what is significant for indoor and outdoor events.

It should be noted beforehand that there are more measures to be taken to prevent the transmission of the coronavirus, like basic hygiene measures (such as disinfecting one's hands), closing schools and prohibiting international travel. In this Chapter we have limited our search to the measures that have the greatest – potential – impact on events.

3.1.1 Search strategy and selection criteria

The sources in this Chapter were found with the aid of two online search engines: PubMed and Google Scholar. In the table below are indicated the search terms that were used for each paragraph.

Paragraph	Search terms used for PubMed & Google Scholar
3.2 1.5-metres social distancing	'Social distancing SARS'; 'Social distancing SARS'; '1.5 metre SARS'; 'distance SARS' (since 2020)
3.3 The use of face masks (by the general public)	'SARS CoV-2 face mask'; 'Covid-19 + face mask'
3.4 The use of ventilation	'SARS ventilation'; 'SARS airborne'; 'SARS HEPA filter'; 'SARS airplane'; 'SARS mechanical ventilation'; 'SARS-CoV-2 ventilation' (since 2020)
3.5 The use of UV radiation	'UV SARS'; 'UV SARS-CoV-2'; 'SARS UV irradiation'; SARS UV light' (since 2020)
3.6 Cancellation of events	'SARS mass gatherings'; SARS gatherings'; 'SARS-CoV-2 gatherings'; 'SARS events cancellation'

We also used a number of papers that were found by cross-referencing and studying a number of sources in other papers.

3.2 Keeping a distance of 1.5 metres

Scientific literature shows that social distancing is associated with a lower transmission of the coronavirus (in indoor spaces). However, there is no scientific consensus about the minimal distance that is effective. It should also be noted that the research into social distancing is focused on indoor spaces. Whether or not and to what extent distancing is helpful or necessary in outdoor environments has not been scientifically researched.

The scientific grounds of the 1 to 2-metre distancing rule can be traced back, partly, to a study from 1942 that demonstrated with the aid of photographic techniques that the majority of large drops crossed a distance of 1 metre.[119] This study was criticised later. The technique that was used wasn't suitable for photographing smaller drops and the setting was such, that the drops that crossed a distance of 2 metres were not even registered. In addition, the study did not take into account the influence of air streams.[120]

Many years later, researchers of other infectious diseases, like rhinovirus and meningococcus, also found indications that a shorter social distance is associated with a larger risk to get infected with the virus.[121]

Recently, Australian researchers have compared 10 studies looking into the horizontal distance that large drops can cross when people sneeze or cough – in a laboratory setting. They observed that larger drops can cross a distance of more than 2 metres in 8 of the 10 studies.[122] Some studies show a distance of 6 to 8 metre. The researchers conclude that the current measure of keeping a social distance of 1 to 2 metres (the distances vary in various Western countries) cannot be substantiated scientifically. Furthermore, the researchers observe that the horizontal distance that these drops can cross is influenced by many factors, including temperature, air humidity, ventilation, exhalation rate and the evaporation rate. The researchers suggest it is therefore difficult to come to an adequate distance of 1, 2 or more metres. Another remark about this study: the researchers haven't checked if such drops contain sufficient virus particles to actually be infectious.

Recently, a group of Canadian researchers has published a study in *The Lancet* where they collected and analysed the effects of some of the more familiar measures, like social distancing and wearing face masks. Based on a comparison of a total number of 172 observational studies into the transmission of Covid-19, SARS and MERS, the researchers conclude that a social distance of at least 1 metre is associated with a reduction of the risk of getting infected.[123] The researchers calculated the risk of getting infected at a social

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[119] Jennison (1942).
[120] Bahl et al. (2020).
[121] Feigin et al. (1982); Dick et al. (1987).
[122] Bahl et al. (2020).
[123] Chu et al. (2020).

distance of less than 1 metre at 13% to 3% if the social distance is less than 1 metre. The researchers therefore conclude that it has been scientifically substantiated that a social distance of 1 metre is valid. On the RIVM website this study is explicitly mentioned as an argument for the 1.5-metre distancing rule (see below).

> **RIVM guideline 'keep your distance' is based on controversial study in *The Lancet***
> *"In the Netherlands we recommend keeping a distance of 1.5 metres to other people. This reduces the risk of people infecting each other and the transmission of the virus. It is known that the most drops emitted with coughing or sneezing do not surpass a distance of 1 to 2 metres.* The Lancet *recently published an article that said that keeping a distance of 1 metre is effective, yet wrote that 2 metres would perhaps be better, even though there was no hard proof for this. Several countries deal with this information in different ways. For this reason, various countries are keeping different distances: 1 metre in Denmark and China, 2 metres in Spain and Great Britain and 1.5 metres in the Netherlands, Australia and Belgium."*[124]

The study from Canada has gathered some controversy. *First*, because the poor quality of some underlying data (the chance of bias is greater sometimes) or not subjected to independent scientific peer-review.[125] *Secondly*, from a repeat analysis of the study, it appeared that the data set was possibly interpreted the wrong way and that the positive effect of social distancing is already seen for 80% at a distance of less than 1 metre.[126] And *thirdly*, another group of researchers have tried to replicate the Canadian study but found that the results were based on unsubstantiated suppositions about social distancing that were stated in the studies used in the meta-analysis.[127]

Scientists of the *Centre for Evidence-Based Medicine* of the University of Oxford and MIT have studied the adequacy of a social distance of 2 metres in order to reduce the transmission of the coronavirus.[128] In order to answer this questions, the researchers used 120 previous studies into the transmission of the coronavirus in various environments, such as households, restaurants, cruise ships and hospitals. A significant finding of the researchers is that it is difficult to draw conclusions about the effect of distancing, because the studies are heterogenous and are therefore difficult to compare with each other. Another finding is that a long-term exposure in a closed-off space, with unknown information about the social distance between people can be correlated with hotspots of infections, like choirs, sporting events and fitness centres. Therefore, the researchers conclude that social distancing is associated with a lower chance of getting infected, yet at the same time they say:

> *"Single thresholds for social distancing, such as the current 2-metre rule, over-simplify what is a complex transmission risk that is multifactorial. Social distancing is not a magic bullet to eliminate risk. A graded approach to social distancing that reflects the individual setting, the indoor space and air condition, and other protective factors may be the best approach to reduce risk."*

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[124] RIVM (2020h) (assessed at 22 July 2020).
[125] Qureshi et al. (2020), not peer-reviewed.
[126] Lonergan, M. (2020), not peer-reviewed.
[127] Heneghan & Jefferson (2020), not peer-reviewed.
[128] Heneghan & Jefferson (2020), not peer-reviewed.

The conclusions of the British researchers, that the chances of getting infected with the coronavirus in an indoor space depends on many factors, resonates in the studies of other authors.[129] Factors that are often mentioned, are: the characteristics of aerosols, indoor air streams, ventilation, type of activity, virus-specific characteristics and specifics of the people gathered (i.e. the measure in which the people inside are susceptible to the virus).[130]

When discussing the scientific literature up to this point, one important note should be made. The findings and conclusions from the British study mainly look at the effects of social distancing in indoor spaces. What has not been mentioned in literature is the measure of social distancing helpful in limiting virus transmission in outdoor circumstances. [131]

3.3 The use of face masks (by the wider public)

At this point in time, scientific literature cannot answer unambiguously if face masks give – extra – protection or not. Studies arrive at different and sometimes conflicting results.[132]

Because of the contradictory advice, there are many different ways of using face masks all over the world.[133] In Norway (and in Sweden too), they have not chosen for an obligatory use of face masks, because the effect, according to the *Norwegian Health Institute*, is practically zero under the current circumstances.[134]

There have been limited studies into the effect of face masks as a protective measure against the coronavirus. In many cases the insights from meta-studies into the effect of face masks as a protection against other viruses (usually SARS and MERS) have been projected onto the coronavirus.[135]

3.3.1 Results of three meta studies

Brainard et al. conducted a meta-analysis of 19 studies. Three of those were randomized control trials that showed a slight, but not entirely significant reduction of primary infections by wearing face masks. A number of observational studies showed a more positive effect. In one study the number of infections was lowered by 19% by wearing a face mask. However, this study investigated the use of a face mask at home and is thus less representative for the use of a face mask in public areas.[136]

[129] Morawska & Cao (2020); Morawska et al. (2020); Kohanski et al. (2020); Setti et al. (2020).
[130] Kohanski et al. (2020).
[131] Kohanski et al. (2020).
[132] Szarpak et al. (2020).
[133] Feng et al. (2020).
[134] Iversen (2020).
[135] Chu et al. (2020).
[136] Brainard et al. (2020), not peer-reviewed.

Chu et al. carried out a meta-analysis of 172 observational studies. 44 of these were comparative studies, of which 7 were studied Covid-19, the others looked into SARS or MERS. The most significant result of this meta-study was that face masks can lead to a significant reduction (-14.3%) on the chance of infection, where medical N95 or comparable face masks have a significantly greater effect than surgical disposable masks or similar cloth masks. [137]

> **RIVM does not find evidence in literature about effect of face masks**
> The RIVM also compiled an overview of the literature. Based on this, they also conclude that the literature is not unambiguous. According to the RIVM the results from the literature they studied are contradictory and therefore they do not see convincing evidence that would justify the use of face masks.[138]

Another meta-study was carried out by Howard et al. Based on their findings they call on authorities to explicitly promote the wearing of face masks for parts of the population. Their main argument for this is that masks can reduce the transmission of particles and are a relatively cheap intervention. The researchers also state that face masks should be used as additional measure, together with limiting social contact, practising hygiene, testing and contact tracing. In this study no actual social cost-benefit analysis was conducted. [139]

3.3.2 Laboratory testing effect of face masks

Face masks come in different shapes and sizes. First, there are the various medical face masks. A study into the effect of medical masks and N95 respirators (both are medical masks) among health care workers demonstrate their protection is comparable.[140]

Secondly, a distinction can be made between medical and non-medical face masks. Research shows that medical masks prevent the transmission of considerably more particles than non-medical face masks. Unfortunately, it is not possible to give an exact indication of the difference, based on research. A well-known study by MacIntyre et al. (2015) shows that cloth masks do not filter out 97% of the particles, where this percentage was 44% for medical masks.[141]

In public transport, people in the Netherlands can also wear homemade masks. Research from 2010 shows that homemade cloth masks allow 40 to 90% of the particles to pass. The conclusion that researchers draw from this is that homemade masks only offer a marginal range of protection against viruses.[142] Another study found that homemade masks stop about half of the number of particles as opposed to medical masks.[143] The

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[137] Chu (2020).
[138] RIVM (2020c).
[139] Howard (2020), not peer-reviewed.
[140] Bartoszko (2020).
[141] MacIntyre et al. (2020).
[142] Rengasmy et al. (2010).
[143] Davies et al. (2013).

exact ratio remains unclear, but it is clear that homemade mask allow through an significant percentage of particles and performs significantly worse than medical masks.

These studies looked at the protective effect of face masks for the wearer, but face masks work two ways. According to research, they also ensure that the wearer emits less particles and will therefore partly prevent the infection of others. Research consistently shows that the medical face masks are more effective in preventing emission of the wearer than preventing infection of the wearer.[144]

Chan et al. carried out an experiment where healthy hamsters were exposed to a hamster with Covid-19 in a laboratory setting. Less healthy hamsters became infected when they or their cages were separated with a medical face mask to protect the healthy hamsters. A significant finding was that if the hamsters did get infected with the use of a mask, they had a smaller viral load when tested and showed less symptoms.[145]

It is important to note that the studies mentioned above do not look at the quantity of virus particles that pass. Depending on the characteristics of a virus, a mask can stop more particles of one virus than of the other. From a study by Leung et al. it appeared for example that medical masks were more effective in blocking virus particles of a person infected with coronavirus than in particles from the influenza or rhino viruses.[146]

3.3.3 Behavioural changes by wearing face masks

Although the effects are small and scientific evidence is meagre, there are scientists claiming that wearing face masks, as an additional measure to social distancing and washing hands, can contribute to mitigating the coronavirus.[147] One of the arguments against the use of face masks, however, is that it gives people a fake sense of security and they will observe additional measures, like social distancing, to a lesser degree. The hazards of this could be much larger than the limited benefits of wearing face masks. It is for this reason that the Outbreak Management Team advised our government against the obligation of using a face mask.

RIVM conducted literature study into behavioural effects face masks
From a literature study by RIVM into behavioural science literature about the use of face masks, it appears there is no evidence that people will behave more unsafely when using face masks. Contrariwise, researchers state that there might be more desired behaviour in view, such as social distancing. According to the study there is too little scientific evidence to come to firm conclusions.[148]

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[144] Leung et al. (2020).
[145] Chan et al. (2020).
[146] Leung et al. (2020).
[147] Anfinrud et al. (2020), not yet peer-reviewed.
[148] RIVM (2020a).

On the other hand, there are scientists suggesting that the use of face masks in public areas could be a reminder to people to observe the measures as they remind them of the epidemic.[149] There is insufficient scientific evidence available to support either one of these suppositions, making it impossible to give a verdict.

3.3.4 Are masks used well?

As mentioned before, face masks offer no complete protection according to research. They let pass a substantial portion of the particles. The percentage of particles passing through is even larger if the face masks are not worn the right way. One argument against the use of face masks is that people do not know how to use a face mask and therefore a lot of faulty use is to be expected.[150] According to Polykova et al. there is no proof for this supposition. They state that the chance of people infecting themselves are regularly mentioned, but that there is no evidence for this.[151]

From two studies into the use of face masks in Hong Kong, it appears however, that the percentage of people wearing a mask is high, around 94%, but that about 13% of the people do not wear the mask the right way and 76% reuse a disposable mask more than once.[152]

These two studies point to a large measure of willingness among the population to wear a mask, but they also show that masks are often not used in the right way. It is important to note that the results of this study cannot be projected on the Netherlands, because the use of face masks in Asia is much more widespread.

3.3.5 No research showing a difference in the development of the epidemic in countries with or without face masks

In scientific literature, we have not found any study showing that the epidemic develops differently in countries where face masks are worn, as opposed to countries without the use of face masks.

An exception forms the study of Cheng et al., investigating the effect of wearing face masks in Hong Kong as opposed to countries where no face masks are worn. First the researchers posit that researchers in Hong Kong have infected less people than for example in Singapore and South Korea – more or less comparable situations. The researchers also found 14 clusters of infections in Hong Kong of which 11 occurred in 'mask off' settings and only 3 clusters occurred in 'mask on' circumstances. The researchers conclude that a wide use of mask-wearing in society can contribute to mitigating the virus transmission.[153] However, it should also be noted that there are more factors that influence the

[149] Howard et al. (2020), not yet peer-reviewed.
[150] World Health Organization (2020a).
[151] Feng et al. (2020); Polykova et al. (2020).
[152] Cheng et al. (2020); Tam et al. (2020).
[153] Cheng et al. (2020).

transmission of the virus and that no conclusions can be drawn based solely on this study.[154]

3.3.6 Conclusion

The literature teaches us that face masks do stop a part of the virus particles, both when exhaling and inhaling. The literature is unanimous about the fact that face masks do not offer complete protection for the carrier but do help an infected person to emit less virus particles. It is unclear to what extent face masks truly contribute to the transmission of the virus.

Literature gives no evidence whether the use of a face mask makes people more observant to other corona measures or less so.

3.4 The use of ventilation

The effect of ventilation on the spread of the coronavirus largely depends on how aerosols play a role in the transmission of the coronavirus. Because ventilation mainly has an effect on aerosols that are airborne and less so on the large drops that are emitted by speech that fall to the ground quickly, for example. If aerosols do indeed play a – large – role in the transmission of het virus, then some tentative conclusions can be drawn, based on the available literature. These are discussed below.

The effect of ventilation on the transmission of the coronavirus goes in two directions: sound ventilation can help extracting, diluting or neutralizing aerosols with virus particles. Dutch research shows, for example, that adequate ventilation will lower the time that aerosols remain airborne considerably. The researchers draw the conclusion that adequate ventilation can help the prevention or the outbreak of Covid-19 infections.[155] Negative air monsters, taken in well-ventilated hospital rooms with corona patients are seen as evidence that ventilation can help with the extraction and dilution of aerosols with virus particles.

What is adequate ventilation?
What 'adequate ventilation means for a space depends on a number of factors, including the size of the space, the number of people (potentially infected or not infected) and the activities that are undertaken. Generally speaking, literature recommends to make as much use as possible of natural ventilation or, if this is not possible, mechanical ventilation, to uphold a sufficient supply of fresh air.[156] The CDC recommends 6 to 12 exchanges of air per space.[157] Studies of SARS-CoV-1 found that ventilation needs to dilute the emission of an infected patient at least 10,000 times with fresh air. At a lower rate of air exchange, there was a plausibility that other people in the same room could get infected, according to the researchers.

[154] Jefferson & Heneghan (2020), not peer-reviewed.
[155] Somsen et al. (2020).
[156] Jiang et al. (2009).
[157] Nardell et al. (2020).

With some ventilation systems, not set to the right conditions – partial – recirculation could occur. Research suggests that this is undesirable with an airborne virus and needs to be avoided[158], unless there are proper filters in use to clean the recirculated air. Research also suggests that the use of HEPA filters, that are used in airplanes, is effective in neutralizing the virus particles.[159] There are also scientists pleading for the use of UVC batteries in ventilation systems. Because of the radiation of these batteries, the air that comes through the ventilation systems is made free of the virus and clean air is released.[160]

Finally, air cleaning systems with a HEPA or a UV filter can contribute to the disinfection of air, according to scientific literature, if the systems are powerful enough to clean the air in the room frequently enough.[161]

A wrong use of ventilation or a lack of it can aid the transmission of aerosols through a building or a build-up of aerosols into a concentration that can make people sick.[162] In a Chinese study mentioned earlier, researchers suggest that inadequate ventilation contributed to the transmission of the coronavirus in a restaurant, for example.[163] A study that looked into the ventilation of the Skagit Valley Choir came to the same conclusion.[164]

According to research ventilation has a large influence on chance of infection
Research by *bba binnenmilieu* into the transmission of the coronavirus through aerosols in the Ziggo Dome and AFAS Live makes clear that ventilation has a great influence on the risk of getting infected in indoor spaces, depending on the transmission route through aerosols. From calculations following the Wells-Riley method, it appeared that the chance to get infected in poorly ventilated restaurants or bars was ten times greater than in well-ventilated concert auditoriums.[165]

There should be made two notes to these calculations. The first and most evidentiary is that there should be one or more infected persons present for there to be transmission of the virus. Secondly, the researchers presuppose that aerosols are spread evenly through a space. If this is not the case – which we cannot know based on scientific literature – this could have either a positive or a negative effect on the risk to get infected.

Other researchers declare that inadequate ventilation in indoor spaces has contributed to the transmission of the previous coronavirus outbreak (SARS-CoV-1) and influenza.[166] A well-known example is a study into an outbreak of influenza on an Alaska Airlines airplane. The plane, with 54 people on board, was grounded due to motor issues for a period of three hours. In order to save energy, the plane's ventilation was turned off, so the passengers breathed in the same air for hours. Within three days 39 of the 54 passengers

158 Morawska & Cao (2020).
159 Yeo et al. (2020).
160 Garcia de Abajo et al. (2020).
161 Nardell et al. (2020).
162 Correia et al. (2020).
163 Li et al. (2020), not peer-reviewed.
164 Miller et al. (2020), not peer-reviewed.
165 Beuker & Boerstra, (2020), not peer-reviewed.
166 Correia et al. (2020).

showed symptoms of the flu. Although it cannot be eliminated that the passengers contracted the virus through direct and/or indirect contact, researchers suggest it is probable that the influenza virus was spread all over the airplane. The lack of adequate ventilation contributed to this, according to the scientists.[167]

Indication of how good ventilation can help: hardly infections in airplanes
Despite the fact that people in airplanes sit close to each other in a relatively small space, there are few cases illustrated in scientific literature where infections took place in airplanes. According to an airplane expert, the air in an airplane is refreshed every two to three minutes, with the help of filters cleaning the air of viruses. Furthermore, the exhaled droplets are pushed downward by the air streams, so-called downward ventilation, so the drops hardly get the chance to remain airborne. The greatest risk of infections in airplanes, according to the expert, is during boarding and disembarking, that allows for a disruption of the airflow in the airplane. This risk does appear to be very small, as no studies have been found that found that people got infected during boarding or disembarking. If the ventilation is turned off and people sit close together for a longer time, there is of course a greater risk of infections (as described above).[168]

3.5 The use of UV radiation

In scientific literature, evidence is found that various UV applications could be used to neutralize virus particles in indoor spaces.[169] Think of applications that remove the virus from the air or surfaces. It should be noted that the effectiveness of these measures has not been determined in practical situations. We have found evidence in literature that UVC radiation effectively disinfected objects in indoor spaces (such as the plastic containers to put in your personal belongings used with office or airport security).[170]

Spanish investigators suggest that UVC applications can help reduce virus transmission through aerosols in indoor spaces like offices, shopping malls, schools and restaurants. The application they suggest is the use of UVC light sources in ventilation grids or just below the ceiling. These light sources could also be used to disinfect much-used surfaces, like bannisters or buttons (in an elevator, for example). UVC lights could be used in toilets to disinfect the room automatically after each use.[171] We would like to repeat here that the effect of these applications has not been established scientifically.

3.6 Cancellation of events

Intuitively speaking, the cancellation of events would seem to contribute to the prevent of the transmission of viruses like the coronavirus. It goes without saying: the less people are in contact, the smaller the chance they transmit the virus to another person. The relevant question here is: does the cancellation of events contribute to the mitigation of the virus transmission? In scientific literature no studies have been found that can sufficiently

[167] Moser et al. (1979).
[168] Fehrm (2020), not peer-reviewed.
[169] Garcia de Abajo et al. (2020).
[170] Cadnum et al. (2020).
[171] Garcia de Abajo et al. (2020).

answer that question. The Centre for Evidence-Based Medicine (CEBM) of the University of Oxford suggests an extensive investigation, based on the analysis of the various studies:

> *"The effect of restricting and cancelling mass gatherings and sporting events on infectious diseases is poorly established and requires further assessment. The best-available evidence suggests multiple-day events with crowded communal accommodations are most associated with increased risks. Mass gatherings are not homogenous, and risk should be assessed on a case-by-case basis."*[172]

Furthermore, three studies were found that indicate or suggest that the effect of het cancellation of events is possibly limited.

In 2015 researchers carried out a meta-analysis of measures taken to curb influenza pandemics (such as working from the home and self-isolation). For this, the scientists looked at 80 studies. About the cancellation of large mass gatherings, the researchers state:

> *"Effectiveness is not proven but may be of theoretical benefit if cancelled around the peak of the epidemic [...] cancellation of mass events is not always straightforward and may be associated with practical problems, but major events can be organized in the midst of a pandemic by taking stringent containment measures (such as isolation of confirmed cases, close monitoring of suspected cases)."*[173]

Other researchers have come to the conclusion that the continuation of sports events in the United Kingdom from March to September would have led to a limited rise of the number of infections, based on a mathematic model.[174] In another study, researchers of het Imperial College COVID-19 Response Team estimate the chance of mass gatherings leading to a lot of new infections is small, because the contact moments are relatively short in comparison with situations at home, at work or in restaurants, among others.[175]

However, this study contrasts sharply with research that has shown that in an *indoor situation* people were infected with the coronavirus in a relatively short period of time, like with Skagit Valley Choir.[176]

This brings us to the conclusion that, based on scientific literature, little can be said at this point about the effect of het cancellation of events for the spread of the coronavirus. It has however become clear that the risk can vary for each event (for example outside versus indoors).

> **RIVM advice used to be large gatherings are okay with flu epidemics**
> The standard RIVM advice with the Mexican flu in 2009 was that large events could still take place. The spread of the New influenza A had to be prevented as much as possible by sound

[172] Nunan & Brassey (2020), not peer-reviewed.
[173] Rashid et al. (2015).
[174] Davies et al. (2020).
[175] Ferguson et al. (2020), not peer-reviewed.
[176] Hamner (2020).

hygiene and people with symptoms of New Influenza A were to be sequestered from healthy people.[177]

3.7 Conclusion and significance for events

The following measures are discussed in literature:

Social distancing: It is evident that social distancing is a measure with a positive effect, depending on the ventilation, the type of activity, the duration, the characteristics of the virus and the characteristics of those present. Scientific literature does not provide evidence that the Dutch 1.5-metres-rule is effective: A significant portion of the positive effect is already valid for distances shorter than 1 metre, and in special conditions, infection can take place indoors – through aerosols or not – over a greater distance, under special conditions.

Face masks: According to literature, face masks do stop some of the virus particles, both when breathing in and when exhaling. However, literature clearly shows that face masks do not offer significant protection to the wearer but do help an infected person to emit less virus particles. The measure of effect in daily practice remains unclear.

There is no evidence in literature that wearing a face mask leads to a better or worse compliance with the other corona measures.

Ventilation: In literature we find evidence that sufficient indoor ventilation can prevent infection through the aerosol route. With ventilation we mean refreshing the air by letting in fresh outside air or by recirculation with the cleaning of the extracted air. Adequate ventilation depends on the characteristics of the space and the activity, among other matters. Although well-ventilated situations, like in airplanes, are described in literature, no standard calculations are offered for in indoor activities. However, with the aid of the generally accepted Wells-Riley method, where several parameters can be entered, like the number of infected persons, duration and ventilation regime, it is possible to get an indication of the chance of infection in indoor spaces.

UV radiation: From scientific literature it appears that natural or simulated sunlight and/or UV radiation can neutralize coronavirus particles within minutes. In literature several applications are discussed using UV radiation. Some examples are: UVC batteries in ventilation systems or UVC lights in special ceiling lamps.

From all the above, we can conclude:

- For indoor events adequate ventilation will help to mitigate the risk, al dan in combination with appliances working on UV radiation.

[177] RIVM (2009).

- As a reminder: the chance of infection is already sufficiently low at indoor events and in literature we do not find firm evidence that some measures would be demonstrably effective to further mitigate the transmission of the virus.

4 Comparing corona with other risks

In this Chapter we compare the mortality risk of corona with other risks we consciously take as a society, and find acceptable, because we are willing to run it or because it is counterweighed by something of critical importance.

4.1 Introduction

In this Chapter, we compare the risk of corona with other day-to-day risks. In order to do this, we will have to calculate risks. We will express to risk of corona in three units: micromorts, loss of life years and excess and under-mortality. We will also set the risk of a corona death against the generally accepted safety standard in the Netherlands.

Where we calculate risks in this Chapter, we wish to emphasize that there is always a certain amount of uncertainty, as we work with derivative assumptions. Therefore, the results should not be interpreted as accurate figures, but should be seen as a 'ballpark' estimate.

4.2 Corona mortality compared with overall mortality

One of the problems with calculating the mortality of the coronavirus is the unreliability of the data. Because we were ambushed by the coronavirus all over the world, there simply wasn't sufficient capacity to test all people. This increased both the actual number of deaths and the actual number of infections.

4.2.1 Severe excess death in period of weeks 11 until 21

An alternative way of calculating the number of deaths by Covid-19 is counting excess deaths so you arrive at a number that one gets by comparing the actual deaths in a period of time against the expected number of deaths for that period, taking into account that there wouldn't be an epidemic. The mortality number exceeding the expected number of deaths can be attributed to the coronavirus.

On July 29 2020 it was widely broadcasted that the true death count of Covid-19 was 1.5 to 2 times higher than the reported deaths up to that point.[178] The Central Bureau for Statistics (CBS) had a used a much more refined method to calculate the excess mortality for weeks 11 until 21 and arrived at an estimate of 10,164 excess deaths. The lower and upper limits of this estimate were 8,593 and 11,691. This was about 1.5 to 2 times higher than the number of 6,000 plus deaths that had been tested and recorded up to that point.

[178] See De Volkskrant (2020) for example.

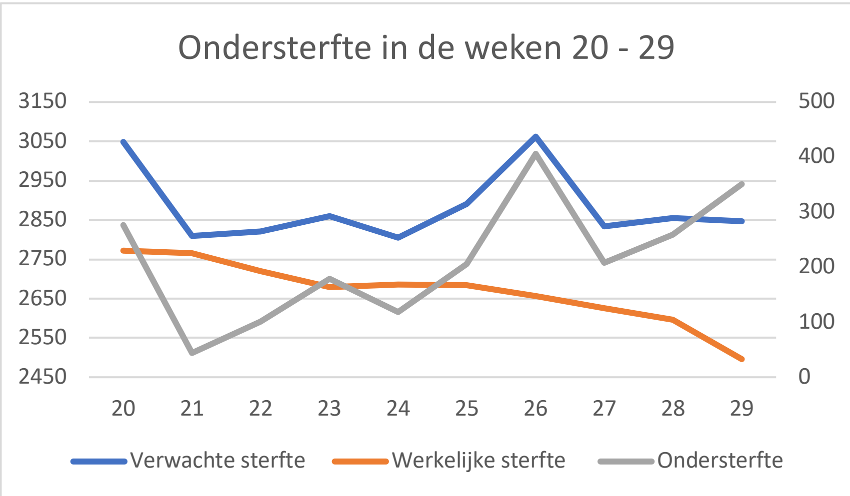
The CBS also says that the lockdown measures could have led to excess mortality and emphasizes that the excess mortality numbers represents all extra deaths at the peak of the corona epidemic and that indirect victims are also included in these numbers.[179]

4.2.2 Under-mortality since week 21

It is important to point out that, following the earlier excess mortality, there was a period of under-mortality. This happened for the first time in week 20: the CBS mortality on May 22 reported that the total number of deaths in week 20 was about 200 below the expected number.[180]

The CBS has calculated the early excess death in several ways and reported this (see graph below). For calculating under-mortality, we used the same method that the CBS used at first.

If we look at the data published by the CBS on a weekly basis, we notice that since week 20 there is a structural under-mortality. The total number of under-reported deaths for this period of ten weeks, until week 30, there are 2,149 fewer deaths than would be the case under 'normal' circumstances. This has been rendered in the graph below.[181]



Source: CBS-data. Ondersterfte = under-mortality, werkelijke sterfte = real deaths, verwachte sterfte = expected deaths.

A period of under-mortality following a period of excess mortality is not unusual and is called the 'harvest effect.'[182] It is known effect that occurs after a heat wave, for example. This 'shift' of mortality suggests that the people who died in that period of excess deaths, were probably in a final phase of their lives and would have passed away some weeks or months later.[183]

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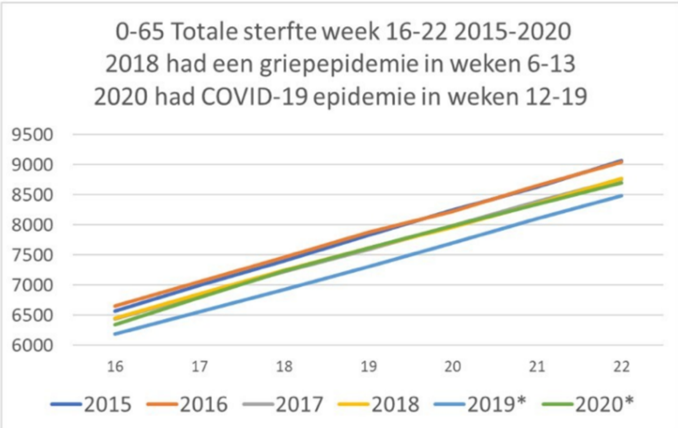
179 Husby et al. (2020).
180 Centraal Bureau voor de Statistiek (2020).
181 Table based on CBS data (2020b).
182 Murray et al. (2006).
183 Huynen et al. (2001); Hajat et al. (2020).

Various calculating methods CBS
The CBS uses a number of different methods to calculate excess mortality. In their report 'Oversterfte tijdens de corona-epidemie: toepassing van een dynamisch regressiemodel' (Excess mortality during the corona epidemic: using a dynamic regression model) the CBS presents four models for calculating excess mortality. Op July 29 the CBS published this report (about weeks 11 to 21) where they state that, although the results of all four models are within the same range, the results of the newly used method, the 'dynamic regression model' is the most accurate.

4.2.3 Differences in excess death compared in groups

Both the excess and under-mortality was presented on a national level, as seen above. It would seem that the excess and under-mortality are similar for each demographic group in the Netherlands. This is emphatically not the case. Excess deaths are mainly concentrated in the older cohorts of the population; especially in long-stay care homes.

In weeks 11 to 19 there were 62 more deaths than would be expected in this period for the youngest age group (< 49 years). This means an excess mortality of 7% for this group. There is some excess mortality, but since it is less than 1,000 for this age group in absolute numbers it is a small number, making it sensitive for 'chance' outliers. Bob de Wit and Bo van der Ree, both teaching at Nyenrode Business University, calculated the excess deaths in the age group 0-65, based on the data from CBS, at being 216 on a population of 14 million. The mortality in this age group was only lower in the past five year in 2019.[184]



Source: De Wit & Of der Ree (2020).

The largest excess mortality in the Netherlands was recorded among people in long-stay care homes, following the 'wet langdurige zorg' (Long-term care Act). The total death toll in weeks 11 to 19 was more than 15,000. This means there was an excess mortality of more than 5,000. A great many of the residents of care homes who died, have not been tested, certainly not at the beginning of the outbreak. These extremely higher mortality

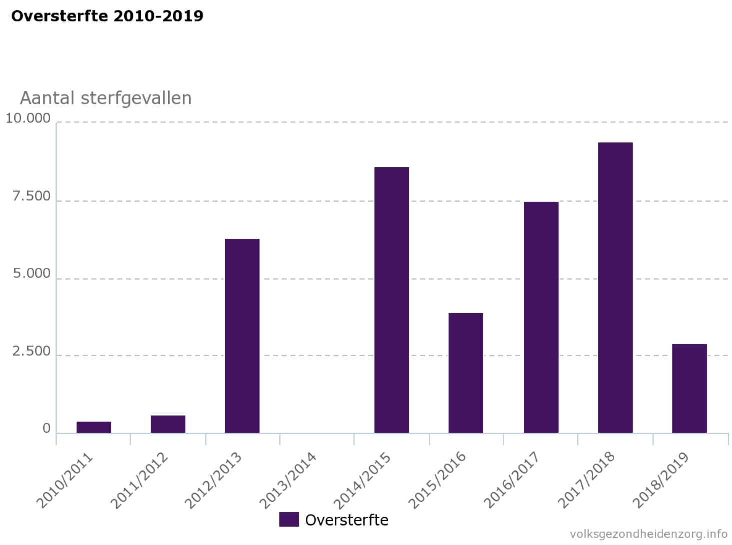
[184] De Wit & Of Der Rhee (2020).

numbers in the care homes will explain the difference between the recorded corona deaths and the excess deaths.[185]

4.2.4 *A comparison with other infectious diseases*

Virus infections and epidemics are not new to our world. The comparison between the coronavirus and the flu virus are therefore made regularly in the media and the public debate. The RIVM started the systematic recording and analysing of deaths in 2009, in order to map pandemics.[186]

Over the period of 1999 to 2010, the mortality of flu was estimated to 2,000 deaths annually.[187] In 2009 RIVM started with monitoring mortality more closely. If we look at recent flu seasons, it is clear that the severity of a flu season can vary greatly, depending on the excess mortality. A recent example of a severe flu season was the winter of 2017 and 2018. During that flu season there was an excess mortality of about 9,500 that could largely be ascribed to the flu virus. Additionally, there were 16,000 hospitalizations because of the flu virus.[188] The number of deaths by corona is 10,000; slightly higher than those of this flu season. The number of hospitalizations is lower now. Up to August 4, 11,959 people with Covid-19 have been hospitalized.[189]



Source: Reukers et al. (2019).

During a severe flu season (like the recent one of 2017 and 2018, for example) the total number of flu victims comes close to the current number of corona deaths (measured by excess mortality), but on average, the flu makes considerably less victims each year. Still, it is true that deadly victims among the young and small children is very rare for the corona

185 Centraal Bureau voor de Statistiek (2020b).
186 RIVM (2020d); Reukers et al. (2019); Of Asten et al. (2007).
187 Wijngaard et al. (2012); Of Asten et al. (2012).
188 RIVM (2018).
189 RIVM (2020b).

virus, while the number of victims among young children due to respiratory infections (like the flu) is fairly high. Scientists have calculated that in 2018 an estimated 870,000 children under the age of 5 were hospitalized all over the world, as a result of an influenza epidemic, and 34,000 children of this age group eventually succumbed to this infection. About 36% of these victims was younger than 6 months.[190] The majority of these victims (>80%) lived in low-income countries.[191]

It should also be noted that the measures taken to prevent the flu or COVID-19 differ greatly. When fighting flu, the most vulnerable groups can be protected with a vaccine. Because there is no vaccine for corona, only preventive and non-medical interventions can be used (such as basic hygiene measures and social distancing).

In scientific literature, there are different opinions about the benefits or necessity of the strict lockdown measures taken all over the world. In the Netherlands, Jaap of Dissel, director of the Centre for infectious Disease control of the RIVM, in his briefing to the Dutch parliament, stated that this policy had prevented about 23,000 ICU hospitalizations.[192] At the same time it is true that the reproduction number in the Netherlands had ducked below 1.0 before March 16 march, so before the proclamation of the severest measures, showing the curve of the epidemic was already starting to go down.[193]

The exact effect of lockdown measures remains unclear

International research also shows differences of opinion as to the effects of severe lockdown measures. In the renowned scientific magazine *Nature*, two articles were published where scientists calculated, with the help of statistical models, that hundreds of millions of infections and deaths had been prevented by the severe measures.[194] However, these studies compared the situation with interventions with a modelled situation without measures or unimpeded exponential growth. It is a matter of discussion whether such a scenario of sustainable exponential growth of the virus is realistic. Additionally, it is impossible to distinguish the relative effect of the different measures. The British Department of Health and Social Care (DHSC) supposes that the secondary consequences of the lockdown cost more QALYs than the primary consequences of corona, but that the lockdown was justified because an unmitigated scenario would have cost 1.6 million lives: 500,000 direct corona deaths and 1.1 million excess deaths as a consequence of an over-burdened health-care system.[195] To arrive at these calculations, the researchers were forced to make large assumptions and there is some discussion about a number of these assumptions. The DHSC, for example, uses an IFR of 4% in an unmitigated scenario, a percentage that is much higher than the most realistic estimates. For this reason, there are scientists who are very critical of the lockdown measures, based on the comparisons of the relative morality rates where countries with severe lockdown measures do not show lower numbers than the countries where less strict measures were in place. [196]

190 Wang et al. (2018).
191 Okomo et al. (2020).
192 RIVM (2020e).
193 RIVM (2020b).
194 Flaxman et al. (2020); Hsiang et al. (2020).
195 Department of Health and Social Care (2020).
196 Feys et al. (2020), not peer-reviewed; Chaudhry et al. (2020).

4.2.5 Conclusion

Following a period of severe excess mortality in the weeks of 11 to 19 (over 10,000) there has been a structural under-mortality since week 20 (over 2,000). This suggests there is a substantial number of people that died during the peak of the corona epidemic, who would have died some weeks or months later.

There were many differences in excess death counts between age groups. The majority of excess deaths were found among the elderly. In the age group of 0 to 65-year-olds, relatively little excess death was found. The mortality rate for this group was at the lowest level since 2015, aside from the year 2019.

If the flu and the coronavirus are compared, it should be noted that the current coronavirus makes more victims than an average flu season. In terms of excess mortality, the numbers are 10,000 Covid-19 deaths, as opposed to 2,000 flu victims per year on average. The severity of a flu season can fluctuate. At end of 2017 and the beginning of 2018 there was a flu season that lasted for 18 weeks and during that period caused 9,500 casualties. The number of hospitalizations (16,000) was even higher than in the current corona crisis. A very severe flu season could have a similar effect as the current corona epidemic. The criticism that severe measures were taken here is not entirely conclusive: we already pointed out that there are studies that show hardly any difference between countries with severe, light or no lockdown measures. The action people take to protect themselves and their loved ones is what cause a systematic distortion: if there is a flu epidemic, people hardly take self-precautionary measures.

4.3 Years of life lost as a result of mortality due to corona

A measuring unit used to quantify the severity of a risk, is the number of life years that are lost, also called *Disability Adjusted Life Years* or DALYs. DALYs can be used to compare risks and to determine if the measures taken to mitigate a risk are proportional.[197] In the Netherlands, the DALY is used to determine rational and proportional safety and health.[198] In the Dutch health care system, the maximum investment to gain a DALY is €80,000.[199]

In this paragraph we present a first estimate of the number of lost DALYs based on the available data of the RIVM and the CBS. We will compare these results with the albeit somewhat limited insights in scientific literature. We will also compare the size of the estimated lost DALYs with other documented risks.

[197] Homedes (1996).
[198] De Hollander & Hanemaaijer (2003).
[199] Raad voor Volkgezondheid en Zorg (2006).

4.3.1 A first – very simplistic – calculation of the number of lost DALYs in the Netherlands

To come to a first estimate of the number of years of life lost due to corona, we look first at known Covid-19 deaths.

With the suppositions below, the number of lost DALYs is calculated.

- As a data source for the age of the deceased corona patients, we used the open-source data of the RIVM.[200]
- As a data source for the number of years of life lost per age, we used the public data of the state or health care system.[201] In doing so, we have used the average life expectancy for both women and men.
- For the number of years of life lost we made a distinction between men and women.
- The RIVM publishes the number of deaths per age groups of 4 years and starting 95+-year-olds. To calculate the average lost life year, we assumed the entire group had the same age, based on the average life year in the age group. An example: in the age group 65-69 there are 340 deaths. Since we calculated the lost life year of the entire group starting at the age of 67. For this age group, we have calculated this as follows: 340 (total number of deceased in this group) * 18.9 years (= residual life expectancy for 67-year-olds) = 6,426 years of life lost in this age group.

Based on these assumptions, it was fairly easy to calculate that the number of years of life lost (up to Monday August 4) as a consequence to corona was 59,910. Until that date, there had been 6,145 deaths. The average loss of life years for each deceased, based on these assumptions, is 9.75 years.

However, this calculation is altogether too simplified and overestimates the number of years of life lost, as we will show below.

4.3.2 Limitations to the calculation of years of life lost

It is instantly clear that there are significant limitations to the simplified calculations mentioned above. Firstly, only the confirmed cases are used in our calculation and a large number of deaths are not counted. As we mentioned before, the true number of corona deaths will be in the range of 10,000, based on the excess mortality. Adding these excess deaths to the total tally will increase the lost DALYS. In that sense the number of lost DALYs is underestimated.

However, there are also some limitations to this calculation that will cause an overestimation of the average number of DALYs. A large part of the excess mortality will be found in deceased residents of the care homes. This group saw a high mortality and was tested relatively little, at first, because the goal of testing was only to determine if corona was present in an institution. If two residents were tested positive on a floor, no more

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[200] RIVM (2020g).

[201] Ministerie of Volksgezondheid, Welzijn en Sport (2020).

tests were carried out.[202] On June 5, the number of deceased residents of care homes was about 2,750 while the total excess mortality (until week 19) was amounted to more than 5,000. Care home residents have a rather lower life expectancy than their peers who do not reside in care homes. It is suggested in the media that the average life stay in a care home went down by 9 months, following the Long-term care Act. According to the 'Society of geriatric specialists' (VERENSO) it is longer than 9 months, although they cannot give an exact average.[203] It would seem reasonable to assume that the life expectancy of care home residents is no longer than 1.5 years. This is much lower than the average of 10 years of life lost calculated above, and this would lower the average years of life lost. The fact that a period of under-mortality follows a period of excess mortality would also suggest that a large part of the corona victims was in the final stages of their lives and would probably have passed away some weeks or months later.

A second indication is that the medical condition of corona victims is unlike that of the entire population. As was suggested in Chapter 3, most corona victims have severe underlying medical problems. This would have lowered their life expectancy even without a corona infection.[204]

There is a methodological flaw in all these studies. They make insufficient amendments for the heavier medical burden, on average, of people dying of Covid-19 as opposed to their peers. This allows for an overestimate of the number of years of life lost. In one of these studies, by Hanlon et al., where they adjust the average number of years of life lost downward due to medical conditions of the victims.[205] They adjust the numbers from an average of 14 and 12 years of life lost for women and women respectively, to 11 and 13. However, we think this is still an overestimation. There is no data, for example, about the severity of the underlying illnesses and therefore it is assumed that the group of corona victims are representative for the entire population of the same age group and with the same underlying conditions. Due to the fact that the majority of infected people survives the illness (this also goes for the over-80s) it is highly probable that people with the weakest health, on average, will succumb to the virus. These people are therefore not representative of their peers and by all means have a significantly lower life expectancy.

Hanlon et al. used Italian data of over 700 recorded victims.[206] Their average ages were 77 for the men and over 81 for the women. An average residual life expectance, corrected for underlying conditions, would then appear to be 11 years for the men and 13 for the women, which would an average age of 88 for the men and 94 for the women. These numbers are high in a similar age group without any underlying conditions, but now they are incredibly high, if you look at the actual burden of their medical conditions. In this group, only 2% has no underlying illnesses, 20% has 1 underlying medical condition, 26% has 2 and over 50% has 3 or more underlying illnesses. The risk of people dying within 1

[202] Ministerie of Algemene Zaken (2020a).
[203] Verenso (2019).
[204] Cho et al. (2015).
[205] Hanlon et al. (2020).
[206] Palmieri et al. (2020).

year, for people over 80 and 85 and over with more than 3 underlying illnesses, is about 17% and 27% respectively.[207] Therefore it is likely that at least 20% of the deceased Covid-19 patients would have died in the coming year, if they had not died from Covid-19.

Therefore, we think it likely that the average number of years of life lost, mentioned in this and similar studies is an overestimation of reality.

4.3.3 comparison number of lost DALYs with other risks

With an estimated loss of 60,000 DALYs, it is clear that corona makes for a significant burden of mortality. In absolute numbers it is fairly large. Yet is important to see this number in perspective; to relate it to other risks we have accepted in our society and that are responsible to many DALYs every year.

In a publication from 2003, the RIVM put together a large number of risks, based on scientific research (see table below).[208] We can see that smoking is the largest risk for losing DALYs, on a yearly basis, 440,000 are lost. The second largest risk of the list is obesity, coincidentally (or not) one of the most significant risk factors for dying from a corona infection. Yearly 8,000 people in the Netherlands die of obesity, at a cost of 170,000 DALYs a year. The risk of dying from corona, calculated on the basis of the confirmed deaths, when compared to the risk factors in this list, would be comparable to household accidents. It is important to take into account that the risks on this list return every year. This is not the case for corona, although we do not know how long the virus will circulate and how many more deadly victims it will make.

Tabel 1.1. Ruwe ramingen van jaarlijkse sterfte en verlies aan gezondheid gewogen levensjaren (DALYs) door een aantal risico's in Nederland (voorlopige cijfers, Van Oers, 2002; De Hollander et al., 1999; De Hollander et al., 2003).

Risicofactor	**Sterfte/jaar**	**DALYs/**
het roken van sigaretten	20.000	440.000
overgewicht	8.000	170.000
lichamelijke inactiviteit	8.000	135.000
ongezonde voeding (verkeerd vet)	7.000	137.000
alcohol	2.200*	195.000
ongevallen thuis	2.200	52.500
ongevallen verkeer	1,200	85.000**
luchtverontreiniging stof***	1.300	1.800
radon in woningen	800	7.900
passief roken	530	6.300
Legionella in drinkwatersystemen	80	560****
benzeen	3	140
grote ongevallen	1	40****
bliksem	1,5	40

* exclusief verkeersongevallen
** alleen blijvende letsels
*** gebaseerd op studies naar samenhang dagelijkse variatie in sterfte en luchtverontreiniging
**** alleen verloren levensjaren door sterfte

[207] Bannerjee et al. (2020).
[208] De Hollander & Hanemaijer (2003).

We estimate the number of years of life lost, based on the numbers of confirmed cases of Covid-19 at about 60,000. In absolute numbers this is a severe burden of mortality, yet it is wise to put this number against other daily and accepted risks. The number of years of lost life due to Covid-19 is about the same as the years of lost life as a consequence of household accidents and the cost of smoking costs about seven times as many DALYs on a yearly basis. A base for this calculation is an average loss of a little less than 10 years per corona death assuming all victims have an average health. This is for sure an overestimation of the true number of DALYs, as no correction has been made for the severe burden of disease for Covid-19 victims. Another problem is that this calculation is only based on recorded Covid-19 deaths. There are many unrecorded deaths, for example in care homes, however residents have a shorter life expectancy and thus loss of DALYs than their peers not living there.

4.4 Risk of mortality of Covid-19 after visiting an event

Previously in this Chapter, we described the risk and the burden of mortality on a national level. The risk of Covid-19 can also be calculated on an individual level and can also be compared with other risks. A unit that we be use here is called 'micromort.' This unit is often used to give an insight in various smaller risks and compare these with each other.

The micromort was developed in 1968 by Ronald Howard at the University of Princeton. One micromort equals a 1 in a million chance of dying. An activity for which the chance of dying is 1 in 5 million, like deep-sea diving, is equalled with 5 micromorts. The unit helps to compare risks and put them in perspective. The unit is therefore used often in some industries, and can also be used in the medical world, to communicate the risk of a medical procedure to a patient.[209]

The unit can also be used to compare the risk of death by Covid-19 after to visiting an event with other day-to-day and accepted risks. In order to calculate the number of micromorts for visiting an event, we need to know two other figures: a) the chance to get infected at the event, and b) the chance of dying if you were infected with Covid-19.

This comes down to the following formula:

*Chance of infection * infection fatality rate = personal risk in micromorts*

Chance of infection

For the chance of infection, we work with the target value used in the study by *bba binnenmilieu*.[210] In this report it is advised to use a target value of 1% for the infection route through aerosols in large concert halls like Ziggo. Therefore, we will use a 1% chance of infection for our purpose.

[209] Howard (1989); Ahmad et al. (2015).
[210] Beuker & Boersema (2020).

Infection fatality ratio

As described in Chapter 2, it remains difficult to ascertain the exact percentage of the IFR. The estimates vary within a certain range. Below are a number of different calculations, from a very conservative, worldwide IFR estimate and an IFR based on a study of bloedbank Sanquin (Dutch blood bank) about sero-prevalence in the entire Dutch population and in Dutch people below 70.

In the table below, the number of micromorts for an individual visiting an event is calculated. In the final column some activities are mentioned with a comparable number of micromorts. The extra risk of these activities is added to the risk that an individual runs each year in the Netherlands. Based on the population in the Netherlands this is about 24 micromorts.[211]

Chance of infection	Height IFR	Formula	Number of micromorts	Comparable with this activity
1%	1% (entire population worldwide) [212]	0,01 * 0,01	100	A day in the life of a 75-year-old[213]
1%	0,68% (population in the Netherlands) [214]	0,01 * 0,0068	6,8	• Running a marathon[215] • Carrying out a paid job for one year[216]
1%	0,09% (the Netherlands <70 years)[217]	0,01*0,0009	0,9	• Riding a car for 480 km [218] • Riding a bicycle for 44 km[219] • Riding a motorcycle for 11 km[220] • Flight from Amsterdam to Bali (12,000km)[221]

4.5 Corona mortality compared to safety policy standards in the Netherlands

Generally speaking, the standard for the mortality risk of a person exposed to a risk is 1 in one hundred thousand, usually written down as: $1 * 10^{-5}$. As recent as 2015, the Minister of Economic Affairs has determined that in the case of earthquakes the individual risk in the

[211] Formula: 151.885 deaths in 2019/17,282,163 inhabitants in The Netherlands on 1 January 2019/265 days. Source: CBS.
[212] Ferguson et al. (2020).
[213] Routley (2020), not peer-reviewed.
[214] Ioannidis (2020) bases his calculation on Slot et al. (2020), not peer-reviewed.
[215] H'rala (2016), not peer-reviewed.
[216] Keage & Loetscher (2018).
[217] Ioannidis et al. (2020), not peer-reviewed.
[218] O'brian (2014).
[219] Keage & Loetscher (2018).
[220] Keage & Loetscher (2018).
[221] Keage & Loetscher (2018).

Netherlands is also set at $1 * 10^{-5}$.[222] There are also a number of specific chemical risks for which this risk standard has been refined: for living near a chemical plant the mortality risk has been set at 10^{-6} (this is called external safety policy).

1 in 100,000 is the standard for flood protection in the Netherlands as well
For flood protection (dykes), there is a chance of exceeding: the chance that a certain water level is exceeded, causing the dyke to break. This risk is calculated to once every 10,000 years, for example, in Amsterdam. This equals a mortality risk of one in 125,000 years (with the assumption that 8% of the inhabitants of Amsterdam will perish during such a flood, leading to the complete destruction of city). Within the Netherlands the chances of exceeding vary with the economic value or the evacuation possibilities in the country. The current exceeding chance for the whole of Central Holland is once every 10,000 years, for the region above the rivers, this is once every 1,250 year and for the coastal region once every 4,000 years.[223] The individual mortality risk, stated in the new Delta Policy for a flood risk is set at once every one hundred thousand years (10^{-5}).[224]

To be able to assess the mortality risk of the coronavirus (for people younger than 70 with no underlying medical conditions) with the general standard risk of one in one hundred thousand, we have tried to calculate the individual risk. We believe this is the first time that this has been done, as far as we know:

According to research, 461,622 people had been infected in the Netherlands until April 15. About 82% of all Dutch people are below the age of 65. Using the same 'attack rate' among all groups as a starting point, this comes down to 378,530 infections for people below 65. Based on the number of deaths of people below 70, an IFR for people below 70 has been deduced of 0.09%.[225] This IFR is valid for the entire cohort of people below 70. If, as seen in Chapter 2, the mortality risk of Covid-19 is strongly correlated with underlying conditions, the IFR for people below 70 without these conditions is even smaller.

In another study it was seen that, until April 25, 257 Dutch people below 65 had deceased. For 204 of these it was known they had underlying medical conditions. They were checked on cardio-vascular disease, high blood pressure, diabetes and lung disease, as these conditions had the worst effect when suffering from Covid-19. Of these patients 23 had no other illnesses. This means that 11.17% of all recorded corona dead below the age of 65 (in that study: 204) in the Netherlands did not have underlying medical conditions.[226] For our calculations, we will say that for the entire population of people below 65, about 80% do not suffer from these underlying conditions.

Based on the data it is possible to make a tentative estimate of the IFR for people younger than 65 without underlying medical conditions. The formula would then be written down as follows:

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222 Kamp (2015).
223 Rijkswaterstaat (2006).
224 RIVM (2004); Rijkswaterstaat (2006).
225 Ioannidis (2020), not peer-reviewed.
226 Ioannidis et al. (2020), not peer-reviewed.

IFR <65 and healthy = total mortality <65 and healthy / ALL infected Dutch people younger than 65 and have 0 underlying illnesses

The number '*ALL infected Dutch people younger than 65 and have 0 underlying illnesses'* is estimated by '*ALL infected Dutch people younger than 65'* times '*the percentage of all Dutch people younger than 65 that have 0 underlying illnesses'*

A complete sum would look like this:

IFR <65 and healthy = (257 * 11,27%) / (378.530 * 80%) = 9,6 * 10^{-4}

For healthy people below the age of 65, the mortality risk following a corona infection would be approximately 1 in 10,000, making their individual risk higher than what we would normally deem an acceptable risk. So, under normal circumstances we would for involuntary risks advocate safety regulation. Note that this risk is comparable to dying in traffic or living behind river dikes.

We conclude that visiting an event is a voluntary risk that for healthy people younger than 65 years is in a worst-case situation comparable to driving a motor-bike (also 10^{-4}).

A number of things should be noted regarding this worst-case calculation:

First, we equal the IFR with the individual risk. This is actually an overestimation, because not all people will be infected. It does indicate that we are on the 'safe' side.

In order to arrive at the IFR for healthy people below 65, we used two studies. Both have the same source (data from RIVM), but they used different reference dates. The original IFR (0,09%) is derived from the mortality data until April 15, while the collection of data on deaths under the age of 65 ends at 25 April. Both studies also used two different age groups. The age group for which the initial IFR is was calculated is below 70, while the data collection to distinguish the groups of people with or without underlying conditions, is for people below 65. The initial IFR is thus probably an overestimation, albeit small, of the group below 65.

Generally speaking, the distinction between people having underlying conditions and those who have not, does not take into account the seriousness of these illnesses. It seems probable that a severe underlying illness will increase the risk of a corona infection, whereas, people with less severe illnesses could be compared more readily with healthy people.

One problem with the dataset of 23 people in the Netherlands who were below 65 and did not suffer underlying conditions but died from corona is that, taking into account an IFR of about 1 in one hundred thousand, there must have been 2.3 millions of infections up to the point of April 25 within this healthy population to arrive at 23 deaths. Yet research of Ioannidis et al. estimates the number of infections for the entirety of the Netherlands at a little over 460,000, based on a study among blood donors. Possible explanations might be that among this group of 23 deceased, there are people who do have relevant underlying chronical illnesses that weren't diagnosed or recorded. Or it could be the limitation that the IFR is derived from a seroprevalence study among blood-donors. This group is not representative of the Dutch population as a whole. 14 days prior to donating blood, donors cannot have been ill, and certain groups such as the elderly, ethnical minorities, homeless people, who are more vulnerable to infections, are under-represented in the blood-donor population. There are also strong indications that not all people who were infected will make antibodies that can be measured.

4.6 Conclusion and significance for events

For the majority of the Dutch population (65 years old or younger, healthy) the chance to die from the coronavirus is one in ten thousand. In Dutch safety policy terms, a mortality risk of one in hundred thousand per year is the generally accepted standard norm for involuntary risks. Visitors of events where no measures at all are taken therefor face a risk that in a worst-case calculation compares to motor-biking.

Aside from the mortality risk, there is also the burden of disease of corona that is relevant. People who are infected with corona can get very sick and even after the infection will take long to fully recover. The extent of the differences between the consequences of a corona infection or other infections like the flu, cannot be said on the basis of the current scientific knowledge.

The worst-case calculation of the individual risk of visiting an event assumes an infection rate of 100%. If we assume an infection rate of no higher than 1%, the risk is in the order of magnitude of 10^{-6} and thus neglectable, as we would say for other areas of safety.

5 Overall Conclusion

This Chapter summarizes all the findings of the previous Chapters and presents the significance for events.

5.1 The beginning and central question

On March 15, 2020, the Dutch government decided to take severe measures to tackle the new coronavirus. Schools, day-care centres, sports and fitness clubs, bars and restaurants, and other businesses, were ordered to close their doors on March 16. A little before that companies were asked to let employees work from the home as much as possible and events and concerts with over 100 visitors were cancelled.

That the coronavirus was a potential threat to public health around the middle of March is not challenged here, and never will be. A response by the Dutch government was inevitable, based on what we knew then.

Almost five months after the proclamation of these severe measures, much is still unclear about the facts upon which the Dutch government has based their policy *at this point in time*.

For this reason, concert promoter Mojo has asked Crisislab to present the facts, as they have been reported in scientific literature. Mojo is especially interested in the significance of this for indoor and outdoor events.

For Crisislab, this assignment fitted their goal to develop and spread knowledge in the area of proportional safety policy, because at this moment facts are often missing at policymaking and discussions about safety governance. This means that we are open for new views, for example on the calculations that we made, for the first time, for this report to determine what could be realistic policy.

Below we will indicate, for each theme, a) the findings in literature and b) what are the consequences of organising events, sufficiently safe or not. The presented findings were found in scientific literature up to the first two weeks of August of this year.

5.2 Transmission of the coronavirus

Scientific literature states that the coronavirus is mainly transmitted through direct contact with the larger drops of saliva emitted by infected people 'straight forward' and possibly also through droplets (aerosols) that remain airborne for some time. With activities like singing, laughing and talking loud, both larger and smaller drops, and therefore coronavirus particles, are emitted in larger numbers.

From literature we see that the vast majority of infections take place in indoor spaces. The chance of getting infected with corona is very small out of doors. There is only one recorded, possible case of an outdoor infection has been demonstrated.

Transmission through the touching of contaminated surfaces is theoretically possible, says literature, but in actual practice hardly has a significant role in the transmission of the virus.

Significance for indoor and outdoor events

From the above, we can gather that:

- The chance to get infected at outdoor events is sufficiently small. Additional measures to mitigate the risk of infection do not appear necessary.
- The chance of getting infected with the coronavirus at an indoor event depends on a number of factors, including the number of people who are infected who are present and the duration of the event, but is real without additional measures.
- Finally, visitors of an event can also get infected on the way over or back from the event. However, looking at the minimal number of infections actually taking place in public transport, we estimate this is a limited risk. Yet more research here is needed to gain more insight.

5.3 Risk of the coronavirus

At the beginning it was feared that the Coronavirus would have a high mortality. At the moment that the WHO called out a pandemic of the coronavirus, the organization stated that the patients infected with the virus would have a mortality risk of 3.4%. Together with a high infection rate, Covid-19 was expected to become a severe pandemic, quite often compared with the Spanish flu from 1918 that cost the lives of some 40 million people.

Soon it appeared that this initial estimate was a significant overestimation of the true mortality rate, because at the beginning of the pandemic only the most severe cases were being tested for Covid-19, while a large part of the infections is asymptomatic.

At this moment the estimate of the mortality risk for people infected with corona still varies greatly, but for the entire population must be placed between 0.2% to 1%. Yet, the majority of the studies finds the risk is closer to 0.2% than to 1%.

However, it is crucial to remember that there are large individual differences for the risk of dying from the coronavirus. The average mortality risk is raised considerably by elderly people with multiple chronic illnesses who have a considerably higher chance of dying from Covid-19 than young people.

For the majority of the Dutch population (65-year-olds and younger, healthy) the risk of dying following an infection by the coronavirus is smaller than dan 1 in ten thousand. Dutch safety policy uses a mortality risk of one in one hundred thousand as a standard for acceptable involuntary risks.

Not only the mortality risk is relevant with corona, there is also the burden of disease. People infected with corona can become severely ill and, once better, will suffer from long-term effects. How far the consequences of a corona infection compare with other infectious diseases, like the flu, cannot be said at this moment based on the current scientific knowledge.

Significance for outdoor and indoor events

From all the above, we can conclude that:

- The risk of a healthy visitor, below the age of 65, to die from corona at a random event assuming a chance of infection of less than 10%, is smaller than the usual Dutch standard for risks, and would therefore be acceptably small.

5.4 Possible measures and their effect

There are a number of measures discussed in literature:

Social distancing: It is clear that social distancing has a positive effect, depending on ventilation, type of activity, duration, virus characteristics and characteristics of those present. Scientific literature does not give evidence that the Dutch 1.5 metres distancing rule is effective: an important part of the positive effect is already valid at distances shorter than one metre and on the other hand: in specific indoor situations infection can possibly take place over greater distances (through aerosols or in other ways).

Face masks: According to literature face masks partly stop virus particles, when breathing in and when exhaling. literature is unambiguous in stating that face masks do not offer significant protection to the wearer but do help an infected person with emitting less virus particles. The effect in actual practice is unclear. Literature delivers no studies showing that wearing a face mask leads to better or worse compliance to other corona measures.

Ventilation: Literature shows that adequate ventilation in indoor spaces can prevent transmission through the aerosols route. Adequate ventilation is replacing the existing air with fresh air from outdoors or recirculation if the extracted air is cleaned first. Adequate ventilation depends on the characteristics of the space and the activities for which it is used, among other matters. Although literature describes situations where there is adequate ventilation, such as airplanes, literature does not offer a standard calculation for all activities in indoor spaces. It is possible, using the generally accepted Wells-Riley method, to get an indication of what the infection rate would be for a particular indoor space, using several parameters, such as the number of infected persons, the duration of the activity and the ventilation regime.

UV radiation: From scientific literature it appears that natural and simulated sunlight and/or UV radiation can neutralize coronavirus particles within minutes. In the literature, various applications are discussed working on the basis of UV radiation. Some examples: UVC batteries in ventilation grids or UVC lights in special ceiling lamps.

Significance for indoor and outdoor events

From all of the above, we conclude that:

- Ventilation will help mitigate the risks for indoor events, in combination with applications working on the basis of UV radiation.
- As a reminder we would like to note that the risk of infection is sufficiently small at outdoor events and we even find firm evidence in literature that additional measures will have a significant impact to further mitigate the transmission of the virus.

5.5 Final conclusion

Based on the current scientific literature, our conclusion is:

Outdoor events do not lead to an unacceptable risk for visitors or their contacts, simply because transmission hardly takes place out of doors.

For indoor events there is a real risk of infection, but the mortality risk for healthy people below the age of 65, once they are infected, lies below the usual standard of one in every one hundred thousand per year if the chance of infection at the event is less than 10%. We would like to point out here that the relative risk of infection (as opposed to the number of visitors) is smaller in a large and adequately ventilated event location than in bars or restaurants. This point to a not explicatable difference in policy for indoor events with that for bars and restaurant where a certain infection risk is, rightly, accepted.

Besides the individual risk for the visitor of indoor events, there is also, of course, the risk of a visitor infecting other people. Here we also find a difference in policy with other activities that are allowed to take place. Theoretically speaking, this risk can be limited by appealing to the sense of responsibility of visitors of events and to ask them to limit their social engagement with other, more vulnerable, people for two weeks following their attendance at an event.

6 Literature

In this final chapter, we give an overview of all sources we used. Publication dates and page numbers have not been given for all sources. If this is the case, the reason is either that the article is in the pre-print phase, or the article has been published online by the journal in question, but there has not yet been a printed edition of the journal. Almost all sources can be found and are freely available through the search engine 'Google scholar'. The URL of all used internet sources have also been given.

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