

Modelling scenarios for the SARS-CoV-2 Omicron VOC (B.1.1.529) in Norway, January-February 2022

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Samandrag

I denne rapporten gir vi ei oppdatering av modelleringsresultata om spreinga av Omikronvarianten i Noreg, som vart publisert 22. desember 2021. Ved bruk av nye norske og internasjonale data oppnår vi meir presise estimat for spreingstakta og alvorlegheita til Omikron. Vi utforskar framtidige epidemiiske forløp i ulike scenario der vi varierer effekten av tiltak mot smittespreiing og dei epidemiologiske eigenskapane til Omikron-varianten.

Målet med rapporten og modelleringa er å bidra til eit best mogleg beslutningsgrunnlag for myndigheiter og helsevesen, ved å ta inn oppdatert kunnskap og illustrere korleis usikkerheiter i data og ulike tiltak spelar saman og påverkar epidemiens vidare utvikling.

Hovudfunna i denne rapporten er:

- Modellen finn at risikoen forbunde med Omikronvarianten i Noreg framleis er høg. Den raske framveksten av den nye varianten kan føre til stor byrde på helsevesenet, sjølv om Omikron gir mindre alvorleg sjukdom enn Delta. Modellen finn i alle scenario ei bølge av infeksjonar, og påfølgjande sjukehusinnlagte, som får sin topp rundt månadsskiftet januar-februar.
- Avhengig av kor god effekt dei smittereduserande tiltaka har, og kor alvorleg sjukdom Omikron gir, kan denne toppen vere på mellom 100 og 400 nye innlagte kvar dag. Dette svarer i modellen til mellom 500 og 2500 inneliggjande pasientar samstundes. Til samanlikning har det høgste talet på innlagte pasientar så langt i Noreg vore ca. 350, i desember 2021.
- I dei fleste av scenarioa vil det å fjerne kontaktreduserande tiltak 15. januar, føre til markant høgere tal på samtidig smitta og innlagte.
- Viss kontaktreduserande tiltak i staden fjernast éin månad seinare, 15. februar, er biletet meir komplekst. Då finn modellen alt frå ei vellukka gjenopning utan store konsekvensar, til ei stor ny bølge. Dette kjem i stor grad an på kor mange som allereie har blitt immune gjennom Omikroninfeksjon på det tidspunktet, og heng dermed tett saman med kor effektive dei noverande tiltaka er.
- I separate, kontrafaktiske scenario demonstrerer vi kva som kunne skjedd om ikkje dei kontaktreduserande tiltaka i desember var blitt innført. I desse scenarioa finn modellen ein topp midt i januar på 150 000 daglege smitta, og ein påfølgjande bølge med opptil 700 nye innlagte på sjukehus kvar dag.

¹ See the end of the document for a list of all contributing authors

Summary

In this report, we present an update of the modelling results published on December 22nd about the spread of the Omicron variant in Norway. We update estimates of the transmission rate and severity of the new variant using data gathered so far in Norway and internationally. We explore future epidemic trajectories in different scenarios varying the level of infection-control measures and investigating different epidemiological characteristics of Omicron.

The simulations aim to support policy-decision makers based on the current knowledge and answering 'what-if' questions to illustrate how uncertainties in the parameters and different interventions might affect the development of the Omicron epidemic. Due to reduced testing during the Christmas and new year holidays, the level of uncertainty surrounding the epidemiological parameters and effect of interventions is still high.

The simulations show a narrowed range of epidemiological outcomes, compared to the previous report. The doubling time of the Omicron variant, which before was assumed to range between 2.4 and 4 days, has now been estimated to be around 2.9 days, in the first week of December before implementing interventions. The effect of interventions implemented in mid-December remains one of the biggest uncertainties. In this report, we choose a range of reductions in the contact rates that correspond reasonably to the current observed growth rates of the Omicron variant.

The model indicates that the risk posed by Omicron in Norway is still high. The rapid growth of the Omicron variant could lead to substantial burden on the health care sector even if Omicron is less severe than Delta. All the scenarios show hospitalization numbers peaking in late January or early February. In the worst-case scenario, where interventions are assumed to lead to a 30% reduction in the contact rate, we could expect a wave of infections that might cause up to 400 daily hospital admissions. In the more optimistic scenario, assuming 50% reduction in the contact rate, the peak number of daily hospital admissions is reduced to 100.

Currently there are still large uncertainties regarding the severity of infections of the Omicron variant. Although there is evidence that Omicron cases have a lower risk of hospitalization, we still do not have robust estimates. In our baseline scenarios, we halved the risk of hospitalization for Omicron cases, compared to Delta cases. In alternative scenarios we assume instead that the risk of hospitalization due to Omicron is lowered by 70% compared to Delta, leading to a significantly lower burden on the healthcare system, with approximately 200 fewer hospitalizations per day at peak in the worst-case scenario. In the more-optimistic scenarios, the peak of hospitalizations is comparable with the wave caused by the Delta variant in December.

We also perform counterfactual simulations which demonstrate the importance of the interventions implemented in December, showing that we could have faced waves with peaks of 700 daily hospitalizations without control measures. Moreover, we found that a reopening of the society in mid-January could result in many additional infections and hospitalizations. However, the size of this disease burden depends on assumptions on the severity of infection of the Omicron variant that is still uncertain. Finally, we simulate an alternative set of scenarios where a reopening instead happens in mid-February. Then the picture is more mixed, either resulting in a successful reopening with limited consequences, or a large new wave, depending on how effective the contact-reducing measures have been, and hence how many people have already been immunised by Omicron infection at that point.

The model and assumptions will be refined in the coming weeks, as more data and information will be gathered.

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Main changes compared to the previous report

In the previous report published December 22nd 2021ⁱ, given the lack of knowledge on the emerging Omicron variant, we assumed the same severity of infection for the Omicron and Delta variant, reflected in the same risk of hospitalization. International data now show evidence that Omicron infections have a lower risk of hospitalization compared to Delta infections^{ii iii iv}. This matches with preliminary studies of Norwegian data. Analyses of the severity of omicron infections in Norway will be published as soon as they are ready. We have thus refined our assumptions reducing the hospitalization risk of Omicron vs Delta (see sections *Baseline scenarios* and *Alternative scenarios* for further details).

In addition, we have updated our estimates of the growth rate of Omicron before the interventions in December. We now estimate an initial growth rate of 2.9 days compared to the assumption of 2.4 and 4 that were used in the previous report. This report also includes calibration of the effect of recent interventions on data from the last weeks. Given the reduced testing over the holiday, there is still significant uncertainty about the current epidemiological situation.

How we model Omicron

We study the spread of COVID-19 using a stochastic individual-based model (IBM) that explicitly models the spread of the Omicron and Delta variants as two separate strains of SARS-CoV2. This means that the model will keep track of who is infected with what variant, and upon transmission to other individuals, they inherit the variant from their infector.²

The IBM contains detailed socio-demography of the Norwegian population combined with exact information about the number of vaccine doses administered by date, municipality and age. It simulates human contacts in different settings including households, schools, workplaces and in the community. It has been used extensively in the past to model and monitor the COVID-19 epidemic in Norway.^v

We seed the Omicron variant by introducing 100 positive cases randomly in the population on November 24, 2021. The index cases will become infectious, either symptomatically or asymptotically, and begin to infect others. Depending on what assumptions we make for the transmissibility and vaccine evasion of Omicron compared to Delta, Omicron may outcompete Delta and become dominant over time.

Determining Omicron parameters

The main uncertainties for the Omicron variant are its ability to evade vaccine-induced immunity from infection and its intrinsic transmissibility relative to Delta. These two parameters together determine the observed growth rate of Omicron cases in a population. An additional source of uncertainty regards the severity of infection of the new variant, affecting the pressure on healthcare systems.

To define these three parameters, we use the following sources of data:

² In the present version of the model, we assume complete cross-immunity between the strains – meaning that a person who has undergone Delta infection cannot be reinfected by Omicron. This is a simplifying assumption at odds with the data we have on Omicron so far, and we aim to make this more realistic in the next version of the model.

- Preliminary data from the United Kingdom^{vi} on how well the vaccines protect against infection.
- Data on how fast Omicron spreads in Norway so far. Using the number of cases detected in Norway, we estimate the transmission rate of the Omicron variant by fitting the fraction of Omicron cases over time.
- Data from different countries on comparing hospitalizations of Omicron cases and Delta cases.^{ii iii iv}

Modelling scenarios

It is not possible to predict the COVID-19 epidemic over long time periods. This is due both to uncertainties in the epidemiological characteristics of the circulating virus variants, and because the disease transmission depends on intervention levels and people's behaviour, which are extremely hard to predict.

Therefore, we present scenarios of how the epidemic might play out given specific assumptions about policy implementation, people's behaviour, and other factors governing the epidemic, such as the effectiveness of vaccines and the duration of natural and vaccine-derived immunity. We assume there are no changes in human behaviours affecting the contact rate during the simulations. While it is possible to include in the model an effect of change of behaviour as a result of different levels of infection, this would require many assumptions on the size and thresholds of these effects for which we do not have any data. For this reason, we choose not to include such effects in the model. Because of these factors, the scenarios shown are not predictions of how the epidemic is likely to develop in the future but are the modelled outcomes of a specific set of assumptions.

Baseline scenarios

Based on the above considerations, we define our baseline scenarios with the following assumptions about Omicron's properties:

The **vaccine effectiveness (VE) against infection and onward transmission** is reduced by either

1. 20 percentage points (e.g., from 90% (Delta) to 70% (Omicron)), or
2. 35 percentage points (e.g., from 90% (Delta) to 55% (Omicron))

For each of these assumptions, we estimate the relative transmissibility of the Omicron variant so that we get a good match with data on the fraction of Omicron cases over time until now.

In addition, we define a range of **effects of interventions** that fits the observed number of cases, correcting for underreporting (see the *Methods* section for details). We thus assume that due to measures introduced on December 8th, 2021, the contact rate was reduced by 20%. We then vary the reduction in the contact rate due to stricter interventions imposed on December 15th to give a total reduction of the contact rate compared to pre-December 8th of either:

1. 30% reduction in the contact rate;
2. 40% reduction in the contact rate;
3. 50% reduction in the contact rate.

Our baseline scenarios thus consist of two different scenarios of vaccine effectiveness and three different reductions in the contact rate due to interventions. In addition, we make the following assumptions:

- a. **Vaccine protection against severe disease** (i.e., hospitalisation and death) given infection is the same as for Delta.³
- b. **Severity:** There is large uncertainty about the severity of an Omicron infection. We assume that the infection hospitalisation rate for Omicron is reduced by 50% compared to Delta.
- c. **Vaccine uptake:** No further uptake of 1st and 2nd doses of vaccines than SYSVAK as of December 31st. Booster doses are offered to everyone aged 18 and above, with age-dependent uptake according to survey data (see the *Methods* section for details).
- d. **Time delay between 2nd and 3rd (booster) dose** is set to minimum 4.5 months.
- e. **Home isolation** adherence rate is set to 70% for infected when symptomatically ill with COVID-19. A 6-day isolation starts from the next day of developing symptoms.
- f. **Vaccine effectiveness and waning** are based on data from the UK and Norway, and assume a linear waning for 33 weeks (see the *Methods* section for details – the “more waning” scenario is used exclusively in this report)
- g. The **seasonal variation** of the transmission rate is 35% between the warmest and coldest days of the year.
- h. **No future changes in interventions** are implemented.

Alternative scenarios

Having defined the baseline, we then explore alternative scenarios where we independently vary parameters’ assumptions as following:

1. **Severity:**
 - a. The infection hospitalisation rate (IHR) for Omicron is reduced by 70% compared to Delta.
 - i. In a sub-analysis, we also show how an additional 50% reduction in the risk of needing ventilator treatment given hospitalisation, may affect the prevalence of ventilator patients.
2. **Effect of interventions:**
 - 20% reduction in the contact rate on December 8th; no further reduction in the contact rate on December 15th
 - No interventions on December 8th and December 15th
3. **Future changes in interventions**
 - a. Reopen on January 15th to
 - i. a 20% reduction in the contact rate as on December 8th; or
 - ii. the contact rate levels before December 8th
 - b. Reopen on February 15th to
 - i. a 20% reduction in the contact rate as on December 8th; or
 - ii. the contact rate levels before December 8th

Uncertainties, limitations and assumptions

1. One of the main uncertainties in the simulations is represented by the epidemiological profile of the Omicron variant. In particular, the intrinsic transmissibility, severity and the

³ Note that we assume it is the *conditional* protection against severe disease *given infection* that is unchanged.

capacity to escape vaccine protection are currently highly uncertain and different assumptions have a decisive impact on the future Omicron epidemic.

2. Due to the uncertainty about intervention-induced and spontaneous, self-regulating behavioural changes in the population as well as properties of the virus and effect of vaccines, the results are very uncertain.
3. The precise reduction in the contact rate resulting from the last bundle of measures implemented in December cannot be quantified from the current data due to underreporting during holiday. We thus ran simulations with different values to take into account a range of more optimistic and more pessimistic scenarios.
4. The model simulates the spread of two strains, Omicron and Delta variant. We assume that individuals infected with one strain gain lifelong protection against COVID-19 reinfection by any strain, and that this immunity does not wane over time. This assumption might potentially underestimate the spread potential of the new strain. The model estimates that ~10% of the population is infected with the Delta variant at the time of Omicron introduction, thus reducing the number of susceptibles to Omicron. However, part of this effect will be adjusted by the calibration to the Omicron doubling time. With a less-than-complete cross-immunity between strains, it is also possible that the two strains would co-exist in the long run.
5. The estimated prevalence of patients in hospital and on ventilator treatment depend on the assumed length of stay (LOS). The length of stay of Omicron cases is unknown. In this report we assume the same LOS for patients infected with the Omicron and Delta variant. The prevalence numbers in this report are thus highly uncertain and should be viewed as crude estimates.
6. The model takes into account differences in the vaccine distribution at the municipality and age level based on current Norwegian data. However, we do not consider the effect of clustering of unvaccinated individuals within households or in social mixing in the public setting. Small groups in the community with low vaccine coverage, might lead to the emergence of local outbreaks.
7. Assumptions about vaccine effects and vaccine deliveries are uncertain. The policy of vaccinating population has been changing these days. We model the current Norwegian vaccine policy and do not consider giving 2nd doses to aged 12-15 and 1st doses to aged 5-11. The model will be updated if the current policy is changed.
8. There is a lack of data about the current level of adherence to individual control measures, such as home isolation. We run the baseline scenarios in the model assuming a 70% proportion of home isolation among symptomatic cases. Adherence to home isolation is kept constant throughout each run. In reality, this parameter as other intervention-related parameters might change in time, depending on the evolution of the pandemic and future changes in the infection-control policies.
9. No quarantine measures are included in the model currently. This means that contact rates of pre-symptomatic individuals remain at the levels before December 8th, which could be overestimated now. In the model, setting-specific measures including home quarantine, school closures and home office are now reflected by the overall intervention effect as one parameter. More details on specific, implemented measures will be added in the next updated report.
10. The relative importance of transmission by asymptomatic and pre-symptomatic individuals is not well known, and these factors significantly impact the transmission dynamics in the model.
11. We assume that Omicron has the same generation time/serial interval as Delta.

Results

We present results of the spread of the Omicron and Delta variants for each scenario consisting of 40 stochastic simulations over the period between December 1, 2021, and February 28, 2022.

Baseline

The baseline scenarios show the outcomes of the two different assumptions for the Omicron vaccine effectiveness (VE) against infection, combined with the three different assumptions for the effect of the interventions on reducing the contact rate. The other parameters are as defined in the baseline above.

The simulations show a peak of infections occurring between mid-January and mid-February, ranging between 25 000 and 90 000 daily cases. This results in a wave of hospitalizations that peaks at around 150 daily admissions in the scenario with a 50% reduction in the contact rate after the 15th of December, and approximately 400 daily admissions in the scenario assuming a 30% reduction in the contact rate after the 15th of December.

It is important to note that estimates for hospitalisation, and in particular ventilator beds, exhibit an additional level of uncertainty because they depend on estimates of risk that are based on limited data. Estimates for prevalence additionally depend on assumptions about length of stay, which are especially uncertain, as stated in the limitations.

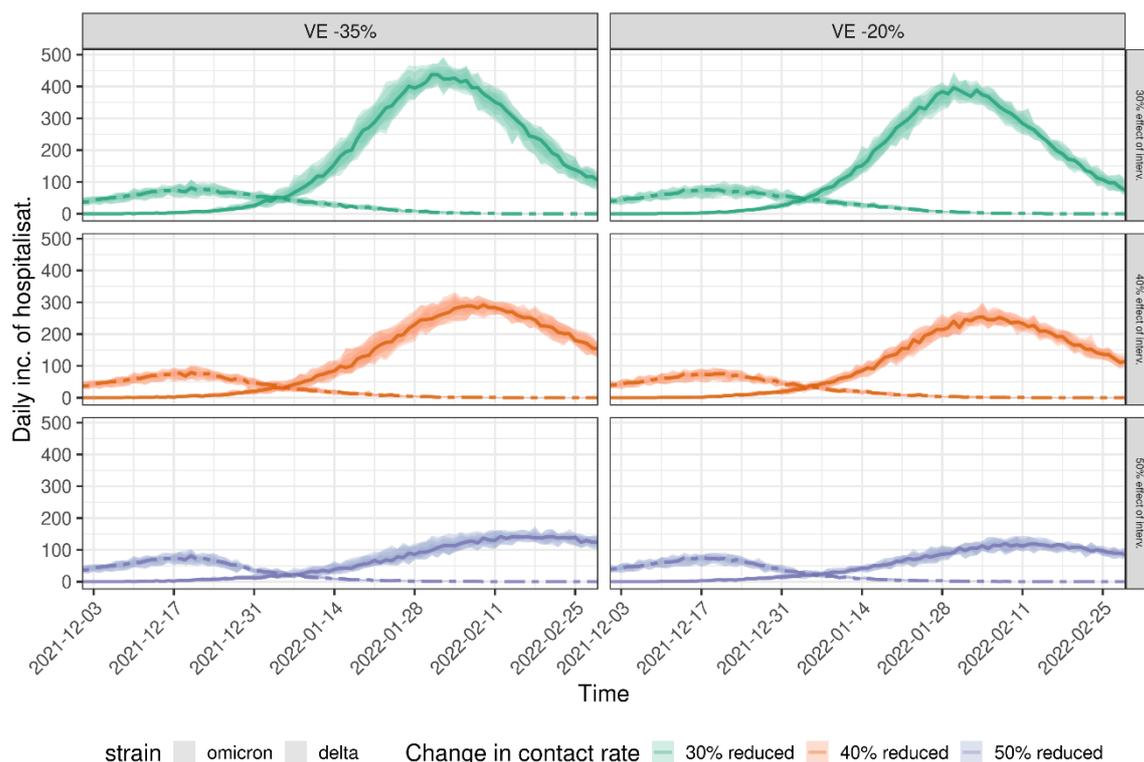


Figure 1: Daily incidence of hospitalizations in the baseline scenarios until the end of February. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.

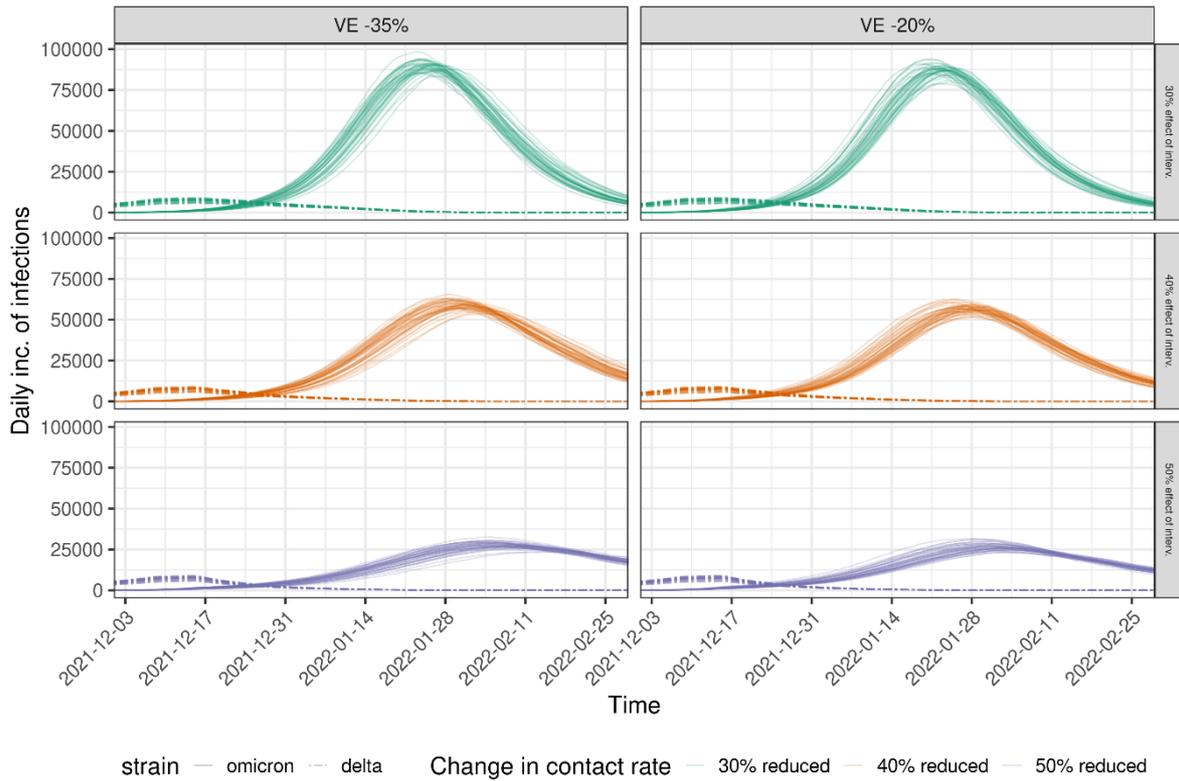


Figure 2: Daily incidence of infections in the baseline scenarios until the end of February. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.



Figure 3: Daily prevalence of hospital beds in the baseline scenarios until the end of February.



Figure 4: Daily prevalence of ventilator beds in the baseline scenarios until the end of February.

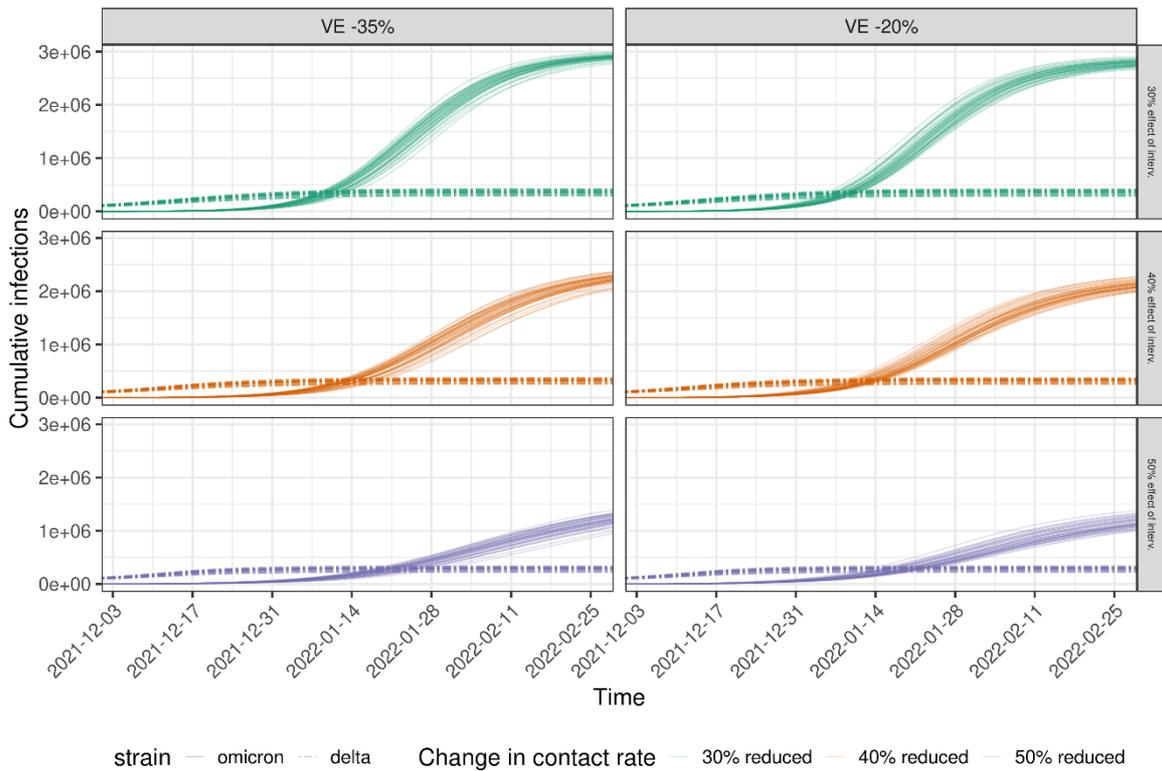


Figure 5: Cumulative number of infections in the baseline scenarios until the end of February. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.

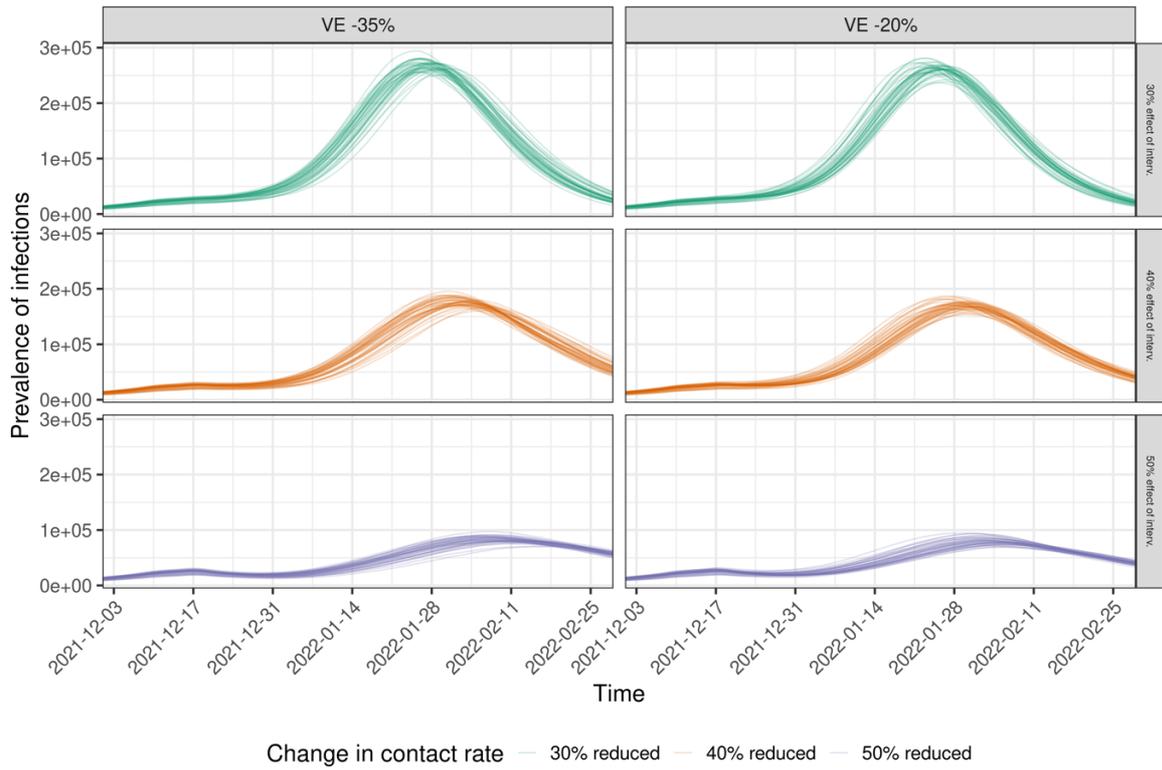


Figure 6: Prevalence of infections in the baseline scenarios until the end of February.

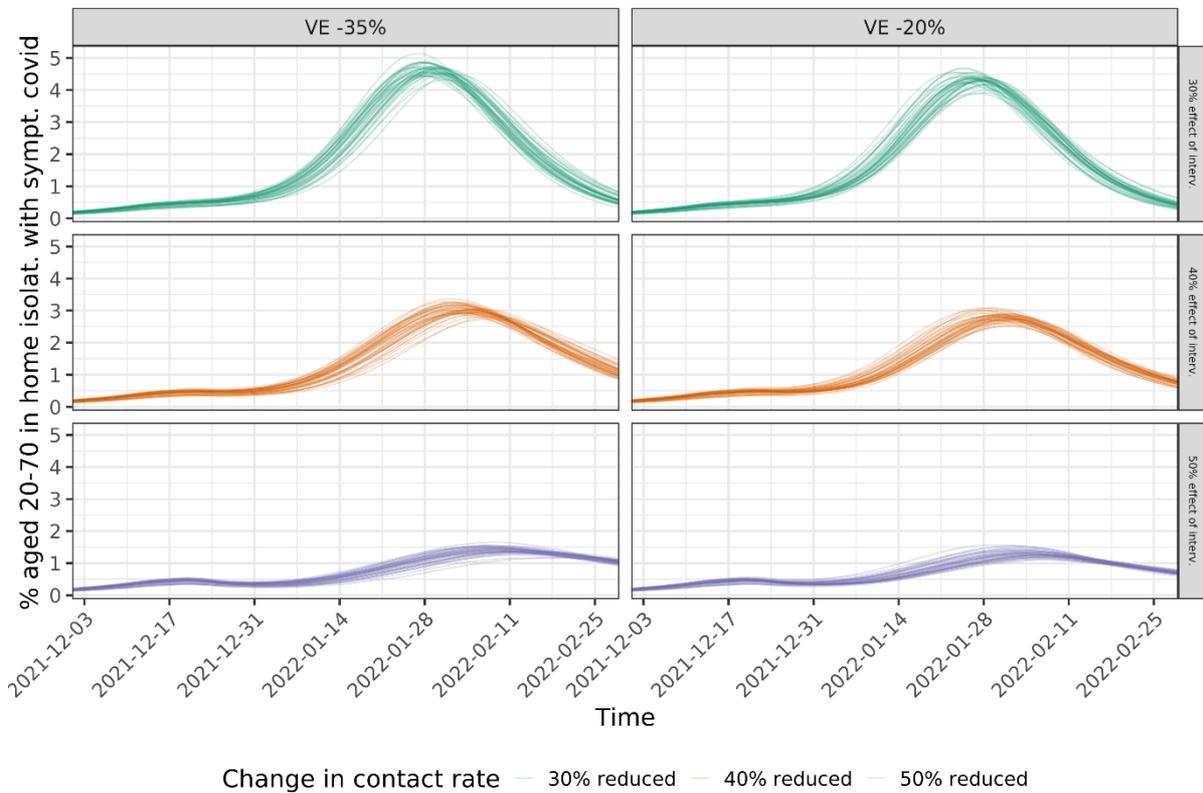


Figure 7: Number of people in working age (20-70 years old) who are at any given time in home isolation due to covid-19. The model assumes that among those who are symptomatically ill, 70%

will isolate at home. Note that this number does not include people who are in quarantine due to contact tracing or similar.

Severity of infection

In this section we show how the pressure on the healthcare systems would change if the hospitalization risk of Omicron cases would be 70% lower than Delta cases, instead of 50% as in the baseline. The results are shown for the three baseline effects of interventions imposed on the 15th of December.

The scenarios show that the circulation of a milder Omicron variant would result in a significant decrease in the number of hospitalizations, with approximately 200 fewer hospitalizations, compared to the baseline, in the worst-case scenario assuming a 30% reduction in the contact rate after the interventions imposed on the 15th of December. In the most optimistic scenario, we see that the Omicron wave of hospitalizations would be comparable with the daily number of hospital admissions caused by the Delta variant in mid-December.

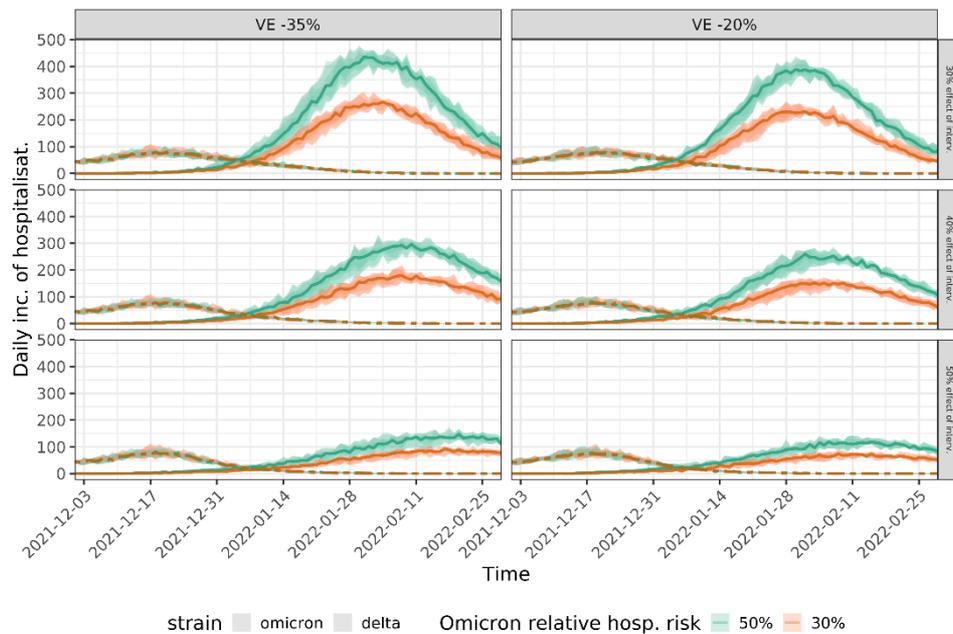


Figure 8: Daily incidence of hospitalizations for different risks of hospitalization of Omicron cases. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.

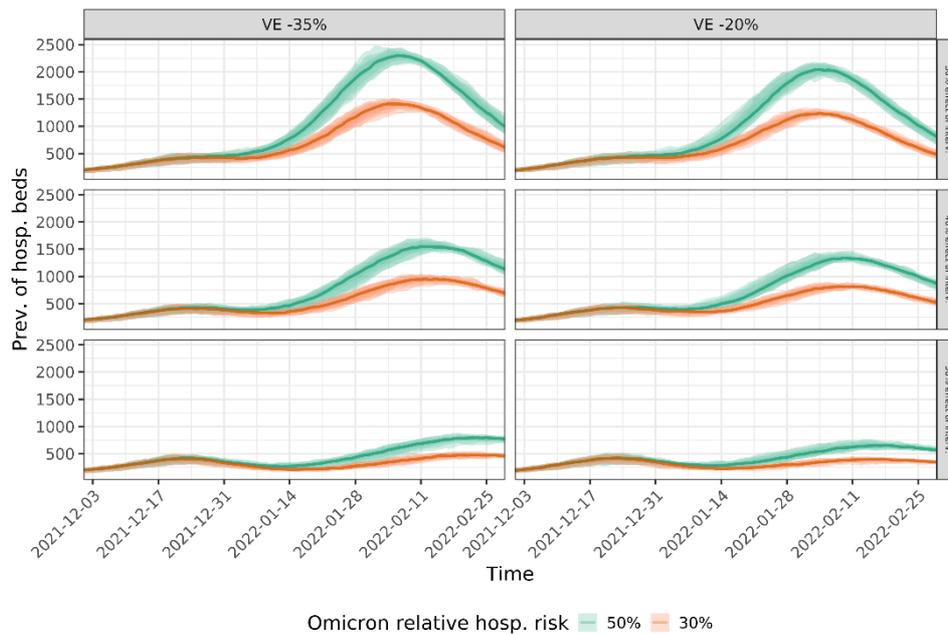


Figure 9: Daily prevalence of hospital beds for different risks of hospitalization of Omicron cases.

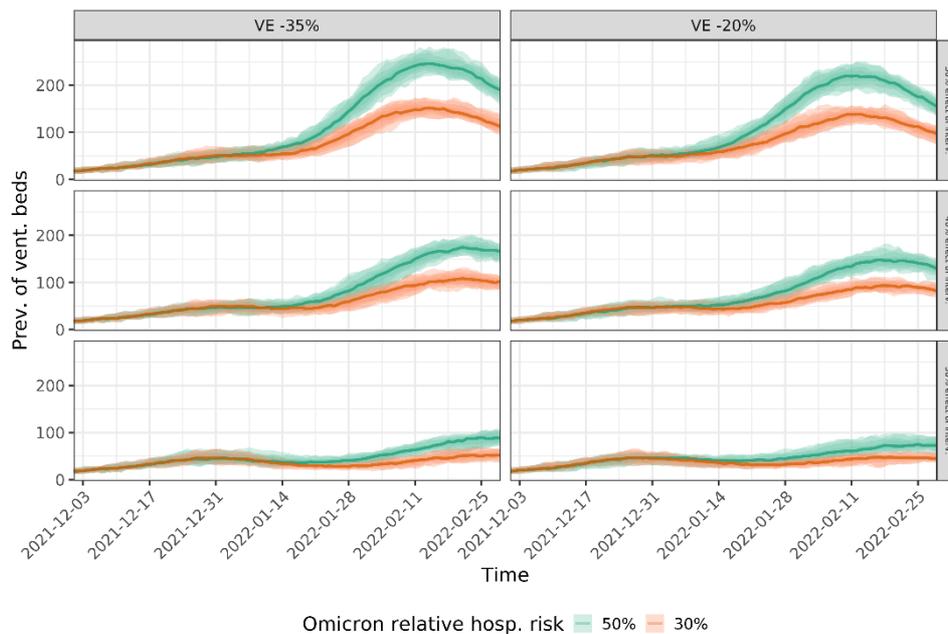


Figure 10: Daily prevalence of ventilator beds for different risks of hospitalization of Omicron cases.

Further reduction in risk of needing mechanical ventilator treatment

In this subsection, we demonstrate the effect of assuming that the risk of needing ventilator treatment among those admitted to hospital, is halved. For example, data from the UK show that patients in the hospital have more than doubled between the 24th of December and the 4th of January, while patients on ventilator beds have remained stable^{vii}. This assumption would come in addition to the assumed reduction in hospitalization risk from Omicron compared to Delta of either 50% or 70%. The following figures are made by simply scaling down the estimates for the prevalence

of ventilator treatments by 50% compared to the figure above. This makes the estimate incorrect for the early period where Delta is dominating but serves as a scenario from January 2022.

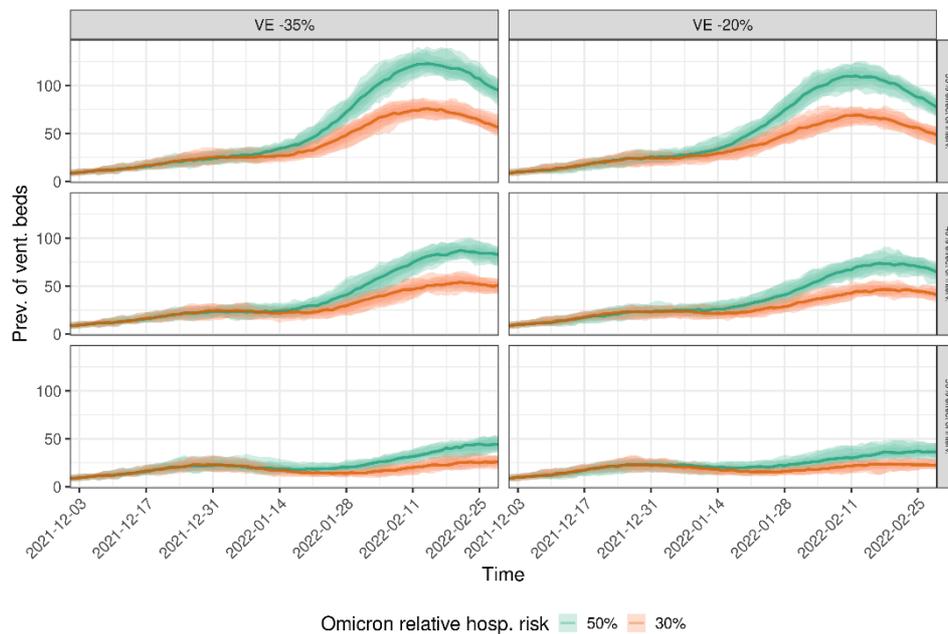


Figure 11: Daily prevalence of ventilator beds for different risks of hospitalization of Omicron cases, assuming that the risk of needing ventilator treatment is halved compared to the estimated risk for Delta.

Counterfactuals: Less strict or no interventions implemented in December

In this section we present two counterfactual scenarios. The first scenario shows the modelled trajectory of the Omicron epidemic had no interventions been imposed on the 8th or the 15th of December. The second scenario shows what the model thinks would have happened if instead less strict interventions had been in place, reducing the contact rate by 20%, on the 8th of December only.

The model results show a significant effect of the interventions imposed in December. The scenario with no interventions implemented displays a peak of 700 daily hospitalizations and 150 000 daily infections, occurring in the second half of January. The scenario with a 20% reduction in contact rate shows a peak around the 1st of February with 500 daily hospitalizations and 125 000 daily infections

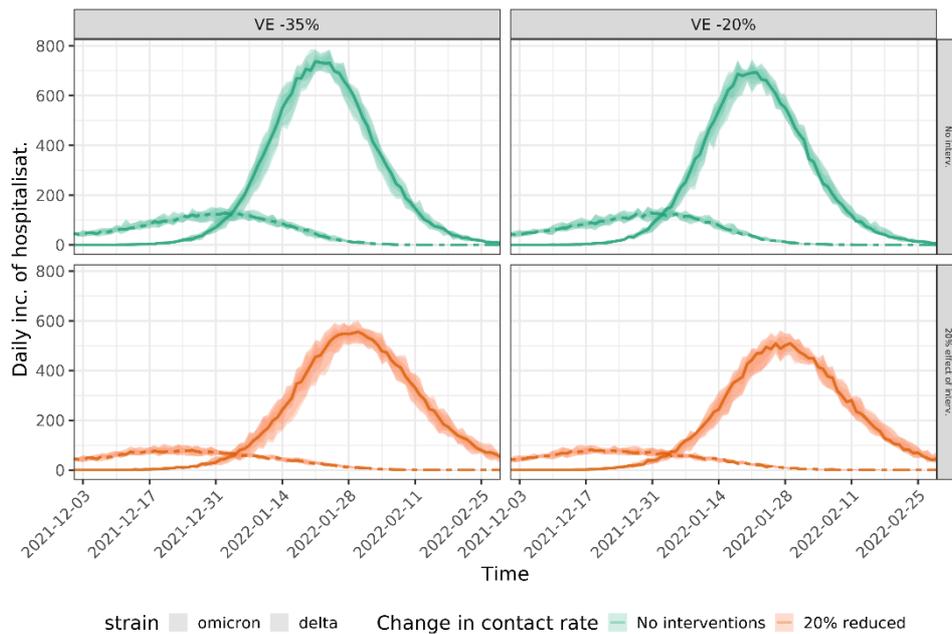


Figure 12: Daily incidence of hospitalizations for alternative scenarios of interventions imposed on the 15th of December. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.

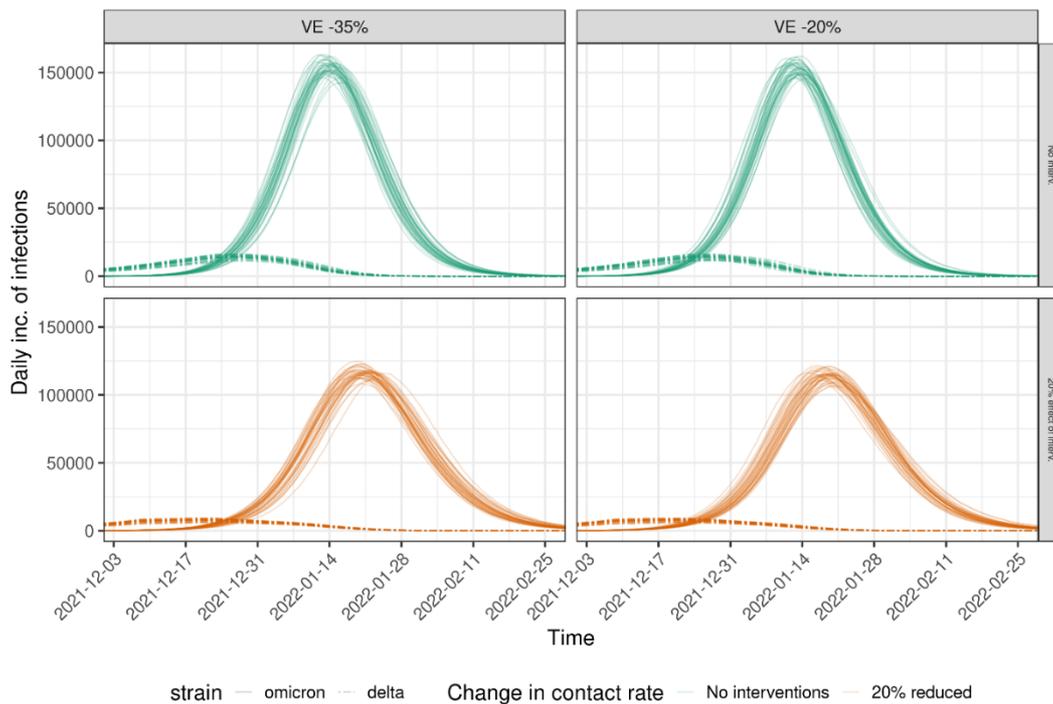


Figure 13: Daily incidence of infections for alternative scenarios of interventions imposed on the 15th of December. Solid lines indicate Omicron cases, dashed lines indicate Delta cases.

Reopening, full or partial

Here, we show different scenarios simulating the effect of relaxing infection-control measures on the 15th of January or 15th of February to reopen the society. The results are shown for the three baseline effects of interventions imposed on the 15th of December.

Reopening on January 15th

The simulations show that a full relaxation of the control measures in mid-January might result in a wave of hospitalizations with 600-800 daily admissions at the peak, occurring in the first half of February. This effectively means that the interventions will have delayed the wave, but not reduced it much in size compared to the counterfactual scenarios above. This happens because not many people become infected before the reopening, and thus there is not much build-up of immunity from infection. The increase in number of people with booster doses helps to reduce the wave somewhat, especially in the scenarios with less escape of vaccine-induced immunity by Omicron.

A partial reopening of the society to the level of the first measures implemented on the 8th of December, would instead results in a peak of 400-500 hospitalizations.

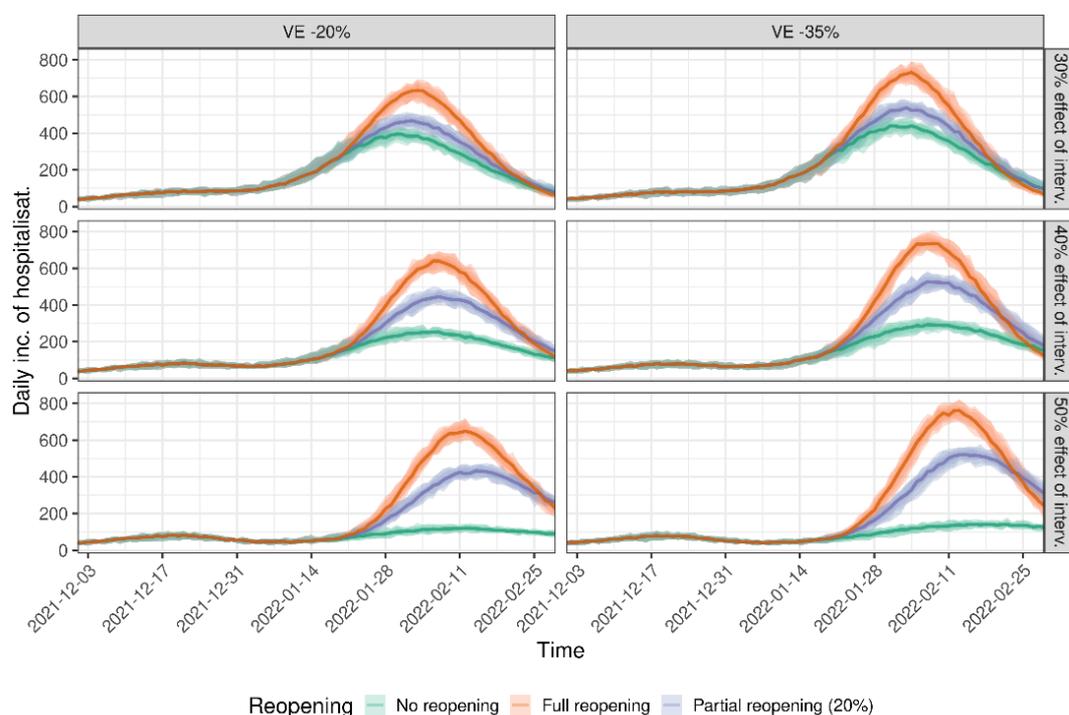


Figure 14: Daily incidence of hospitalizations for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on January 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

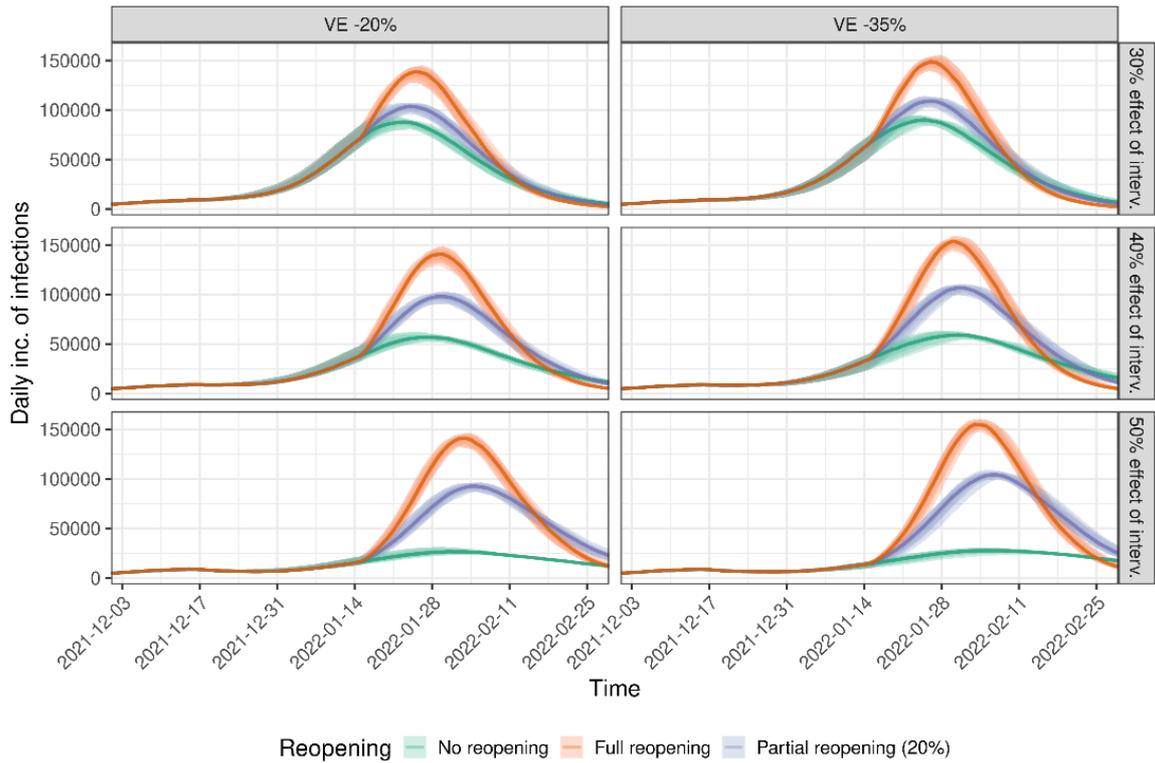


Figure 15: Daily incidence of infections for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on January 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

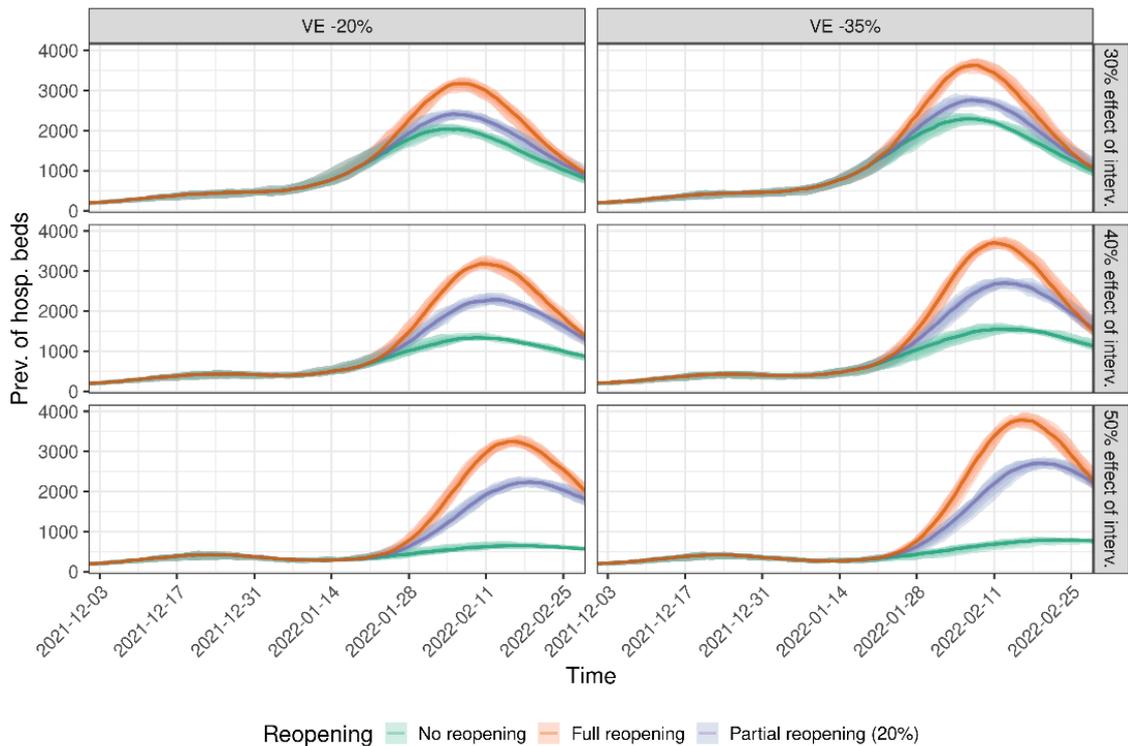


Figure 16: Prevalence of hospitalizations for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on January 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

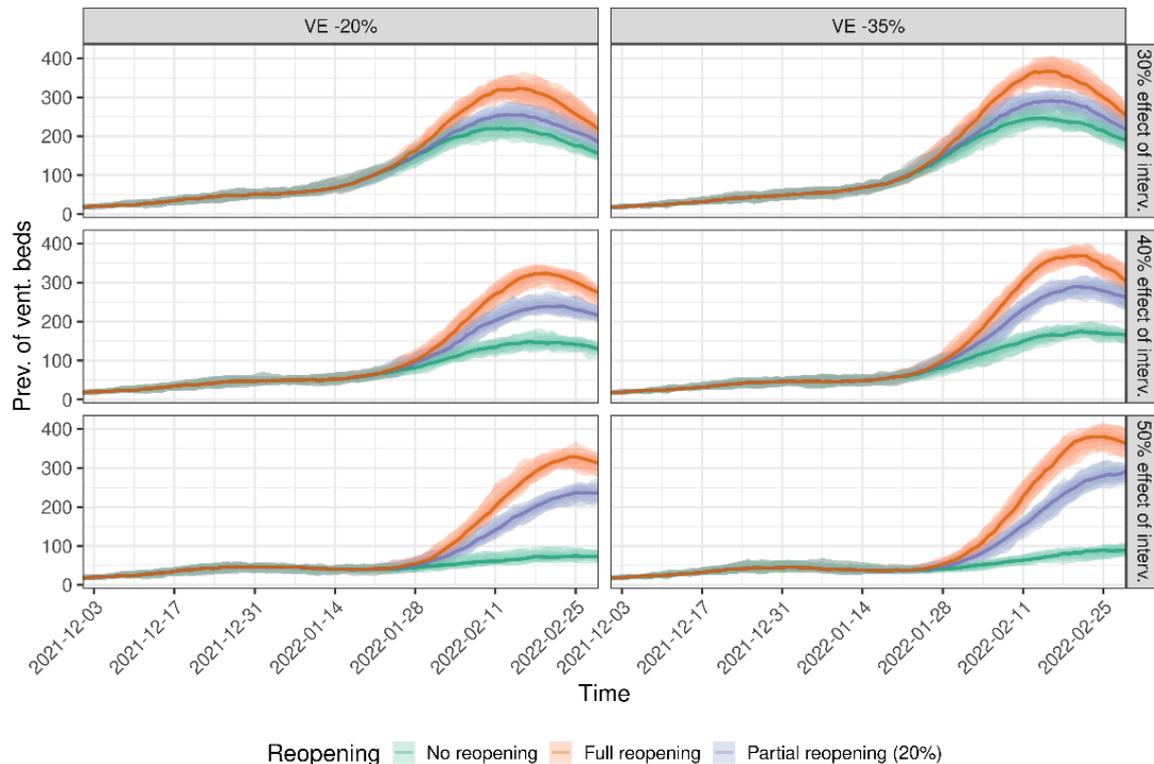


Figure 17: Prevalence of patients on ventilator treatment, for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on January 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

Reopening February 15th

We also simulate an alternative set of scenarios where the contact-reducing measures instead are kept for one month longer, until February 15th, and then they are either removed or relaxed. The resulting picture is a bit more complex and depend on how effective the contact-reducing measures have been during the preceding wave. In scenarios where the contact-reducing measures have not been so effective (30% reduction, top row), then a full or partial reopening on February 15th is not so dramatic. This is because the first winter wave in these scenarios will have led to such a large number of infections in the society that there is widespread immunity against reinfection, regardless of contact rate. In scenarios where the contact-reducing measures have been more effective (50% reduction, bottom row), a reopening, somewhat paradoxically, leads to a large wave in March, because there has been less buildup of immunity during the January-February wave. The middle scenarios (40% reduction) give a result in between, where the reopening leads to a second wave of similar magnitude as the first. All scenarios with full reopening result in approximately the same total number of infections during the simulation time.

Note that the effect sizes and timings in these scenarios may be extra vulnerable to our assumption of complete immunity gained after Delta infection, as stated in the limitations section, because the true number of Omicron-susceptible individuals in the population could be larger than what the model assumes. As with any of the modelling results, this should be interpreted with caution.

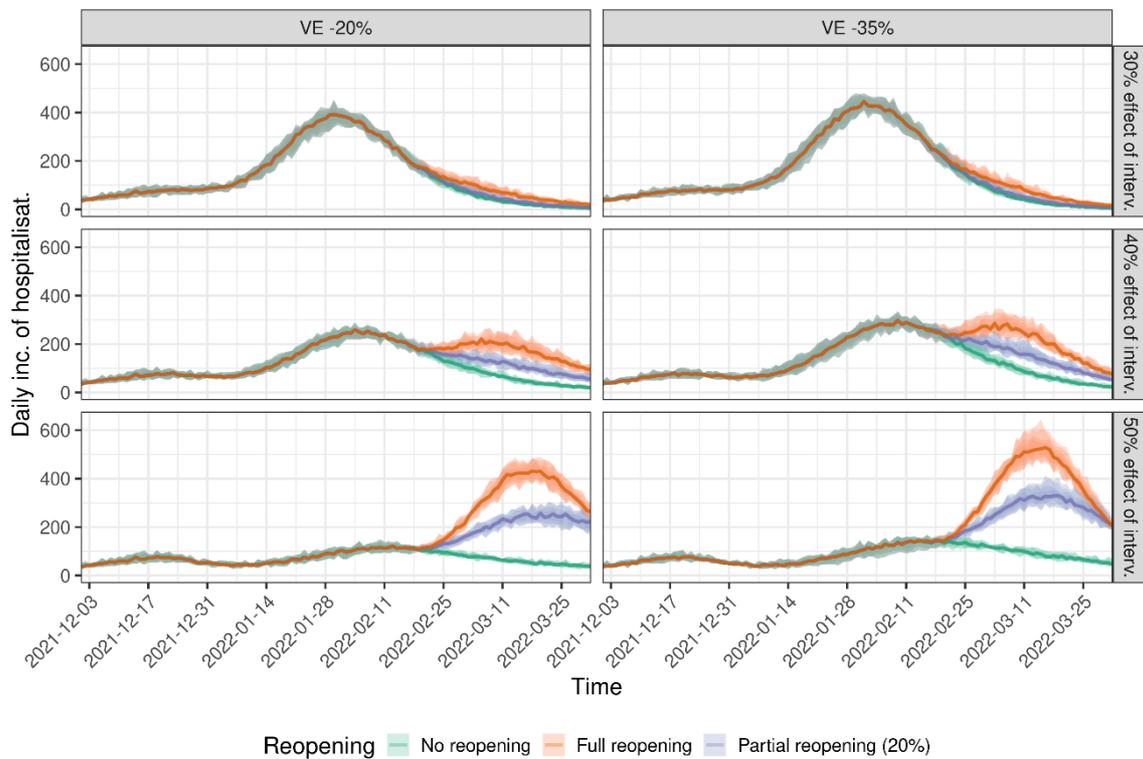


Figure 18: Daily incidence of hospitalizations for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on February 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

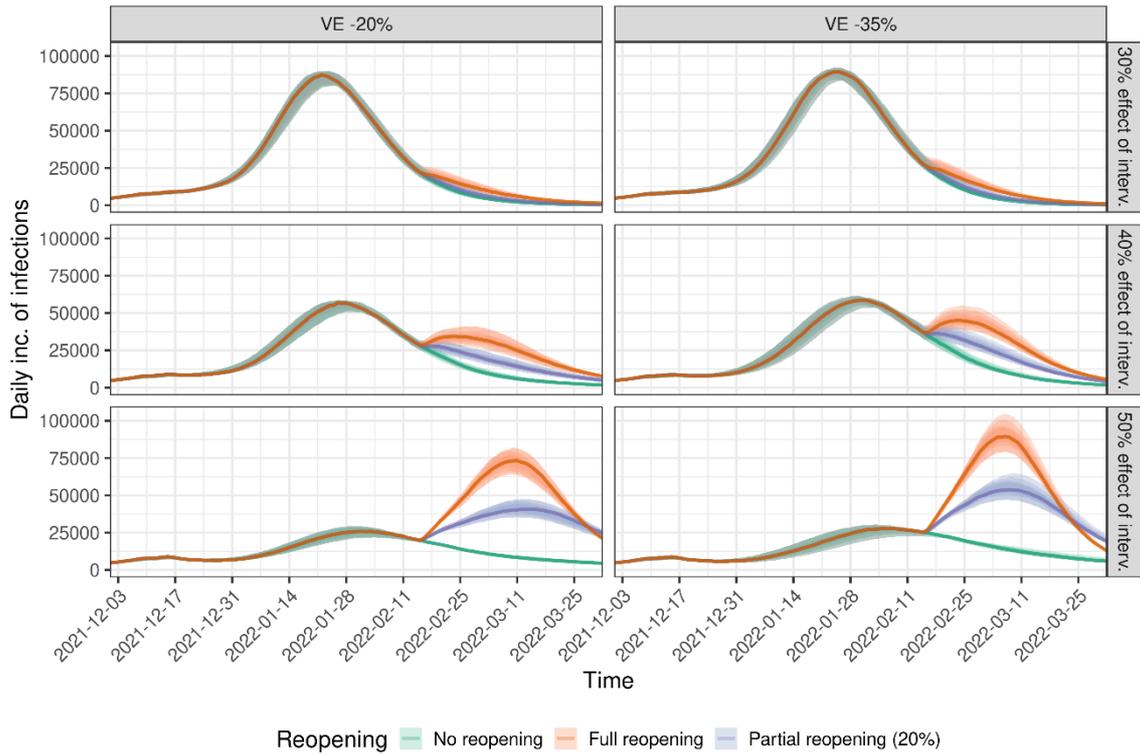


Figure 19: Daily incidence of infections for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on February 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

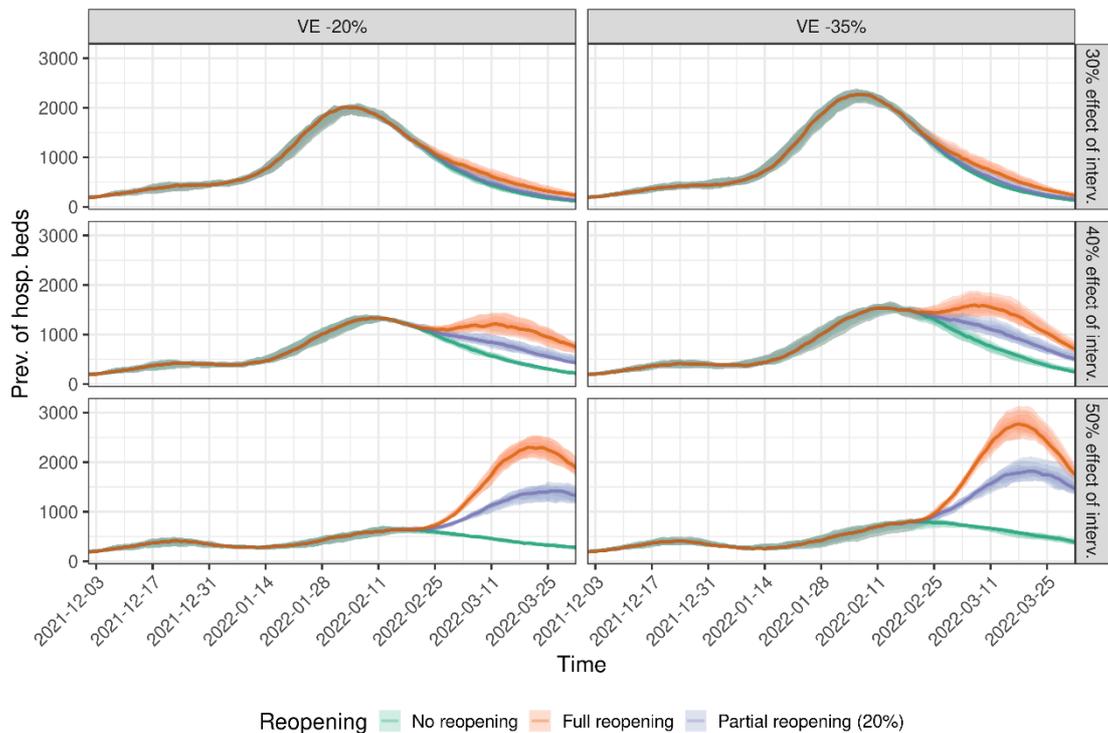


Figure 20: Prevalence of hospitalizations for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on February 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

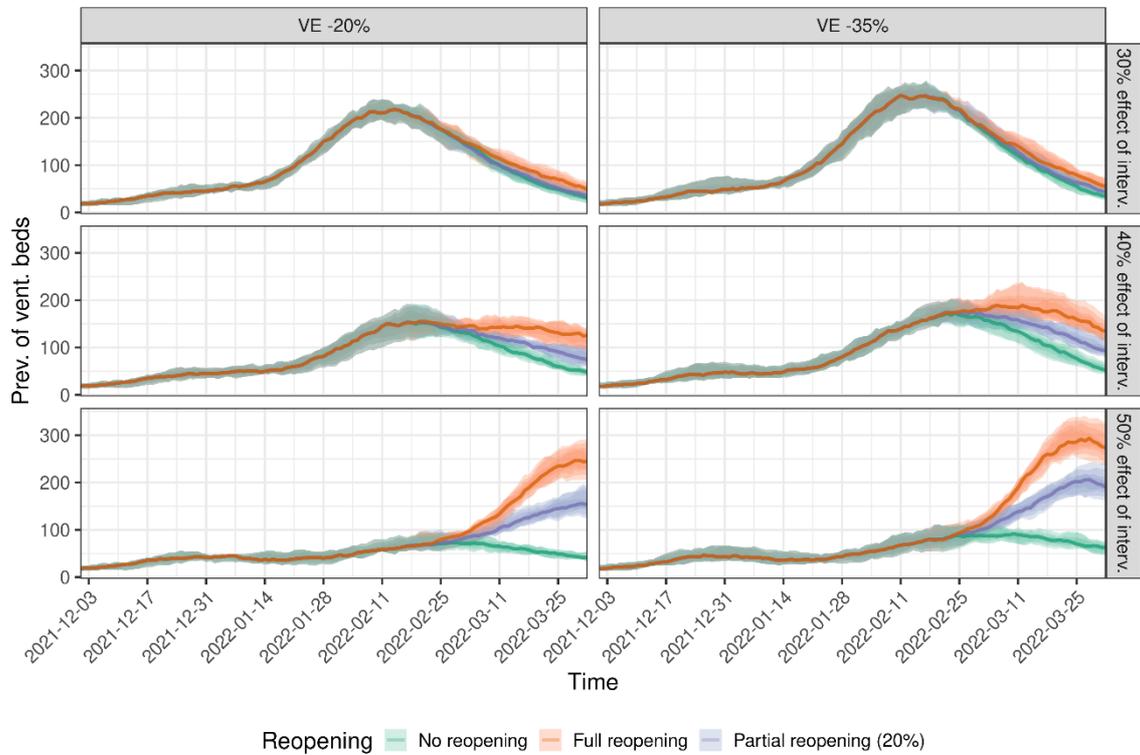


Figure 21: Prevalence of patients on ventilator treatment, for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on February 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

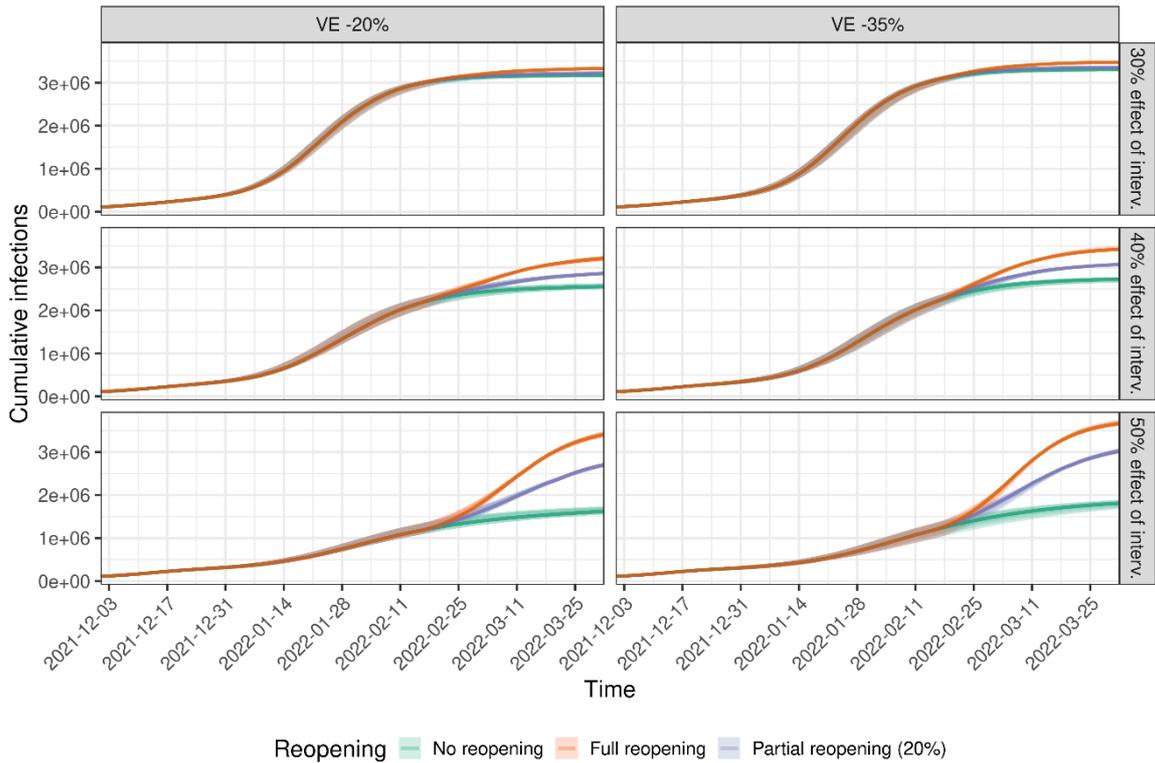


Figure 22: Cumulative number of infections, for different reopening scenarios. The panels show each of the six baselines as in earlier figures. The colors show varying levels of reopening (increased contact rate) on February 15th: No reopening (green), partial reopening to bring us to a 20% contact rate reduction compared to pre-interventions (blue) or full reopening taking us back to the contact rate pre-interventions (red).

About the model and methodology

Most of this section is as in the previous Omicron modelling report from December 22nd, but we have altered and expanded the methods for fitting to the latest available data and calibrating the Omicron properties and effect of interventions.

The model is described in detail in the Long-term scenario report from 28th October 2021^{viii}. The main changes from the previous long-term scenario report are the following:

- The model simulates the spread of two different strains, the Omicron and Delta variant.
- The calibration of the transmission rate of the Delta variant, β , is performed by fitting the hospitalization incidence from September 27th to December 5th. The transmission rate of the Omicron variant is calibrated such that Omicron has a growth advantage over Delta that matches what we see in the Norwegian data.
- We implemented a more detailed simulation of vaccines by explicitly modelling the effect of 1st, 2nd, and 3rd doses (see below for a more detailed description).

Two-strain model

The model used in this study explicitly simulates the circulation of both the Omicron and Delta variant as two different strains. This means that people can be infected by one of the two variants that they will potentially transmit to their contacts. We assume full cross-immunity between strains so that a person infected with one specific variant cannot be re-infected by the other variant.

The main differences between the Delta and the Omicron variant concern the transmission rate, β , and the level of escaping vaccine-derived immunity (see section *Vaccination* below).

Calibration of transmission rates of two strains

The aim of the calibration process is to ensure that the model gives a good fit to observed data so that scenarios of the future are based on our best knowledge of the current situation. There are three key parameters we want to be informed by data. The first one is the transmissibility of the Delta variant before new interventions put in place on the 8th of December. The second is the transmissibility advantage of Omicron over Delta, that includes the effects of intrinsic transmissibility and vaccine evasion. The third is the effect of the interventions and behaviour change in December. We have reasonably good data to estimate the first two of these parameters, but the reduction due to the interventions is difficult to assess given the lack of testing during the Christmas holiday.

We first calibrate the transmissibility, β , of the Delta variant by fitting the hospital incidence between September 27 and December 8, through a maximum likelihood estimation approach. The following plot shows the fit during this period.

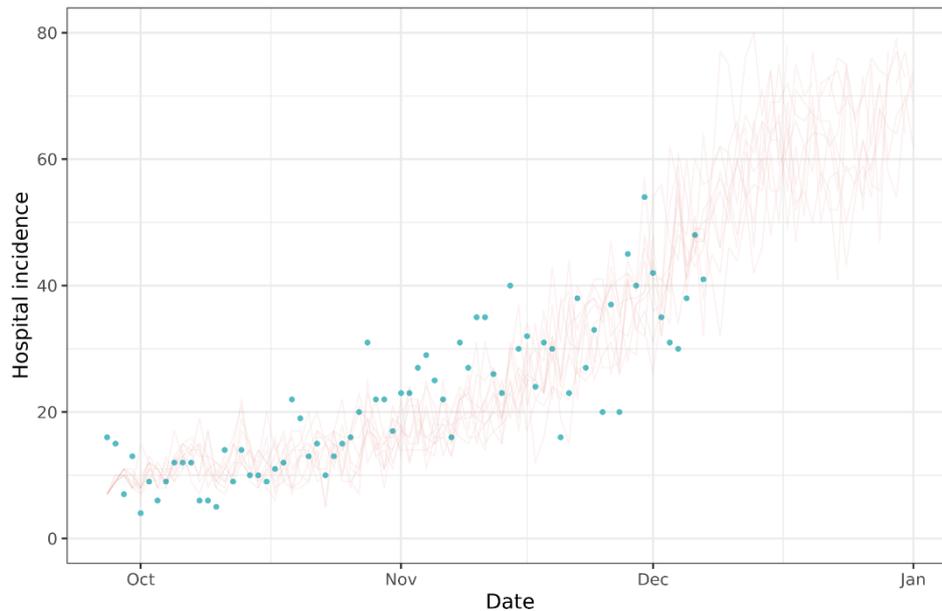


Figure 23: Comparison of the model's daily incidence of hospitalization (red curves) with the Norwegian data (blue dots) over the calibration period.

Secondly, we use the growth in the fraction of confirmed or suspected omicron cases among the screened positive tests to assess the growth advantage of Omicron over Delta. This growth advantage depends on the intrinsic transmissibility of Omicron, the amount of vaccine evasion and the vaccination coverage in the population. Norwegian data indicates a constant trend in log-odds space of this fraction, which suggests that the growth advantage has been stable over time. We therefore fit the intrinsic transmissibility of Omicron in the two vaccine evasion scenarios such that the model replicates this constant growth in the fraction of Omicron. Figure 24 shows the development over time of the fraction of the Omicron variant compared to the fitted models. We note that this fitting procedure combined with the fit of the transmissibility of Delta above gives an estimate for the doubling time of Omicron prior to the interventions of the 8. of December of 2.8-2.9 days. This estimate is between the two assumptions made in the previous report and close to the values used in the initial Omicron modelling report^{ix}. Additional data has allowed us to narrow the range of values and confirms that the values used in both previous models were reasonable.

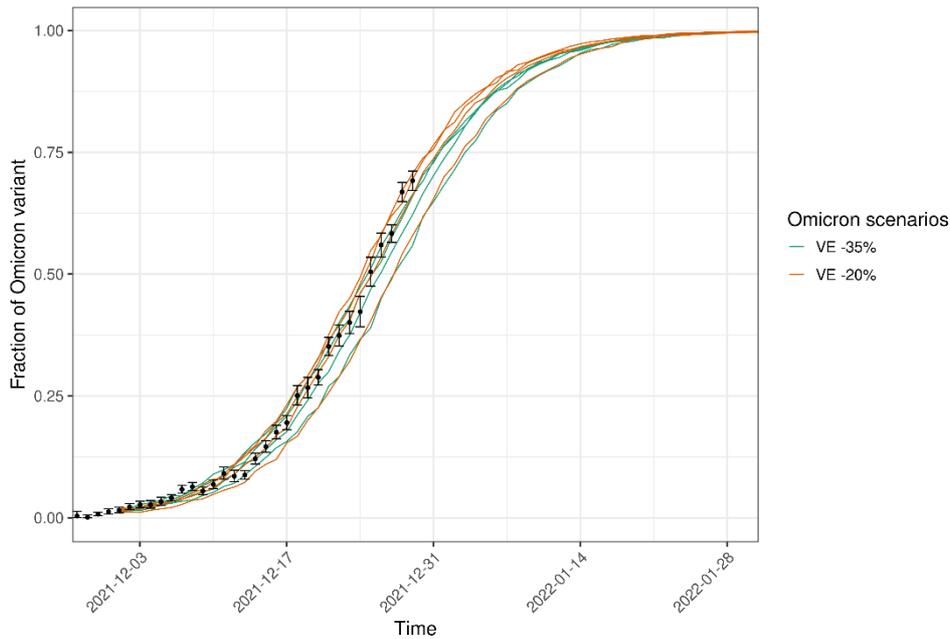


Figure 24: Comparison of the model and data on fraction of Omicron cases in Norway.

Finally, we estimate the current contact rate in the society by comparing the growth rate of Delta and Omicron cases over the last few weeks since interventions were imposed, with data on the number of positive cases of each variant. This comparison is difficult with a lot of uncertainty due to the significant change in the number of people being tested for covid-19 in the second half of December. We have tried to correct for the reduction in testing as follows:

$$Corrected\ cases(t) = Observed\ cases(t) \cdot \frac{1}{fraction\ of\ positive\ tests\ screened(t)} \cdot \left(\frac{max(number\ of\ tests)}{number\ of\ tests(t)} \right)^\alpha$$

This correction depends on the correction factor α , which we vary between 0 and 1. For $\alpha=0$, the model says we will not find any new cases even if we increase the number of tests. This is equivalent to using the raw number of observed cases of each variant adjusted for how many tests were screened for variant. For $\alpha=1$, the model indicates that if we double the number of tests, we will double the number of positive cases we find. The most likely value of α is between these two extremes. Still, since we don't know what α is, we choose three scenarios for the level of interventions corresponding to a range of values where the scenario with lowest effect of interventions correspond to $\alpha=1$ and the scenario with the highest effect of interventions correspond to $\alpha=0$. We find that a combined reduction of the contact rate of 30%, 40% or 50% gives a reasonable fit to the number of observed cases of both variants for the different values of α . This corresponds to a current R for Omicron of between 1.4-1.8 and a doubling time of Omicron of 5-9 days after the interventions⁴.

⁴ The doubling time of the Omicron variant depends on the effect of the control measures imposed in mid-December. We found that a reduction in the contact rate of 0%, 20%, 30%, 40%, and 50%, as a consequence of interventions, results in a doubling time of 3.4, 4.1, 4.8, 6 and 8.5 days respectively, in the period between the 16th and the 31st of December.

We thus selected a range of reductions in the contact rate that gave us a plausible number of cases, taking into account underreporting.

Vaccination

Vaccination is modelled considering each dose separately. This means that each individual may take 0, 1, 2 or 3 doses of the mRNA vaccine in the model. We do not consider AstraZeneca vaccines in the model but assume everyone vaccinated and recorded in SYSVAK has gotten mRNA vaccines for simplicity.

Historical vaccinations in the IBM are based on SYSVAK data; from SYSVAK, the model is informed about how many first, second and third (booster) doses have been distributed by date, age, and municipality.

During the simulations, the distribution of vaccines depends on age-specific uptake values for each dose, vaccination capacity and with a minimum time interval between doses, which is 6 weeks between 1st and 2nd doses and 20 weeks between 2nd and 3rd doses. Given the latest vaccine delivery schedule, we let the model distribute up to 7000, 22000, and 400000 doses per week as the 1st, 2nd and 3rd doses, respectively. The model selects individuals at random from the population, and if they are eligible for a vaccine dose (fulfilling time interval requirement, etc.), they are vaccinated.

The following table shows the uptake assumptions for the booster doses based on an internal FHI survey conducted in the days preceding the first Omicron cases.

	Age 0-17	Age 18-29	Age 30-39	Age 40-49	Age 50-59	Age 60+
Dose 3	Not offered	76%	79%	81%	87%	89%

Each dose of vaccine is assumed to give a protection to an individual against 5 outcomes: asymptomatic and symptomatic disease, passing the disease on to others, hospitalisation and death. The vaccine effectiveness over time for each type of protection is shown in the figures below. The numbers are also reported in supplementary tables at the end of the document. The different panels show different assumptions for the VE values, as well as different delay times between dose 2 and 3.

We assume that the Omicron variant could reduce vaccine effectiveness (VE) in several ways including protection against severe diseases (i.e., hospitalization and death in our model). For example, given the assumption of 0% reduction, we assume that the **conditional VE** given infection remains the same. However, the **overall VE** (given that the individual is susceptible) could be reduced according to the assumed reduction in immune escape, which affects protection in symptomatic and asymptomatic infection and onwards transmission. The figures below show the overall VEs against the Delta variant, and the ones against Omicron are not shown.

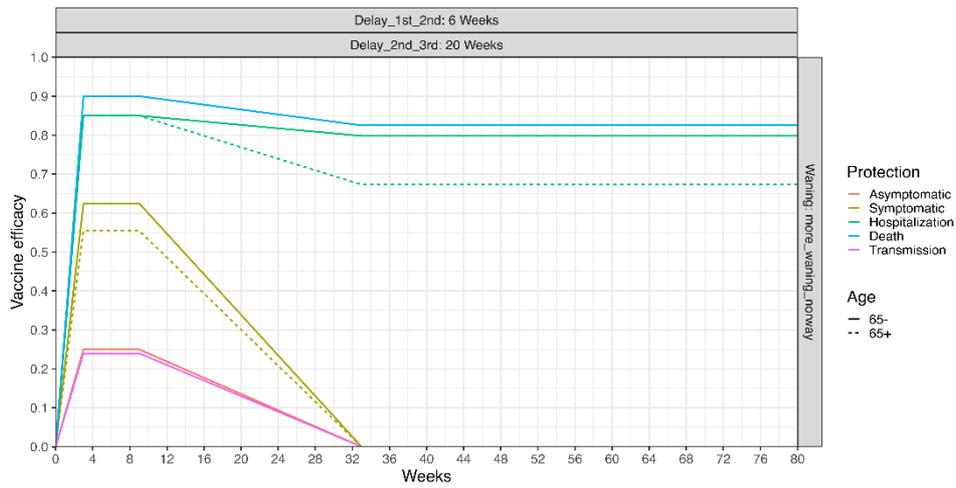


Figure 25A: Vaccine effectiveness over time of the 1st dose only.

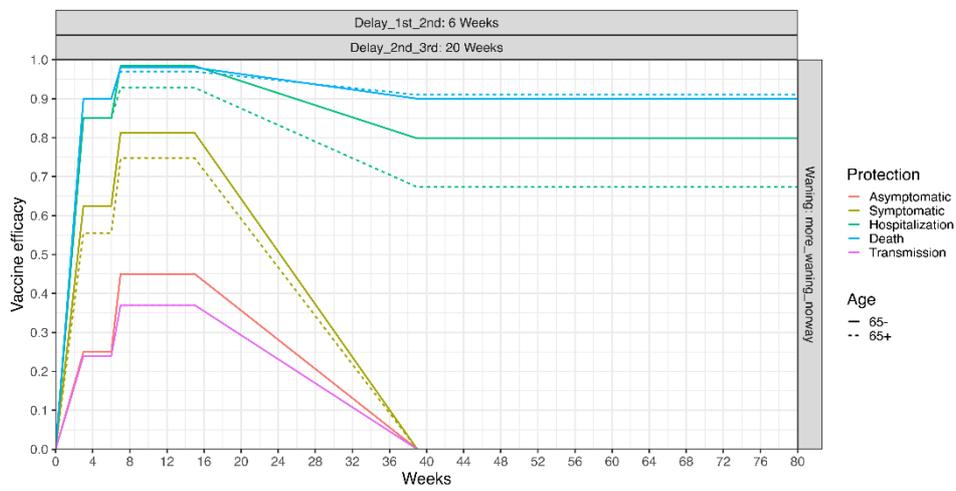


Figure 25B: Vaccine effectiveness over time of the 1st and 2nd doses only.

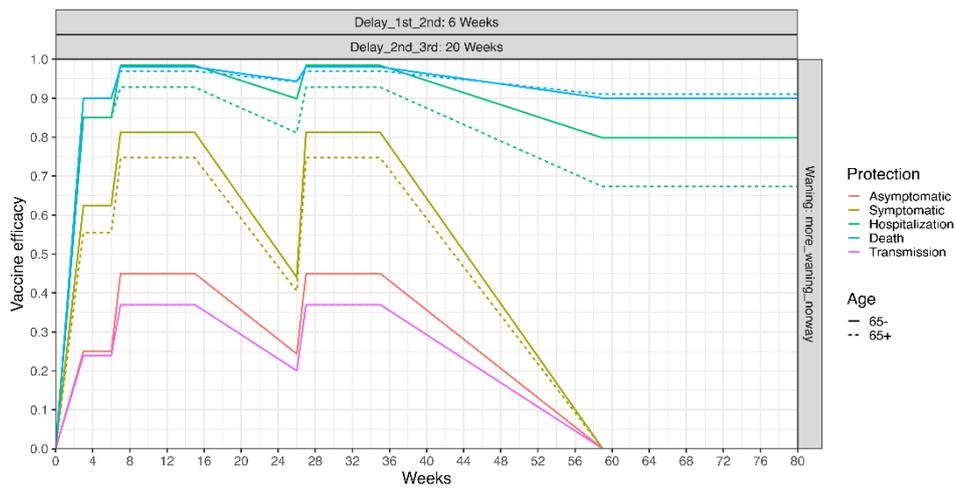


Figure 25C: Vaccine effectiveness over time of all 3 doses.

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Supplementary tables

Vaccine effectiveness

Vaccine effectiveness is compiled based on a wide range of international studies^x. The parameters for waning are compiled based primarily on data from the UK^{xi} and on an internal preliminary FHI study of Norwegian data. Where we have not found numbers in literature on, e.g., amount or duration of waning, we have made estimates based on similar numbers for other doses, or protection against other outcomes. The following tables should not be interpreted as a definitive set of best-estimates for vaccine efficacies but are assumptions that we believe gives a reasonable estimate of reality.

The following table shows the VE parameters used in our scenarios.

Table 1: Time parameters.

<i>Dose nr.</i>	<i>Time from shot to full effect (weeks)</i>	<i>Time from shot to start of waning (weeks)</i>	<i>Time from shot to end of waning (weeks)</i>
1	3	9	33
2	1	9	33
3	1	9	33

Table 2: Vaccine effectiveness (VE) parameters for the Delta variant.

	<i>VE full effect (aged below 65)</i>	<i>VE full effect (aged above 65 or risk group)</i>	<i>VE waned (aged below 65)</i>	<i>VE waned (aged above 65 or risk group)</i>
<i>Asymptomatic infection, dose 1</i>	25%	25%	0%	0%
<i>Asymptomatic infection, dose 2</i>	45%	45%	0%	0%
<i>Asymptomatic infection, dose 3 (booster)</i>	45%	45%	0%	0%
<i>Symptomatic infection, dose 1</i>	62.5%	55.5%	0%	0%
<i>Symptomatic infection dose 2</i>	81.2%	74.7%	0%	0%
<i>Symptomatic infection, dose 3 (booster)</i>	81.2%	74.7%	0%	0%
<i>Hospitalisation, dose 1</i>	85%	85%	79.8%	67.3%
<i>Hospitalisation, dose 2</i>	98.4%	92.8%	79.8%	67.3%
<i>Hospitalisation, dose 3 (booster)</i>	98.4%	92.8%	79.8%	67.3%
<i>Death, dose 1</i>	90%	90%	82.5%	82.5%
<i>Death,</i>	98%	97%	90%	91%

dose 2 Death, dose 3 (booster)	98%	97%	90%	91%
Onward transmission dose 1	24%	24%	0%	0%
Onward transmission dose 2	37%	37%	0%	0%
Onward transmission, dose 3	37%	37%	0%	0%

Length of stay in hospital

The length of stay (LOS) in hospital depends on the age of the infected individuals and it has been modelled as a random variable with a negative binomial distribution, whose parameters have been fitted to Norwegian data. Vaccinated individuals have an average LOS that is approximately 20% lower than unvaccinated patients^{xii}.

Table 3: Length of stay in hospital (LOS). The LOS for each patient is drawn from age-dependent negative binomial distributions. The values of the parameters reported in the table (mean and size) have been estimated from Norwegian data.

Age group	Length of Stay in Hospital	
	Mean (days)	Size
0-9	1.8	3.9
10-19	3.5	1.1
20-29	3.6	1.4
30-39	3.4	2.1
40-49	4.7	2.0
50-59	5.5	2.3
60-69	6.4	2.6
70-79	6.4	2.0
80-89	6.4	2.4
90+	5.1	1.6

ⁱ https://www.fhi.no/contentassets/e6b5660fc35740c8bb2a32bfe0cc45d1/vedlegg/nasjonale-og-regionale-rapporter/omicron_modelling_report_2021_12_22.pdf

ⁱⁱ Covid-19 Rapport om omikronvarianten 31. Dec, 2021 (Statens Serum Institut, Denmark).

<https://files.ssi.dk/covid19/omikron/statusrapport/rapport-omikronvarianten-31122021-ct18>

ⁱⁱⁱ Early Estimates of Omicron Severity in Ontario based on a Matched Cohort Study, November 22 to December 17, 2021 (Public Health Ontario, Canada). https://www.publichealthontario.ca/-/media/documents/ncov/epi/covid-19-epi-enhanced-estimates-omicron-severity-study.pdf?sc_lang=en

^{iv} SARS-CoV-2 variants of concern and variants under investigation in England Technical briefing: Update on hospitalisation and vaccine effectiveness for Omicron VOC-21NOV-01 (B.1.1.529). 31 Dec, 2021.

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1044481/Technical-Briefing-31-Dec-2021-Omicron_severity_update.pdf

Severity of Omicron variant of concern and vaccine effectiveness against symptomatic disease: national cohort with nested test negative design study in Scotland <https://www.research.ed.ac.uk/en/publications/severity-of-omicron-variant-of-concern-and-vaccine-effectiveness->

^v FHI COVID-19 modelling group, *Long-term scenarios for Norway for the fall and winter 2021–2022* (2021). https://www.fhi.no/contentassets/e6b5660fc35740c8bb2a32bfe0cc45d1/vedlegg/nasjonale-og-regionale-rapporter/2021-10-28-long_term_scenarios_report_updated.pdf (Accessed December 19th 2021)

^{vi} SARS-CoV-2 variants of concern and variants under investigation in England Technical briefing: Update on hospitalisation and vaccine effectiveness for Omicron VOC-21NOV-01 (B.1.1.529). 31 Dec, 2021. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1044481/Technical-Briefing-31-Dec-2021-Omicron_severity_update.pdf (Accessed January 5, 2022)

^{vii} <https://coronavirus.data.gov.uk/details/healthcare>

^{viii} https://www.fhi.no/contentassets/e6b5660fc35740c8bb2a32bfe0cc45d1/vedlegg/nasjonale-og-regionale-rapporter/2021-10-28-long_term_scenarios_report_updated.pdf

^{ix} Modelling scenarios for the SARS-CoV-2 Omicron VOC (B.1.1.529) in Norway during the winter 2021–2022. https://www.fhi.no/contentassets/e6b5660fc35740c8bb2a32bfe0cc45d1/vedlegg/nasjonale-og-regionale-rapporter/omicron_modelling_report_2021_12_22.pdf

^x Tande, A J et al., *Impact of the Coronavirus Disease 2019 (COVID-19) Vaccine on Asymptomatic Infection Among Patients Undergoing Preprocedural COVID-19 Molecular Screening*, *Clinical Infectious Diseases*, <https://doi.org/10.1093/cid/ciab229> (2021)

Tang, P et al., *BNT162b2 and mRNA-1273 COVID-19 vaccine effectiveness against the SARS-CoV-2 Delta variant in Qatar*, *Nature Medicine* 27 (2021)

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^{xi} Andrews, N. et al. *Effectiveness of BNT162b2 (Comirnaty, Pfizer-BioNTech) COVID-19 booster vaccine against covid-19 related symptoms in England: test negative case-control study* (2021) <https://www.medrxiv.org/content/10.1101/2021.11.15.21266341v1> (Accessed December 19th 2021)

Andrews, N. et al, *Vaccine effectiveness and duration of protection of Comirnaty, Vaxzevria and Spikevax against mild and severe COVID-19 in the UK*, <https://www.medrxiv.org/content/10.1101/2021.09.15.21263583v2> (accessed December 19th 2021)

^{xii} M. Ramakrishnan and P. Subbarayan, “Impact of vaccination in reducing hospital expenses, mortality and average length of stay among Covid 19 patients. A retrospective cohort study from India”, medRxiv, 2021.