Modelling the growth of the Omicron BA.5 variant in July and August 2022 (Report for assignment no. 68, part 2).

FHI COVID-19 MODELLING TEAM, 13 JULY 2022

Samandrag på norsk

Hovudfunn:

- Scenariomodelleringa som blir vist her, indikerer at den noverande bølgja av innleggingar grunna omikron BA.5-varianten kan nå sin topp rundt midten eller slutten av juli.
- Kor høge innleggingstal vi får, kjem an på dei epidemiologiske eigenskapane til BA.5, samt immuniteten og oppførselen til folk. Modellen finn alt frå 40-50 til 100 innleggingar kvar dag på toppen av bølga, i dei ulike scenarioa. Innanfor rammene av desse scenarioa indikerer ikkje modellen at vi vil få ein større topp enn det vi hadde under omikron BA.2-bølga i vinter.
- Sidan det er kort tid før toppen av bølga kjem, finn modellen ikkje nokon stor effekt på innleggingstala av å vaksinere eldre med 4. dose i juli.

I juni og juli 2022 opplever Noreg ei ny bølgje av covid-relaterte innleggingar i sjukehus, i stor grad grunna framveksten av den nye omikron BA.5-varianten[1]. I denne rapporten viser vi fram modellerte scenario som fokuserer på sommarmånadane juli og august, for å undersøke korleis ulike eigenskapar ved den nye varianten kan påverke storleik og tidspunkt for sommarbølgja. Simuleringane tar høgde for tilbodet om ein fjerde vaksinedose som er gitt til folk 75 år og eldre frå 1. juli, for å undersøke korleis vaksinasjonsfarta kan påverke innleggingstala. Vidare utforskar modellen effekten av moglege endringar i kontaktrata mellom folk grunna sommarferien i juli månad.

Resultata viser at innleggingstala kan nå sin topp rundt midten eller slutten av juli. Storleiken på bølgja av innleggingar i modellen vert sterkt påverka av den epidemiologiske profilen til den nye varianten, spesielt kva evne han har til å spreie seg i folkesetnaden. Scenarioa med ein 5 prosent auka smittsamheit samanlikna med BA.2, kan resultere i 40-50 daglege innleggingar på toppen i slutten av juli. Ein endå meir smittsam profil, 15 prosent høgre enn BA.2, kan forårsake om lag 100 daglege innleggingar, om lag på høgde med BA.2-toppen vi såg i mars 2022.

Når det gjeld vaksinasjonsfarta med fjerde dose, viser resultata at sjølv ein rask utrulling av fjerde dose til aldersgrupper 75 år og eldre frå 1. juli har liten effekt på å bremse sommarbølgja. Det er fordi bølgja av infeksjonar toppar seg i modellen allereie eit par veker etter at utrullinga starta – som gir lite tid for folk til å få tatt oppfriskingsdosen, og lite tid for oppfriskinga til å nå sin fulle effekt. Likevel vil truleg

[1] Folkehelseinstituttets risikovurdering 29.06.2022, https://www.fhi.no/contentassets/c9e459cd7cc24991810a0d28d7803bd0/vedlegg/2022-06-29-risikovurdering-endret-2022-07-01.pdf

auka immunitet i denne aldersgruppa bidra til å beskytte dei mot alvorleg sjukdom i ei potensiell haust- eller vinterbølgje.

Til slutt demonstrerer simuleringane at talet på infeksjonar, og dermed også innleggingar, gjennom sommarbølgja, også kjem an på korleis folk oppfører seg. Vi simulerer scenario der kontaktrata mellom folk i samfunnet (men ikkje i heimen) vert redusert med 20 prosent i juli grunna ferien. Modellen finn at det kan redusere innleggingane med opp mot 20 prosent i scenarioet med ein fem prosent høgre smittsamheit enn BA.2. Med ein meir smittsam variant vert forskjellane mindre. Merk at noko av denne ferie-effekten allereie kan vere tatt høgde for i modellen gjennom den sesongvarierande (med temperatur) smittsamheita.

Ei presis talfesting av kontaktrata i folkesetnaden i den kommande perioden er ikkje mogleg. Dessutan er det framleis store usikkerheiter knytt til den epidemiologiske profilen på den nye BA. 5-varianten, samt i dynamikken som kjem frå vaksinedrevet og naturleg immunitet hjå folk. Det er òg alltid ein moglegheit for at det kjem endå ein ny variant, med nye eigenskapar, som endrar biletet på uføreseielege måtar. Av alle desse grunnane er simuleringane som er vist her, høgst usikre, og skal tolkast som scenario, ikkje prediksjonar. Formålet med dei er å gi støtte til myndigheitene ved å samanlikne ulike "kva viss"-scenario.

Summary in English

Key takeaways:

- Scenario modelling presented here indicates that the current wave of hospitalisations due to the BA.5 variant could peak around the middle or late July.
- Depending on epidemiological characteristics of BA.5, as well as population immunity and behaviour, the peak incidence of hospitalisations may range from approximately 40-50 up to 100 daily admissions. Given the assumptions in these scenarios, the model finds it unlikely that the current wave of hospitalisations will have a higher peak than that of the 2021/2022 winter wave.
- Due to the short time before the wave peak is reached, vaccination with a 4th dose will have limited impact on the size of the current wave at a population level. This should however not dissuade individuals from getting vaccinated according to the public health authorities' recommendations, as the vaccine still could significantly reduce the personal risk of contracting severe disease.

During June and July 2022, Norway is experiencing a new surge in covid-related hospital admissions, mostly caused by the emergence of the new Omicron BA.5 variant[2]. In this report, we present modelling scenarios focusing on the summer months of July and August to investigate how different characteristics of the new variant may affect the size and timing of the summer wave. The simulations include the administration of a 4th dose to the population 75+ years from the 1st of July, to investigate how the

[2] Folkehelseinstituttets risikovurdering 29.06.2022, https://www.fhi.no/contentassets/c9e459cd7cc24991810a0d28d7803bd0/vedlegg/2022-06-29-risikovurdering-endret-2022-07-01.pdf

vaccination speed may affect the increase in hospital admissions. Furthermore, the model explores the effect of potential changes in the contact rate due to the summer holidays in July.

The results show that the hospital admissions could peak around the middle of July. The size of this summer wave is strongly influenced by the epidemiological profile of the new strain, and in particular its ability to spread in the population. The scenarios simulating a 5% increase in transmissibility compared to the Omicron BA.2 variant, could result in 40-50 daily hospitalisations at the end of July. An even more transmissible strain, 15% higher than BA.2, could cause approximately 100 daily hospital admissions, similarly to the BA.2 peak observed in March 2022.

When exploring the vaccination rate of the 4th dose, the results show that even a fast roll-out of the vaccination in July to the population 75 and above, has a limited impact on curbing the summer wave and reducing hospital admissions. This is because the wave of infections peaks in the model already a few weeks after the roll-out started - giving limited time for individuals to get boosted, and for the booster to take effect. However, increased immunity in the target population would likely protect this group, especially against severe disease requiring hospitalisation, in potential future waves in the autumn and winter.

Finally, the simulations demonstrate that the number of infections, and consequently hospital admissions, during the summer wave also depends on human behaviour. We simulate scenarios where the contact rate in the community is assumed to be 20% lower in July because of summer holidays. We found that this would reduce the daily incidence of hospital admissions at the peak up to ~20% in the scenario with a 5% higher transmissibility of the BA.5 variant. However, some of this effect may already be taken into account through the seasonally varying transmissibility that is included in the model.

A precise quantification of the contact rate in the population in the coming period is impossible to anticipate. Moreover, there are still large uncertainties regarding the epidemiological characteristics of the new SARS-CoV-2 variant, as well as waning dynamics of vaccine-derived and natural immunity in the population. Lastly, there is always the possibility that yet another variant could emerge carrying new properties, altering the picture in unpredictable ways. Thus, the simulations presented in this report are subject to a high degree of variability and do not aim to forecast the epidemic trajectories for the next two months, but rather to provide support to policy decision makers by comparing different hypothetical "what-if" scenarios.

Background

During June 2022, a new wave of the COVID-19 epidemic became apparent in Norway, with a new surge in hospital admissions. The wave is assumed to be caused by the emergence of a new omicron variant, called BA.5, and waning immunity in the population.

Folkehelseinstituttet's risk assessment from June 29 concluded that it was not possible to stipulate how large this summer wave would be, and what pressure the hospitals would experience from new admissions. On the same day, the Ministry approved the institute's recommendation to start offering a 4th vaccine dose to the population 75+ years from the 1st of July.

In this report, we present modelling scenarios focusing on the summer months of July and August to investigate how different characteristics of the new variant may affect the size and timing of the summer wave. The simulations include effects of the speed of the implementation of the new vaccination recommendation. Furthermore, the model explores the effect of potential changes in the contact rate due to the summer holidays in July.

The main outcome of the scenarios is the daily number of new COVID-19-related hospital and ICU admissions (incidence) as well as the daily number of hospital and ICU beds occupied by COVID-19-patients (prevalence).

The simulations presented in this report are subject to a high degree of variability and do not aim to forecast the epidemic trajectories for the next two months, but rather to provide support to policy decision makers by comparing different hypothetical "what-if" scenarios.

Scenarios

We simulate alternative scenarios to explore different epidemic trajectories of SARS-CoV-2 for the months of July and August in 2022, considering the recent emergence of the Omicron BA.5 variant.

The scenarios investigate four transmissibility assumptions of the BA.5 variant together with two summer effects and three vaccination strategies for a total of 24 scenarios.

Transmissibility. We assume four different transmissibility assumptions for the BA.5 obtained by multiplying the transmission rate of the BA.2 variant[3] by the following factors:

- 1 (i.e., the same transmissibility as BA.2);
- 1.05 (i.e., 5% higher transmissibility than BA.2);
- 1.10 (i.e., 10% higher transmissibility than BA.2);
- 1.15 (i.e., 15% higher transmissibility than BA.2).

Summer holidays. We assume that the contact rate in the community in July 2022 (compared to the other months in the simulation period) is:

- reduced by 20%[4];

[3] We note that Omicron BA.2 is assumed to be 50-60% more transmissible than Delta variant.

[4] Hens, N., Ayele, G.M., Goeyvaerts, N. et al. Estimating the impact of school closure on social mixing behaviour and the transmission of close contact infections in eight European countries. BMC Infect Dis 9, 187 (2009). https://doi.org/10.1186/1471-2334-9-187

- not reduced.

Vaccination strategies. We simulate alternative vaccination strategies varying the vaccination speed of the 4th dose to the eligible population (i.e., aged 75 years or above) in July and August. Thus, we run scenarios changing the number of doses per week to be:

- 100,000;
- 50,000;
- 0 (i.e., no administration of the 4th dose).

In each scenario we assume that no additional 3rd doses will be distributed after June 29. We assume that everyone who has taken the 3rd dose will accept the 4th dose if it is offered to them. There is no prioritization, and all eligible population who has received the 3rd dose can get the 4th dose, considering a time gap of at least 20 weeks between the two doses.

The other important assumptions that have been made in this report are the following.

- **Cross immunity given natural infection.** We assume that
  - the protection against BA.5 given previous BA.2 infection is 50% during the first 12 weeks;
  - the protection against BA.5 given previous BA.5 infection is 90% during the first 12 weeks;
  - the protection against BA.2 given previous BA.2 infection is 90% during the first 12 weeks;
  - the protection against BA.2 given previous BA.5 infection is 100%, i.e., no reinfection.
- **Waning of immunity.** We assume that immunity against reinfection due to natural infection wanes to no effect in 52 weeks. The reinfected individual retains some protection against severe disease even after waning (see Methods, section "Risk and immunity").
- **Severity** and **vaccine efficacy (VE)** against BA.5 remains the same as BA.2[5].

The model is described in the Methods section below.

Results and discussion

We present results of the scenarios analysis consisting of 100 stochastic simulations for each scenario, running over the period between the 15th of February 2022 and the end of August 2022.

We found that approximately 100 000 - 200 000 people could be infected by the BA.5 variant in the summer period. The following figure gives an overview of the daily incidence of hospitalisations across all the above-defined scenarios. The figure should not be interpreted statistically – there is no preference a priori for any one scenario. Given the scenario assumptions above, it seems unlikely that the current summer wave will lead to a higher incidence of hospitalisations than that seen during this winter. However, in the worst-case scenarios we could reach a peak of similar magnitude.

[5] ECDC, Implications of the emergence and spread of the SARS-CoV-2 variants of concern BA.4 and BA.5 for the EU/EEA, 13 Jun 2022 (https://www.ecdc.europa.eu/en/news-events/implications-emergence-spread-sars-cov-2-variants-concern-ba4-and-ba5)

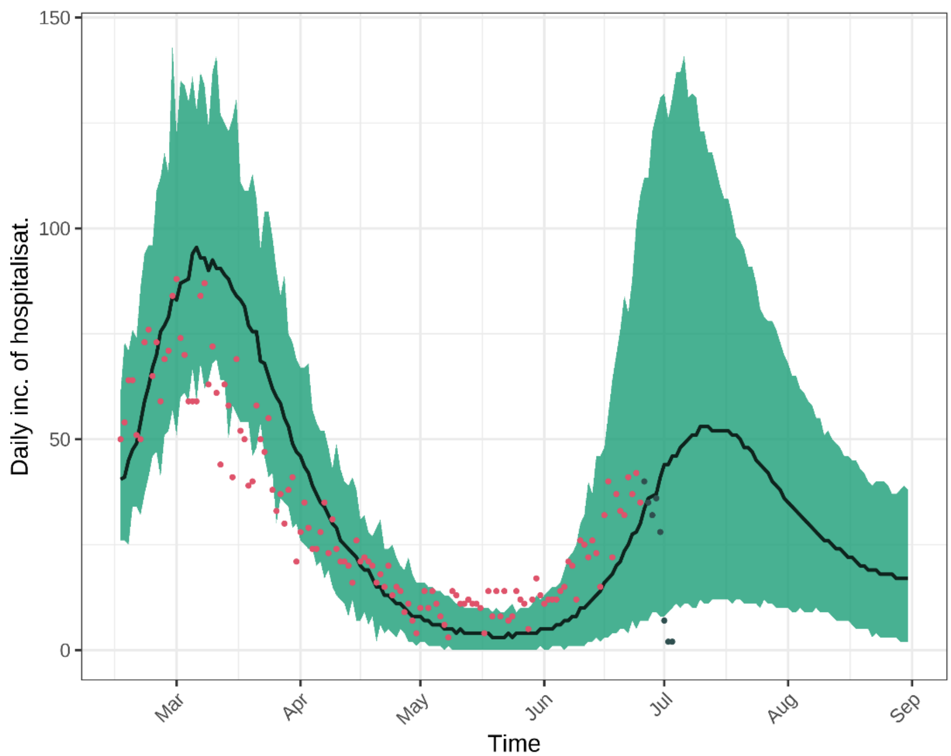


Figure 1: The total span of outcomes for daily hospitalisation incidence across all scenarios (green band). The black line is the median. The red points represent data. The most recent points are likely affected by reporting delay and are coloured blue.

Breakdown of results by scenario

In the following figures, we display the modelled epidemic trajectories in each of the scenarios described above.

The size of the summer wave is uncertain and depends on different factors: firstly, the epidemiological characteristics of the new Omicron BA.5 variant; secondly, human behaviour and the contact rate of the population in the summer period; thirdly, the level of immunity in the population. There is also a possibility that yet new variants emerge, with new properties that could change the picture . The model only considers BA.2 and BA.5.

Currently there are large uncertainties about the level of transmissibility of the new variant compared to the BA.2 variant, which caused the previous peak in Norway observed in the first months of 2022. The simulations show that a scenario where the new BA.5 has the same transmissibility of the BA.2 variant is unlikely as the incidence of hospitalisations remains below the observed data. (Figure 2, top row.) There could, however, be other factors, such as the timing of the peak, that explain the mismatch, and hence a small peak size cannot be ruled out.

In the scenarios where the transmissibility of BA.5 is higher than BA.2, we found that the hospital admissions will peak between 50 and 100 new admissions per day for the scenario with 5% and 15% higher transmissibility, respectively. The peak is observed approximately between early July, in the scenario with 15% higher transmissibility, and late July, in the scenario with 5% higher transmissibility (Figure 2).

The model also simulates the hospital prevalence, i.e., the number of concurrently hospitalised patients, by taking into account the expected length of stay of each patient. The same is done for individuals requiring mechanical ventilation (referred to as ICU admissions in this report). The prevalence of hospitalisations and ICU admissions is shown in Figure 4 and 5, respectively.

The simulations show that changes in human behaviour, such as the reduction of the contact rate in July as a result of summer holidays, will affect the summer wave (orange vs green colour in the figures). In the scenario with a 5% higher transmissibility of the BA.5 variant, characterized by a slower and smaller wave, a reduction of 20% in the contact rates could reduce the peak of hospital admissions. There are large uncertainties associated with the value of this parameter. In this report we are using a previous publication (N. Hens *et al.*, BMC Infect Dis 9, 187, 2009) finding an average reduction in the contact rate of 20% during holiday periods. However, it is not possible to precisely anticipate changes human behaviour that might occur in the next two months in Norway.

The simulations suggest that the administration speed of the 4th dose, starting from July, does not have a significant impact on the summer wave (compare the different columns in Figure 2-5). This is likely the consequence of the time it takes to reach the full effect of the vaccine (1 week), combined with the relatively short time until the wave peaks, around the end of July. However, a boosting of the immunity level in the elderly population can provide protection during potential autumn waves, both in terms of their individual protection and, to a lesser extent, the overall rate of spread in the population.

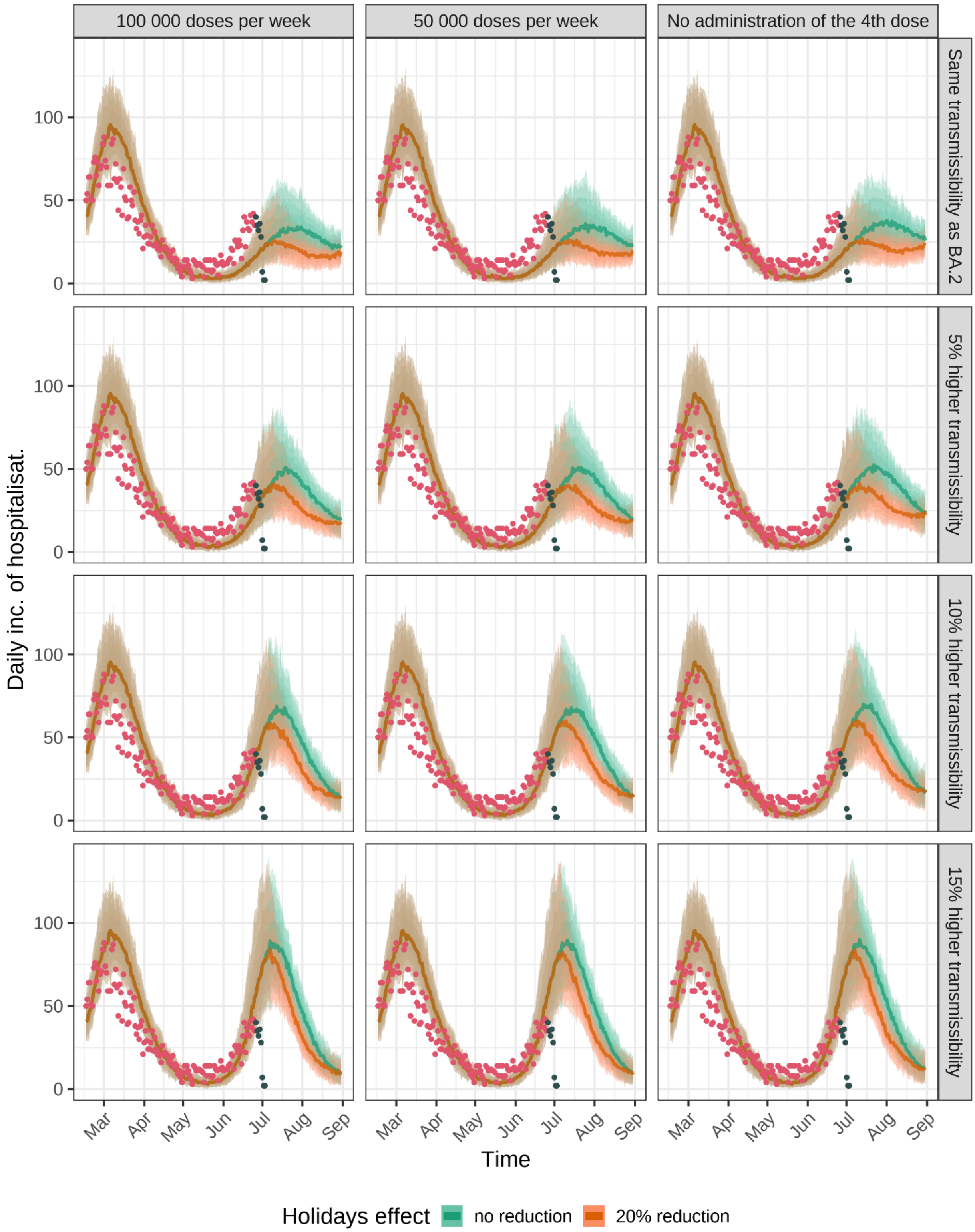
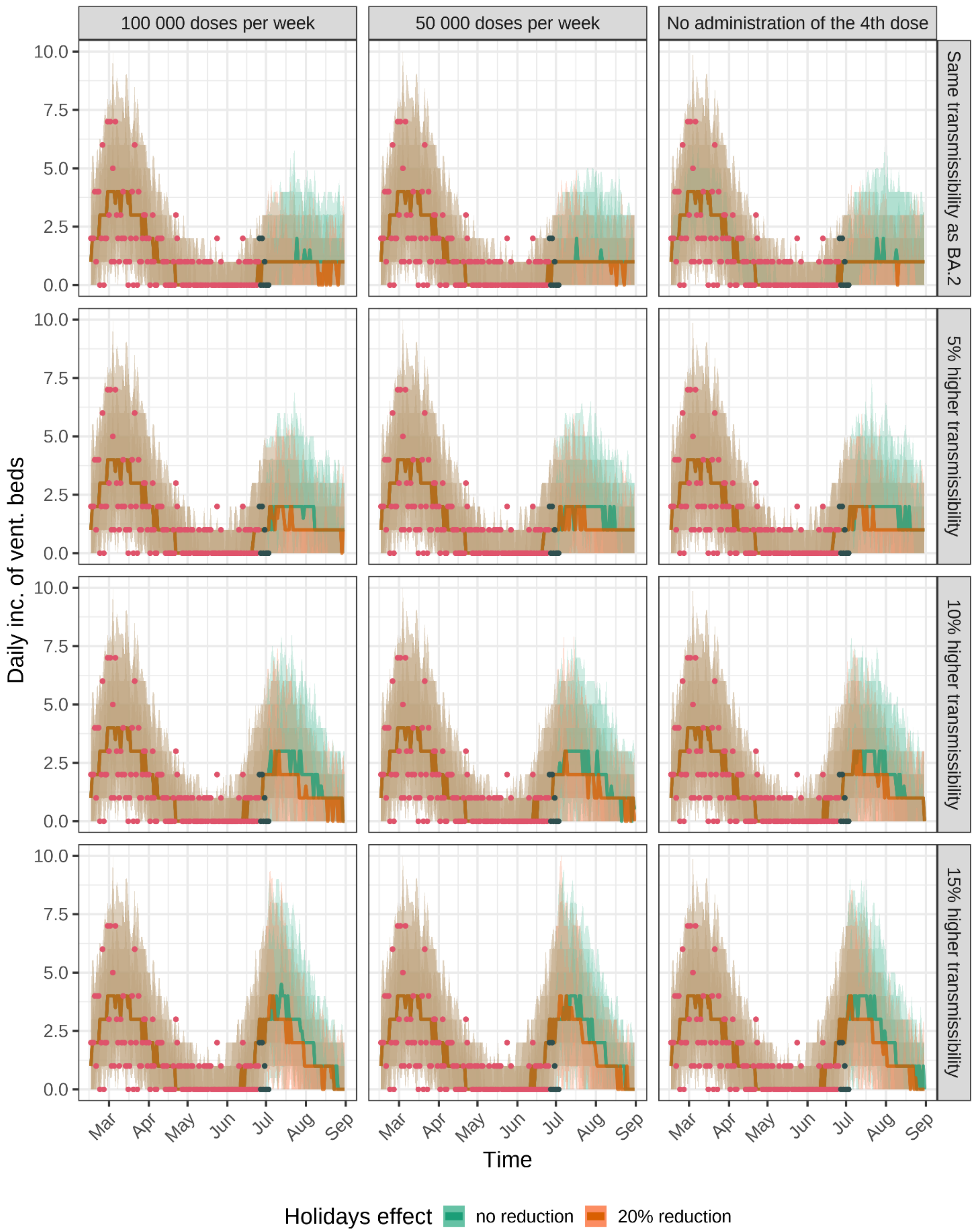
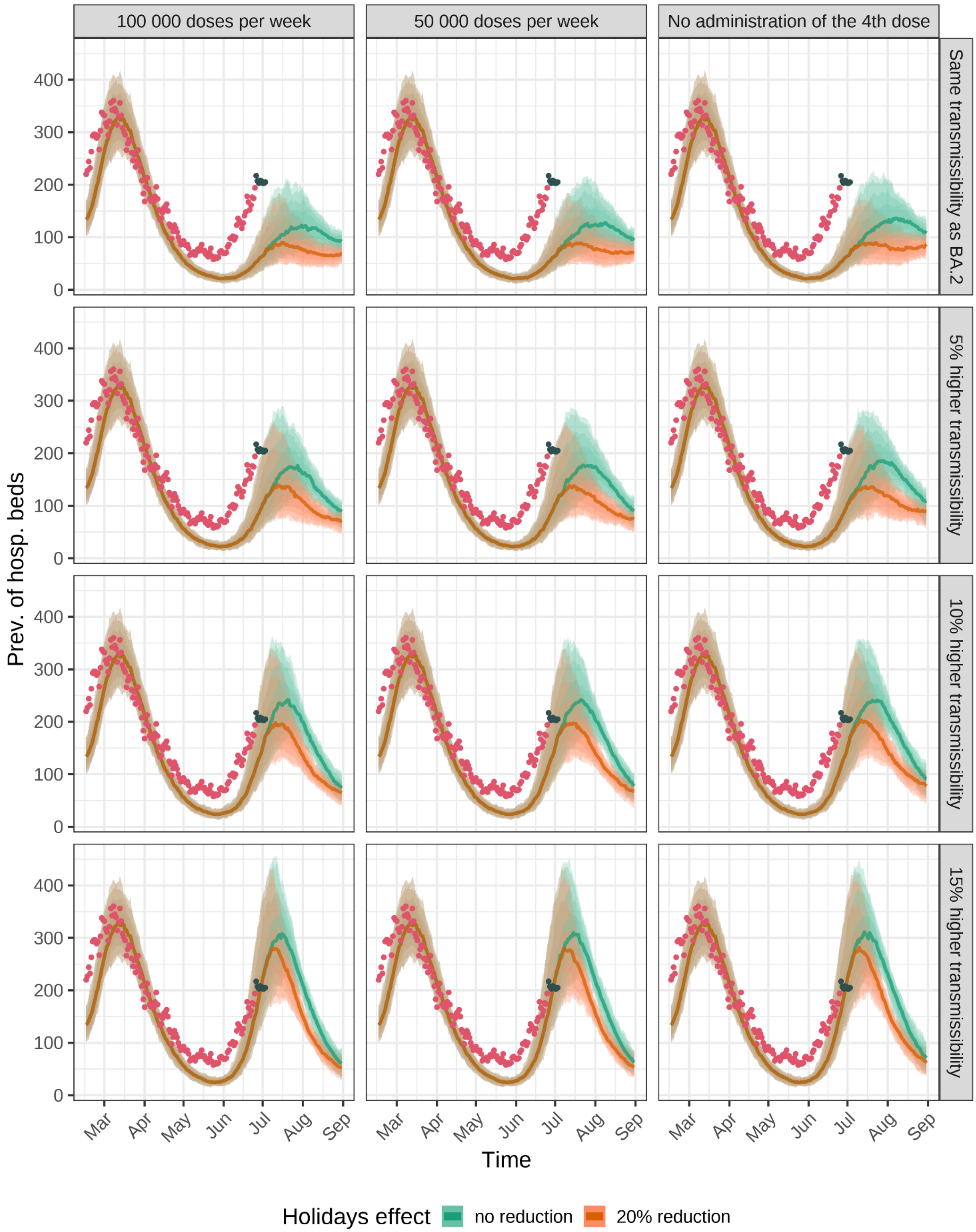


Figure 2. Daily incidence of hospitalisations until the end of August 2022. The figure shows different vaccination strategies of the 4th dose, varying the number of weekly doses, and different transmissibility assumptions of the Omicron BA.5 variant. The colours define the contact rate reductions during the holiday period in July. The most recent points are likely affected by reporting delay and are coloured blue.



100 000 doses per week
50 000 doses per week
No administration of the 4th dose
Same transmissibility as BA.2
5% higher transmissibility
10% higher transmissibility
15% higher transmissibility
Daily inc. of vent. beds
0.0
2.5
5.0
7.5
10.0
Mar
Apr
May
Jun
Jul
Aug
Sep
Time
Holidays effect
no reduction
20% reduction

Figure 3. Daily incidence of ventilator beds until the end of August 2022. The figure shows different vaccination strategies of the 4th dose, varying the number of weekly doses, and different transmissibility assumptions of the Omicron BA.5 variant. The colours define the contact rate reductions during the holiday period in July. The most recent points are likely affected by reporting delay and are coloured blue.



100 000 doses per week
50 000 doses per week
No administration of the 4th dose
Same transmissibility as BA.2
5% higher transmissibility
10% higher transmissibility
15% higher transmissibility
Prev. of hosp. beds
0
100
200
300
400
Mar
Apr
May
Jun
Jul
Aug
Sep
Time
Holidays effect
no reduction
20% reduction

Figure 4. Daily prevalence of hospital beds until the end of August 2022. The figure shows different vaccination strategies of the 4th dose, varying the number of weekly doses, and different transmissibility assumptions of the Omicron BA.5 variant. The colours define the contact rate reductions during the holiday period in July. The red points represent Norwegian data. The most recent points are likely affected by reporting delay and are coloured blue.

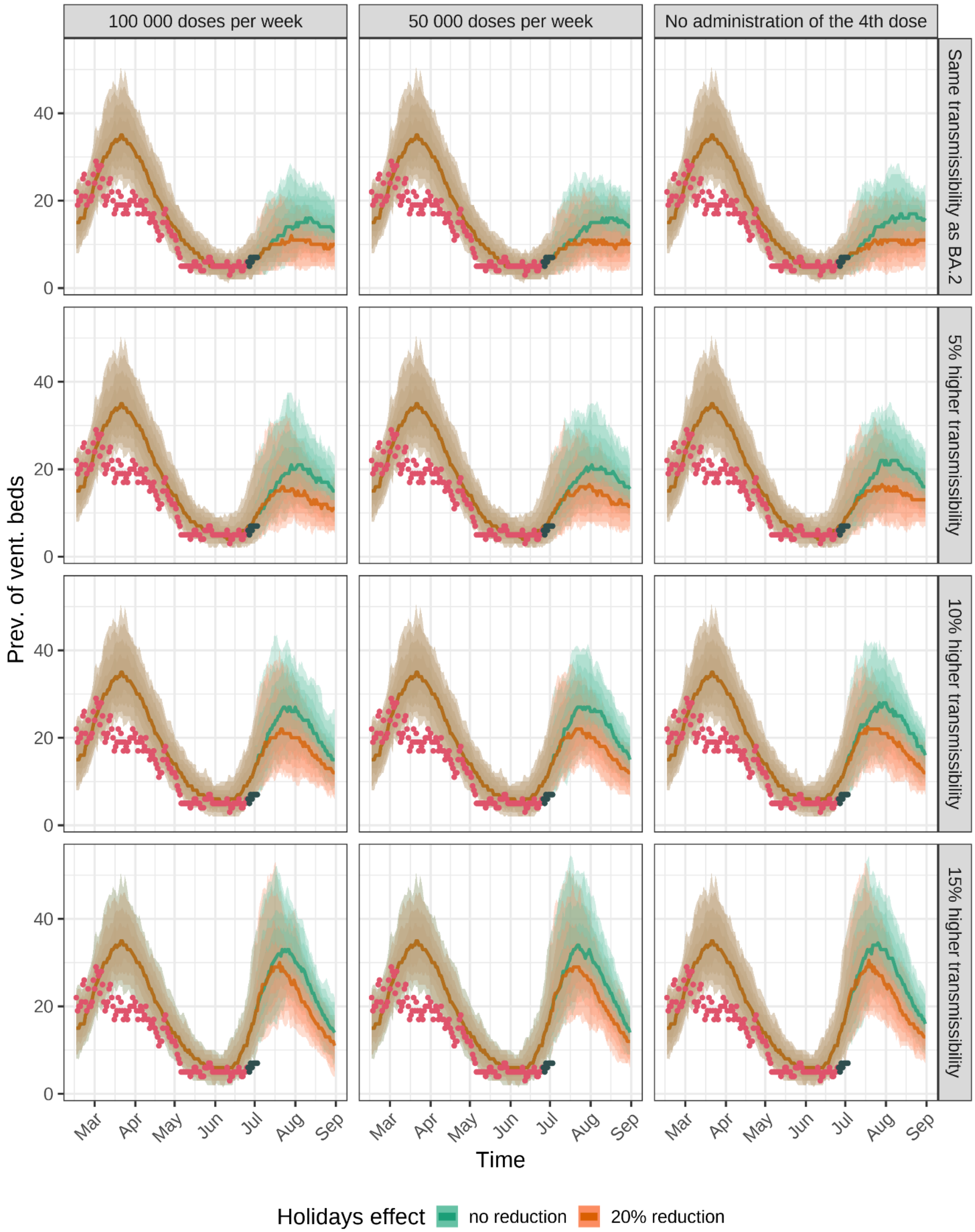


Figure 5. Daily prevalence of ventilator beds until the end of August 2022. The figure shows different vaccination strategies of the 4th dose, varying the number of weekly doses, and different transmissibility assumptions of the Omicron BA.5 variant. The

colours define the contact rate reductions during the holiday period in July. The red points represent Norwegian data. The most recent points are likely affected by reporting delay and are coloured blue.

Further considerations and limitations

The simulations span a period of almost two months forward in time. Considering the large uncertainties and changes in social behaviour that cannot be anticipated, the scenarios presented in this report should not be considered as a forecast of the summer wave.

The emergence of a new variant is always surrounded by new uncertainties. The transmissibility of the Omicron BA.5 strain, its capacity to evade previous immunity, as well as the severity of infection (i.e., the intrinsic virulence) are still largely unknown or not well understood. The collection of new data going forward will enable improvements of the assumptions in the model and improve the epidemic outcomes. As more knowledge becomes available, we will run new simulations refining the assumptions and the parameters in the model.

Currently there are still large uncertainties about waning dynamics of natural and vaccine-derived protection. Another source of uncertainty comes from the number of individuals who have been previously infected in Norway. This information is highly uncertain and cannot be obtained from the surveillance system, considering asymptomatic infections and people who have been through the infection without being recorded in the health registries.

We currently do not consider admissions to hospitals from nursing homes. Recently, there has been an increasing number of reports of outbreaks in health care institutions, which in some cases have led to hospitalisations of residents. However, we have not been able to obtain data to quantify these numbers or to understand if there has been a change in the policy of admission from institutions. We believe that this effect, while important, is not a significant part of the total hospitalisations.

The model only considers the Omicron BA.2 and BA.5 variants. It is possible that new variants emerge with altered characteristics, that could change the epidemiological situation in unpredictable ways.

Methods

The simulations presented in this report have been performed using an individual-based model reproducing the real density and socio-demography of Norway. The model has been described in detail in previous reports.[6]

The model simulates the circulation of multiple variants, including the Omicron BA.5 variant. For simplicity, the model only considers two sub-variants of Omicron: BA.2 and BA.5. BA.2 in this context thus refers to all Omicron variants predating BA.5. BA.2 has been the dominant variant in Norway

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[6] https://www.fhi.no/contentassets/e6b5660fc35740c8bb2a32bfe0cc45d1/vedlegg/nasjonale-og-regionale-rapporter/2021-10-28-long_term_scenarios_report_updated.pdf
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through the winter and spring[7]. The simulations are started in October 2021, when the Delta variant dominated in Norway. The Omicron BA.2 variant is introduced in late November and takes over. The model then tries to follow the dynamics associated with the infection prevention measures that were in place in the period from December to February, before society is reopened and the contact rate increases.

The observed peak and subsequent decline in infections and hospitalisations during the BA.2 wave in February/March 2022 is captured by the model through the epidemiological characteristics directly - i.e., the wave subsides not because the transmission rate is reduced, but because the model reaches "herd immunity". This is important, because we are trying to quantify the level of immunity in the population due to past infection. Matching the peak and decline of the winter wave is a key indicator that this is successful.

Calibration and simulation assumptions

In the model used for this report there are 4 free parameters:

1. the transmission rate of the Delta variant in an open society
2. the effect of the lockdown implemented on December 2021
3. the seeding time of the Omicron BA.2 variant
4. the transmission rate of the Omicron BA.2 variant

These parameters have been calibrated against Norwegian daily hospital admissions for the period between 21st October and 30th May 2022 using a Poisson likelihood to evaluate the goodness of the model output (Figure 6).

[7] FHI risikovurdering 29.06.2022, https://www.fhi.no/contentassets/c9e459cd7cc24991810a0d28d7803bd0/vedlegg/2022-06-29-risikovurdering-endret-2022-07-01.pdf

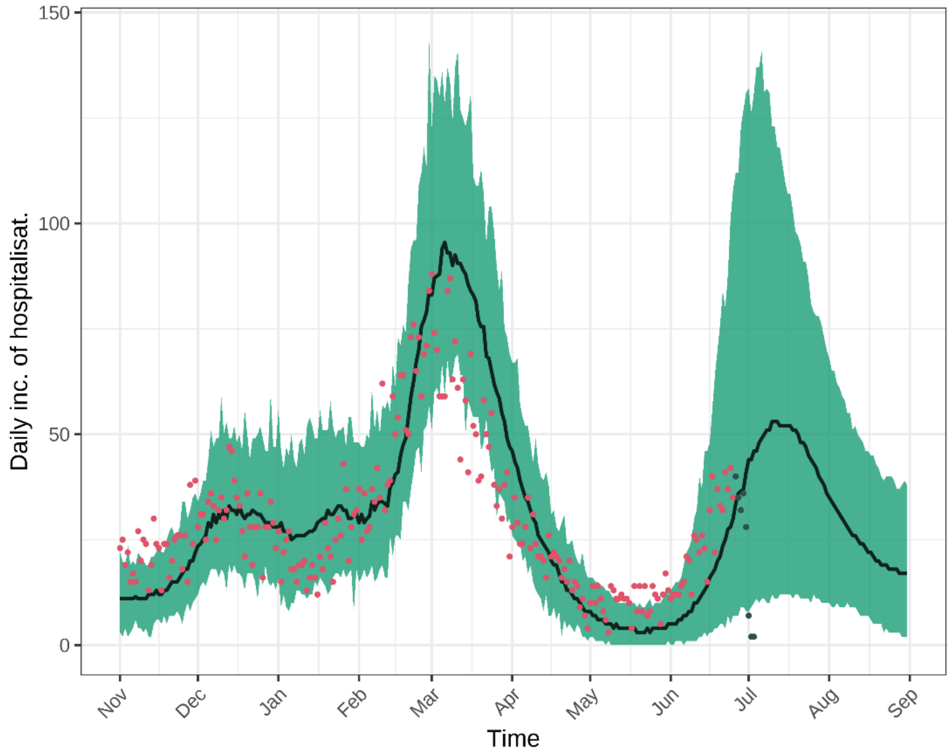

Figure 6. Daily incidence of hospitalisations from the 21st of October 2021 until the end of August 2022. The figure shows the incidence of hospital admissions including the Delta wave observed in Autumn-December 2021, the subsequent Omicron BA.2 wave in Spring 2022 and the Omicron BA.5 wave in summer. The red points represent Norwegian data.

We assume that the introduction of the Omicron BA.5 variant starts from the 25th of April 2022, based on the first cases detected in Norway.[8] The number of BA.5 cases is about 500 per day as taken from previous assumption of imported cases. Figure 7 shows the fraction of the Omicron BA.5 variant over time. By week 24, Omicron BA.5 is responsible for nearly all the infections in the model, similarly to what was observed in the Norwegian data[9].

[8] https://www.fhi.no/contentassets/c9e459cd7cc24991810a0d28d7803bd0/vedlegg/2022-06-29-risikovurdering-endret-2022-07-01.pdf (See Figure 4)

[9] COVID-19-EPIDEMIEN: Risiko ved COVID-19- epidemien, influensa og RSV-infeksjon i Norge Folkehelseinstiuttet, 29. juni 2022 (https://www.fhi.no/contentassets/c9e459cd7cc24991810a0d28d7803bd0/vedlegg/2022-06-29-risikovurdering-endret-2022-07-01.pdf).

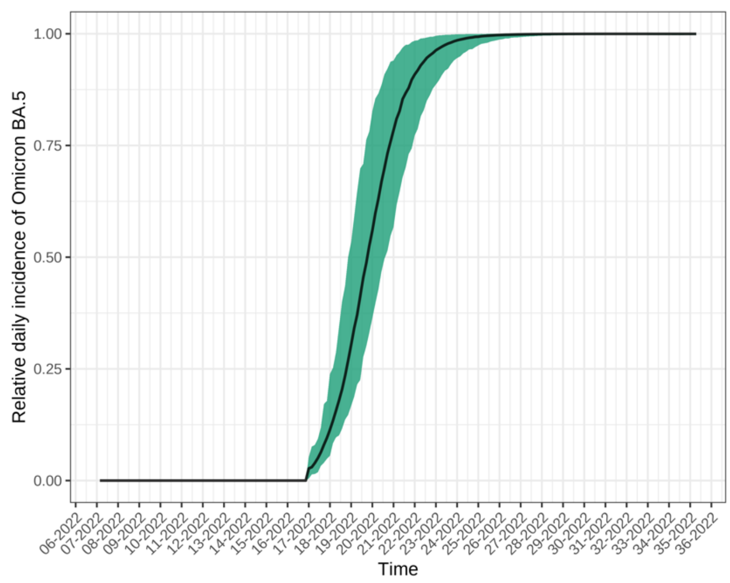

Figure 7. Fraction of Omicron BA.5 infections over time. The figure shows the proportion of infections caused by the emergent BA.5 variant in Norway.

The transmission rate of the BA.5 variant has not been directly calibrated on hospital data. We instead ran different scenarios changing the transmission rate and evaluating the epidemic trajectories of each scenario against the available data on daily hospitalisations.

Furthermore, the model takes into account a 25% seasonal change in the force of infection driven by temperature.

Risk for severe infection and immunity following vaccination and natural infection

As shown in Figure 8, the risk of hospitalisation in the model is age-specific and it rapidly increases with age[10]. People with underlying diseases (risk group) have a higher risk than those without. Moreover, we assume that the probabilities of hospitalisations for people infected with the Omicron BA.2 and BA.5 variants are reduced by age-dependent factors[11]. The omicron hospitalisation probability for the age group 40-49 has been halved to obtain consistency with Norwegian data on hospitalisations. Finally, the overall hospitalisation risk in the model has been adjusted down by a factor of 0.5 to be consistent with Norwegian data, considering the ratio of hospitalisations and reported positive tests. The precise value of the reduction factor is hard to quantify, but it seems clear that Norway has had a lower hospitalisation risk overall than the world average.

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[10] Herrera-Esposito, D. and de los Campos, G., Age-specific rate of severe and critical SARS-CoV-2 infections estimated with multi-country seroprevalence studies. BMC Infectious Diseases (2022). https://doi.org/10.1186/s12879-022-07262-0

[11] Nyberg, Ferguson et al, *Comparative analysis of the risks of hospitalisation and death associated with SARS-CoV-2 omicron (B.1.1.529) and delta (B.1.617.2) variants in England: a cohort study*, Lancet (2022), https://doi.org/10.1016/

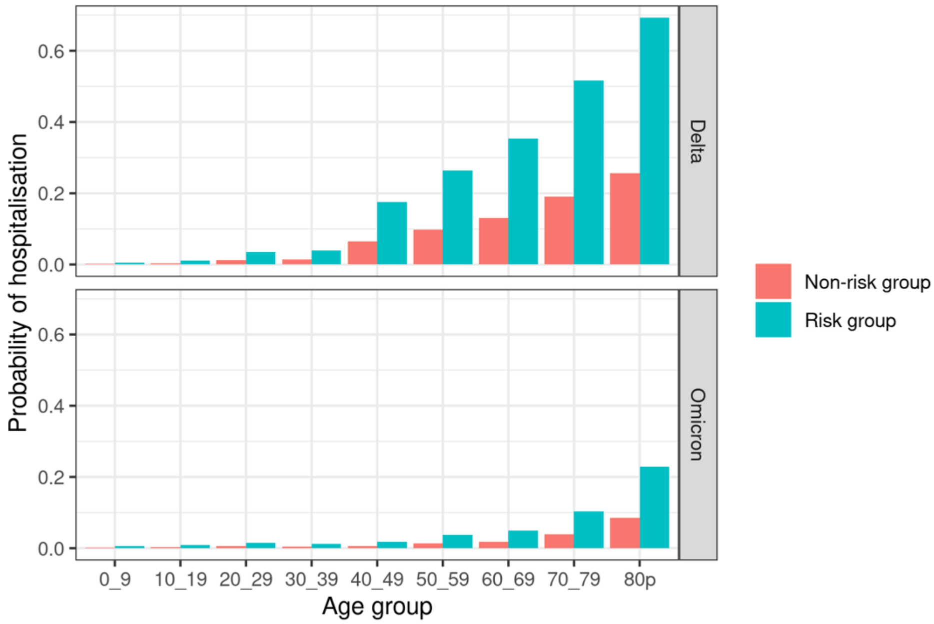


Figure 8: The probability of hospitalisation given infection without vaccination. The risk of hospitalisation given Omicron infection is assumed lower than Delta. People with underlying diseases (blue colour) have higher risk compared to those without (red).

Figure 9 shows the time series of daily hospitalisation incidence separated on age groups. The points are data and the lines are model simulations. The figure only shows the data for a single scenario, to illustrate; however, all scenarios are identical up until April.

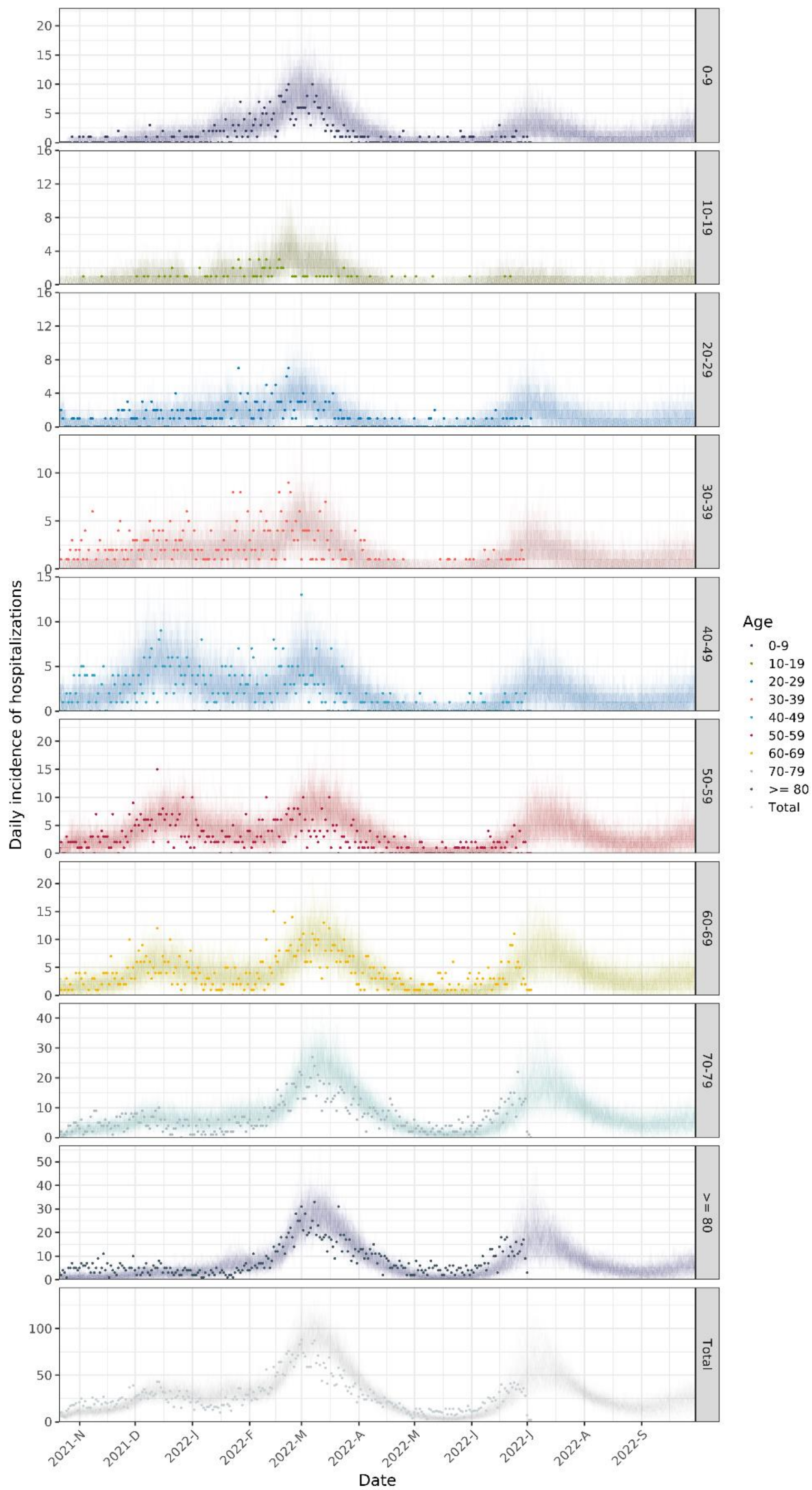
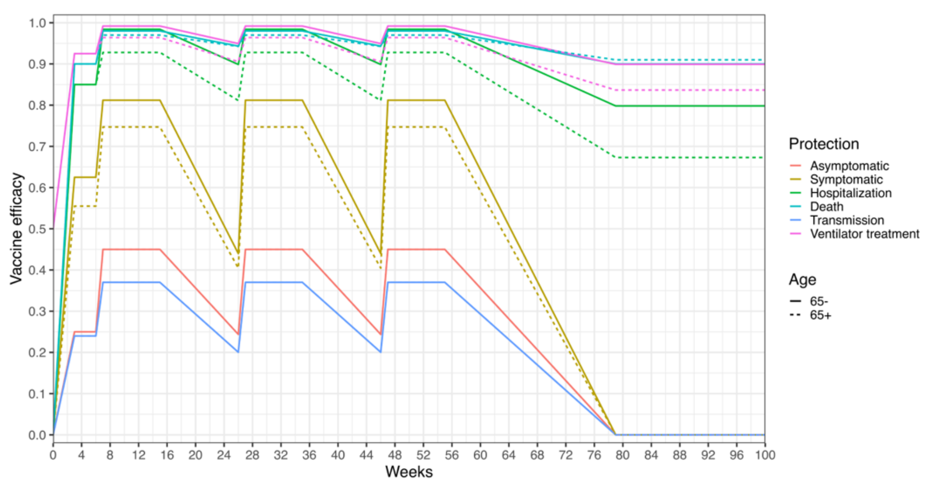


Figure 9: Incidence of hospitalisations by age group. The figure shows the daily incidence of hospital admissions in different age groups.

The vaccine gives 5 different types of protection: against symptomatic infection, asymptomatic infection, hospitalisation, ventilator treatment and death. The vaccine efficacy (VE) varies over time (Figure 10). It is assumed that the VE against Omicron infections is 25 percentage points lower than Delta infections.

As a result of natural infection, people develop immunity against reinfection with the same or different variants. We assume that if people are infected by either Delta or Omicron, they develop full immunity against Delta reinfection, but only partial immunity against Omicron. The immunity given by Delta against Omicron reinfection (Delta – Omicron) is 55% and long-term (does not wane). The protection against reinfection by the same Omicron subvariant (Omicron BA.2 – Omicron BA.2 or Omicron BA.5 – Omicron BA.5) is high but temporary; it starts from 90% during the first 12 weeks and wanes in the following 52 weeks to zero protection. The protection against Omicron BA.5 after infection from BA.2 is assumed to be 50% during the first 12 weeks and wanes in the following 52 weeks to zero protection. BA.5 infection provides complete immunity against all other variants.

Furthermore, we assume that natural infection also protects against hospitalisation if people are reinfected. The protection is modelled as if the individuals obtained an extra dose of vaccine, and the VE is boosted from the time of natural infection.



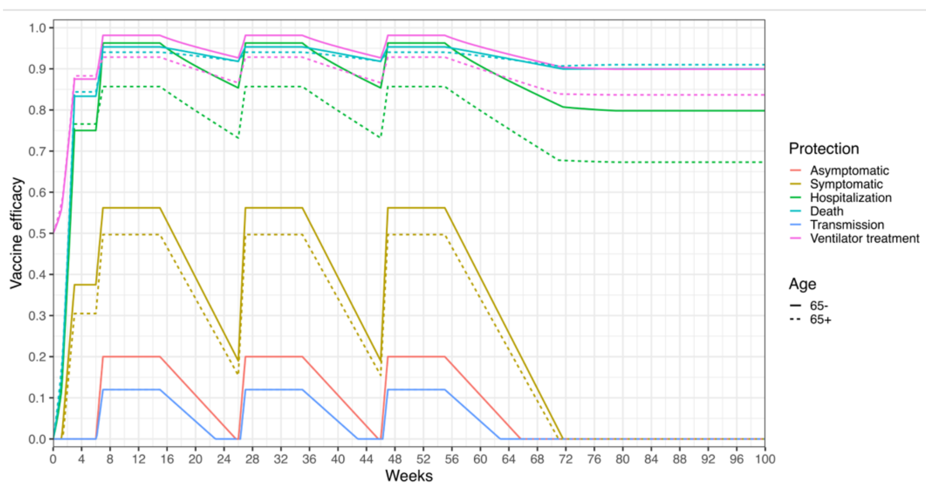


Figure 10: The vaccine efficacy (VE) against Delta (upper panel) and Omicron (lower panel) given 4 doses. The 5 different types of protection increase after vaccination, stay constant and decrease over time. People aged 65 years or above, in general, have lower protection than those younger.

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