Llywodraeth Cymru
Welsh Government

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RSV compartment transmission model methodology report

21 September 2026

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Introduction

Respiratory syncytial virus (RSV) is a major cause of acute lower respiratory tract infections (ALRTIs), particularly among young children and older adults causing a significant burden on primary and secondary care services. In England and Wales, vaccination programmes targeting pregnant women and older adults (as they turn 75 years of age, with an initial catch up for those adults 75 years and over who had not yet attained 80 years of age) were introduced in September 2024[1]. From 1 April 2026, the vaccine programme was expanded to adults aged 80 years and over and all residents in care homes [2]. The aim of this paper is to adapt the previously published compartmental transmission model, calibrate it to hospital admissions data; in order to estimate the number of admissions averted by these vaccination programmes and create admissions projections for the winter season of 2026/27[3].

This paper is currently undergoing peer review. Feedback has been sought from experts. The model passed the Welsh Government modelling annual review assurance framework process last year and will be assessed again this year. For transparency, we wanted to share the methodology underlying the winter modelling work carried out by SRE, but caution should be taken whilst using the outputs of this paper as the updated model is currently under review.

[1] **https://www.gov.uk/government/news/national-rsv-vaccination-programme-announced**

[2] **https://www.gov.wales/update-rsv-vaccination-programme-2026-whc2025053-html**

[3] **Effect of RSV vaccines on hospital admissions in Wales**

Methods

Data sources

Population data

Population data for Wales were obtained from the Office for National Statistics (ONS) 2024 mid-year estimates [4]. The population was grouped into the following age bands: 1–6 months, 7-12 months, 1-4 years, and five-year age bands for older groups (5-9 years, 10-14 years and so on up until years 80 and above).

Contact matrix data

Age-specific contact rates were obtained from the ReCoNNECT social contact survey, which captured social mixing patterns in the United Kingdom after the COVID-19 pandemic which was then formatted using the *socialmatrix* package to align with the age groups described above.[5] [6]

Admissions data

The hospitalisation admissions data was obtained from Digital Health Care for Wales (DHCW). RSV admissions have been identified using the following ICD-10 codes:

- J121 – Respiratory syncytial virus pneumonia
- J205 – Acute bronchiolitis due to respiratory syncytial virus
- J210 – Acute bronchiolitis due to respiratory syncytial virus
- B974 – Respiratory syncytial virus as the cause of diseases classified elsewhere

Further details and caveats regarding this data can be found in the **Annex**.

Vaccine uptake data

Vaccine uptake among pregnant women and adults aged 75-79 years and above was obtained from Public Health Wales.

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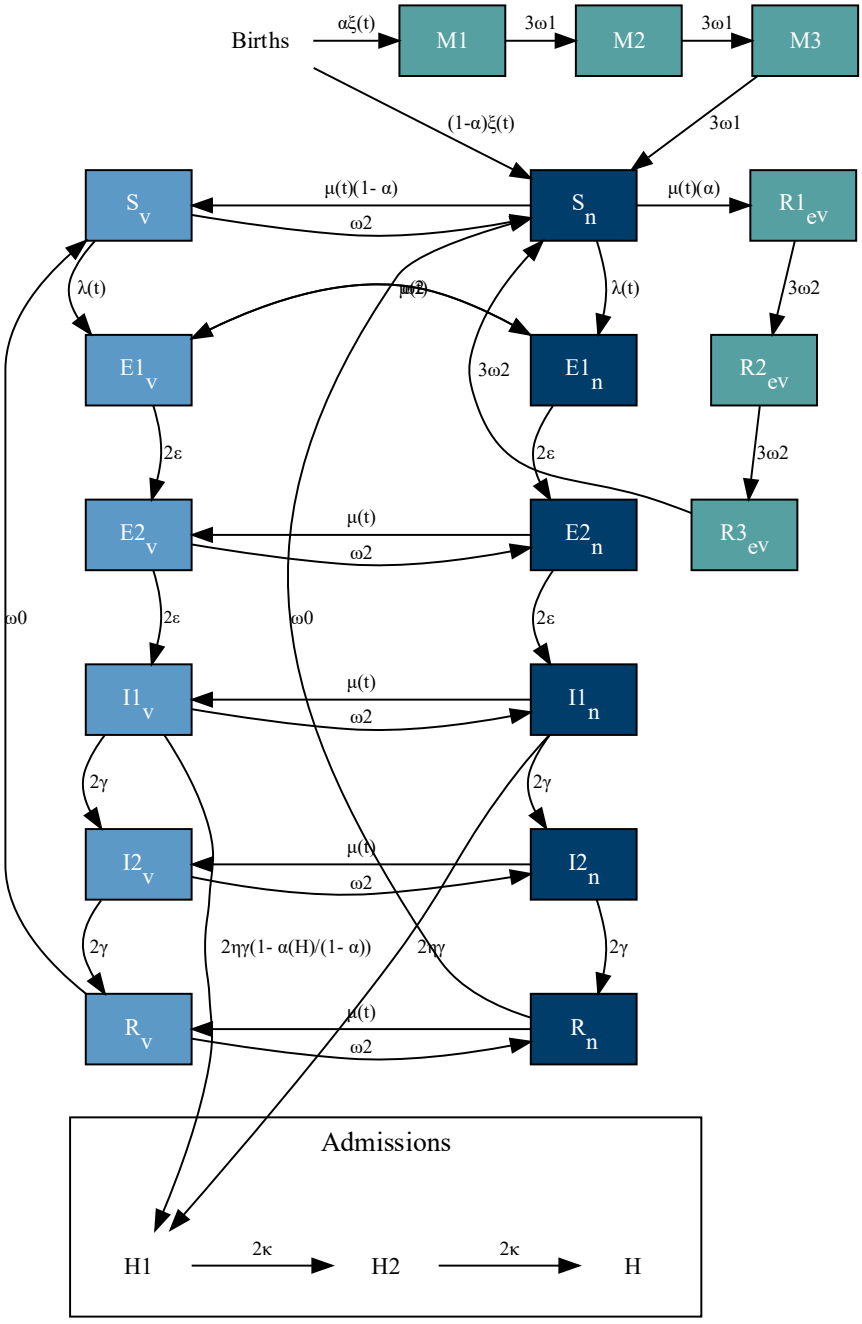
[4] **Population estimates for England and Wales**

[5] **Social contact patterns in the United Kingdom following the COVID-19 pandemic: The Reconnect cross-sectional survey | PLOS Medicine**

[6] **socialmixr: Social Mixing Matrices for Infectious Disease Modelling**

Model structure

Figure 1: Compartment transmission model for modelling RSV admissions



Source: SRE modelling

An age-stratified deterministic SEIRS compartmental transmission model with a fixed population size and non-random age-dependent mixing containing 18 compartments was used: Susceptible (S), two compartments for Exposed ($E1$, $E2$), two compartments for Infectious ($I1$, $I2$), and Recovered (R) their ineffectively vaccinated counterparts (S_v-R_v), and $R1_{ev} - R3_{ev}$ (older individuals who were vaccinated effectively) [7] [8].

Vaccination was assumed to provide partial temporary immunity to older adults and infants protected by maternal vaccination. To account for the effects of maternal vaccination on infant births, a new compartment ($M1 - M3$, or maternally protected) was included in the model. Births protected by the vaccination (as a result of being born to pregnant women who are vaccinated) enter the $M1$ compartment, whilst those not protected by the vaccine enter the susceptible compartment (S_n). The vaccine-induced immunity was assumed to wane according to an Erlang-3 distribution and is modelled by the inclusion of delay states $M1 - M3$ and $R1_{ev} - R3_{ev}$.[9]

$\lambda(t)$, ε, γ and ω_0 represent the force of infection, the loss of latency, the loss of infectiousness and the loss of natural immunity. ω_1 and ω_2 represent loss of vaccine-induced immunity in older adults and infants. α and α^H refer to vaccine efficacy against infection and hospitalisation. $\mu(t)$ and refer to the vaccination rate in older adults and pregnant women while $\xi(t)$ refer to the proportion of births that are protected by maternal vaccination. σ represents the loss of immunity from vaccination. η indicates time delay from being symptomatic to getting hospitalised and κ the proportion of infectious cases that are hospitalised.

[7] **Investigating the impact of non-pharmaceutical interventions (NPIs) on post-pandemic Respiratory Syncytial Virus (RSV) hospitalisations and seasonality in Wales, UK - ScienceDirect**

[8] **The potential global health impact and cost-effectiveness of next-generation influenza vaccines: A modelling analysis | PLOS Medicine**

[9] **Protecting infants against RSV disease: an impact and cost-effectiveness comparison of long-acting monoclonal antibodies and maternal vaccination - The Lancet Regional Health – Europe**

Hospital admissions (H) were counted as a proportion of individuals from $I1_v$ and $I1_n$ compartments who passed through two delay states $H1$ and $H2$ to get Erlang-2 distributed waiting times between infection and hospitalisation.[10] [11]

Force of infection

The force of infection is modelled as a cosine function of time and given by the equation:

$$\lambda_i(t) \quad = b_0\left(1 + b_1 cos(2\pi t/365 - \phi_i)\right) \sum_{i=1} c_{i,j}\, \sigma_i \left[I1_{n,j}(t) + I2_{n,j}(t) + I1_{v,j}(t) + I2_{v,j}(t)\right]$$

Parameter b_0 represents the baseline transmission rate, b_1 scales the seasonal increase in transmission and ϕ the phase difference. c_{ij} represents the age-specific contact rate derived from the contact survey.

Markov Chain Monte Carlo (MCMC) based parameter inference

MCMC runs parameters

The transmission model was calibrated using weekly RSV admissions data between September 2023 and March 2026. Three independent chains were run for 5,000 iterations each. The first 2,500 iterations of each chain were discarded as burn-in, and the remaining 2,500 iterations were retained as samples from the posterior distributions of the model parameters. As some of the parameters showed correlations, parallel tempering with 10 rungs was used to ensure that there was enough mixing.

Posterior samples were obtained by randomly drawing 500 samples from the combined chains. Thinning was not applied. Further details on the likelihood specification and prior distributions are provided in the Annex.

[10] **Influenza hospital admissions prevented by vaccination: a transmission dynamic analysis of the 2022/2023 and 2023/2024 programmes in England**

[11] **Note that admissions are counted as a subset of infections and are not a separate compartment**

MCMC diagnostic

Convergence of the MCMC chains was assessed using both visual inspection of trace plots and the Gelman–Rubin diagnostic statistic which compares within-chain and between-chain variance. Effective sample size (ESS) was calculated to understand sampling efficiency.

Posterior predictive checks and scoring metrics

Model performance was evaluated using weighted interval scores, bias, and interval coverage. In addition, peak height and peak timing of RSV admissions were compared between model outputs and observed data to assess the model's ability to capture the temporal dynamics of RSV transmission.

Projections for the winter of 2026/27

To develop projections for the winter of 2026/27, the effects of vaccinating adults 80 years were included from April 2026. Care home residents were excluded from this analysis. It was assumed that individuals aged 80 years and above would show vaccination uptake rates comparable to those observed for the 75–79 years age group during the first year of the RSV vaccination programme. The model was run using the same posterior samples obtained from MCMC inference, but with the vaccine uptake and vaccine-induced immunity in adults adjusted to account for the alternative scenarios. Table 1 below describes the scenarios in detail. These projections were created before the start of winter 2026/27 and will not be calibrated as we acquire more data as the winter progresses.

Table 1: Scenarios and their underlying assumptions

Scenario name	Vaccine uptake assumptions	Vaccine-induced immunity assumptions
No coverage, baseline immunity	0%	Immunity inferred
Low coverage, baseline immunity	20% lower than observed coverage	Immunity inferred
Baseline coverage, baseline immunity	Observed vaccine coverage	Immunity inferred
High coverage, baseline immunity	20% higher than observed coverage	Immunity inferred
No coverage, longer immunity	0%	25% higher than immunity inferred
Low coverage, longer immunity	20% lower than observed coverage	25% higher than immunity inferred
Baseline coverage, longer immunity	Observed vaccine coverage	25% higher than immunity inferred
High coverage, longer immunity	20% higher than observed coverage	25% higher than immunity inferred

Changes in model from last year

- **Model structure:** To distinguish waning naturally acquired immunity from waning vaccine-derived immunity in older adults (aged 75 years and above and pregnant women), an additional compartment was introduced for individuals in whom vaccination was effective (R_{ev}). Waning of vaccine-derived protection was represented using an Erlang-3 distribution, implemented through three sequential delay states prior to transition back to the susceptible compartment ($R1_{ev}$ –

$R3_{ev})\ and\ (M1 - M3)$.[12] Additionally, two delay states $H1$ and $H2$ were introduced to get Erlang-2 distributed waiting times between infection and hospitalisation.[13] Vaccine effectiveness against infection and hospital admissions were modelled as separate parameters.

- **Contact survey:** Age-specific contact rates were estimated using data from the Reconnect survey rather than POLYMOD, as Reconnect survey captures post-COVID-19 mixing patterns in Britain.[14]

- **Age group:** Infant age groups were changed from 12 one-month age bands to two aggregated groups: 0–6 months and 7–12 months.

- **Vaccination target groups:** The model now includes the direct and indirect effects of vaccinating pregnant women (along with protected infants and older adults).

- **Parameter inference using MCMC methods:** In the previous version of the compartment model, the calibration was restricted to pre-vaccination data. In the current report, calibration was done using hospital admissions data spanning three RSV seasons (September 2023 to March 2026), including two seasons following programme vaccination implementation. To better accommodate overdispersion in the admissions counts, the observation model was reformulated using a negative binomial likelihood. Given the small daily counts, weekly admissions were used in place of daily admissions.

- **MCMC diagnostics and posterior predictive checks:** In addition to convergency checks, sampling efficiency were assessed using effective sample

[12] **Protecting infants against RSV disease: an impact and cost-effectiveness comparison of long-acting monoclonal antibodies and maternal vaccination - The Lancet Regional Health – Europe**

[13] **Influenza hospital admissions prevented by vaccination: a transmission dynamic analysis of the 2022/2023 and 2023/2024 programmes in England**

[14] **Post-pandemic social contact patterns in the United Kingdom: the Reconnect survey | medRxiv**

size (using a threshold of 100). Posterior predictive checks were conducted by comparing model-estimated peak height, peak timing, and total admissions with the observed data.

- **Scenario creation:** From April 2026, adults aged 80 years and over became eligible for RSV vaccination. Scenarios for winter 2026/27 winter now include vaccination in ages 80 years and above assuming that uptake in this age group would be comparable to that observed among adults aged 75–79 years in their first year of vaccination. The effects of vaccinating adults in care homes were not included in the model.
- **Data validation and model consistency checks:** Additional checks were implemented to verify data integrity and model behaviour. These included checks for consistency across input datasets, non-negative population counts, preservation of population mass balance, and correct implementation of the vaccine calendar.

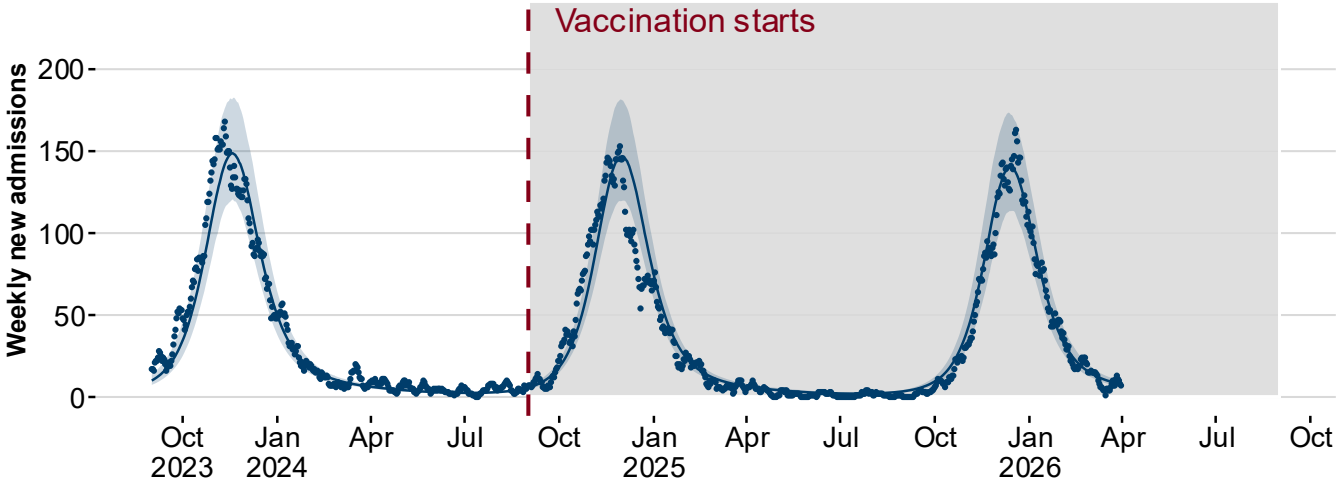
Results

MCMC diagnostics and Model Calibration

Using MCMC methods, we inferred key epidemiological parameters, including natural history parameters, infection-to-hospitalisation ratios, and transmissibility (Priors are reported in **Table S1** and posteriors in **Table S2**). The highest infection-to-hospitalisation ratios were observed in infants aged 1–6 months (5%) and 7–12 months (2.9%). Estimated durations of immunity were 166 days for natural infection, and 189 days in infants and 192 days in adults following vaccination.

MCMC diagnostics are reported in **Table S3**. All 26 estimated parameters achieved Gelman–Rubin statistic value below 1.1 and effective sample sizes of at least 100, indicating good convergence and adequate sampling efficiency.

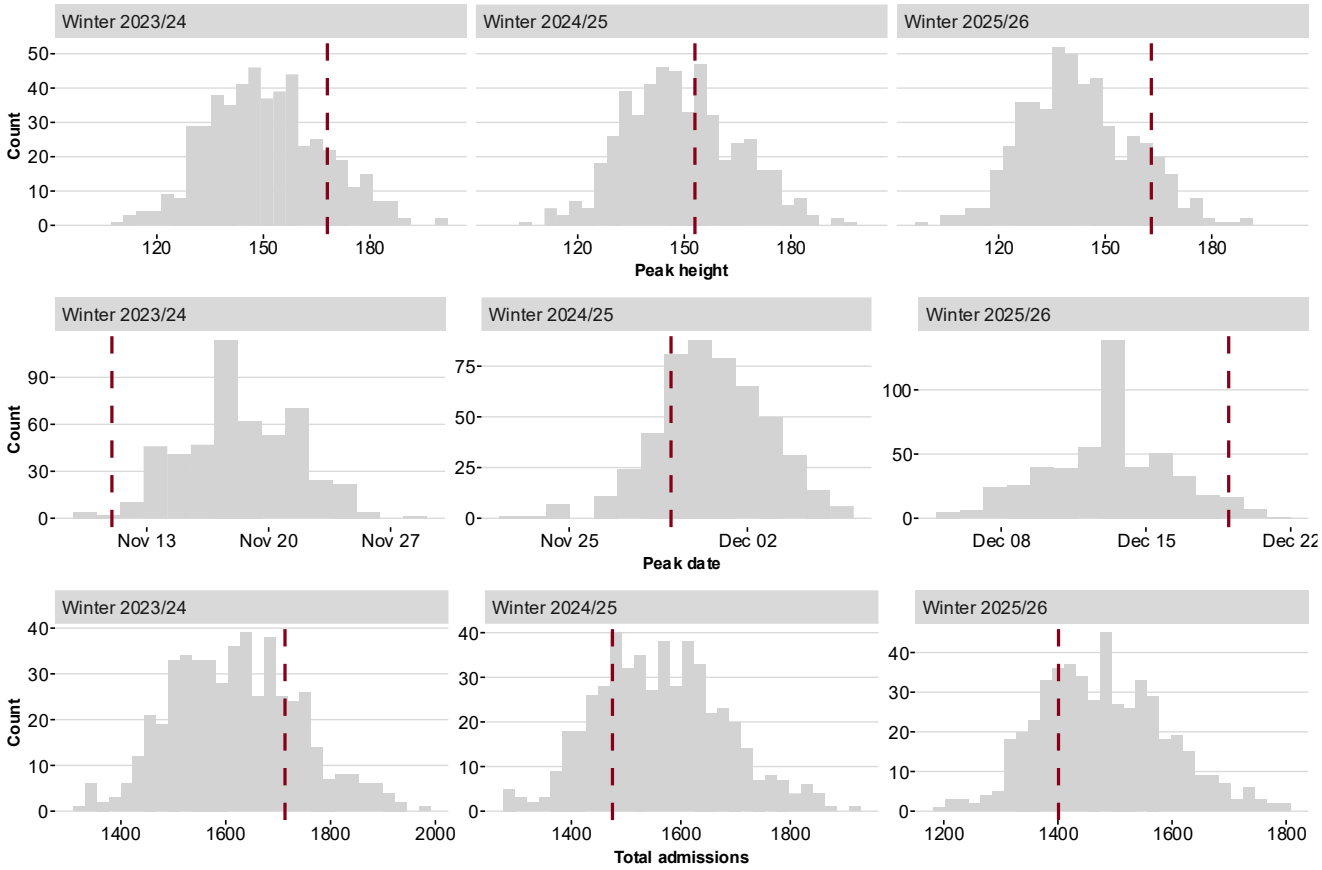
Figure 2: Comparison of model fit and observed RSV admissions between September 2023 and March 2026, in Wales. [Note 1]



Source: SRE modelling

The calibrated model is able to capture seasonality of RSV admissions Wales across age groups (**Figure 2 and 4**). The model accurately predicts the peak number of weekly admissions, estimated median peak heights deviating by only 4% to 13% from the observed values (**Figure 2 and 3, Table 3**). Additionally, the predicted timing of the peaks aligns closely with actual data, differing by just 4 to 14 days over the three seasons (**Figure 2 and 3, Table 4**). However, the model's interval coverage is relatively low, ranging from 40% to 61%. Notably, the bias for the winter 2025/26 season is high (0.35), indicating that the model tended to overestimate admissions during this period (**Table 1**). The model provides an accurate estimate of the total number of admissions due to RSV as well as peak height and date across the three winters, with most true values falling within the model's 95% credible interval (**Figure 3**).

Figure 3: Comparison of peak height, peak date and total number of RSV admissions estimated by the model and observed data, by season. [Note 1]



[Note 1]: The red line shows the observed data while the histogram shows the model estimates.

Source: SRE modelling

Table 2: Performance metrics of the RSV compartment model by winter season

Season	Weighted Interval Score	Bias	Interval coverage (90%)
Winter 2023/24	4.61	-0.17	0.61
Winter 2024/25	6.66	0.13	0.40
Winter 2025/26	3.00	0.35	0.60

Source: SRE modelling

Table 3: Comparison of the observed peak height with the median peak height estimated by the model

Season	Observed peak height	Peak height (estimated by the model)	Reduction in peak height
Winter 2023/24	168	149.62	10.94
Winter 2024/25	153	147.54	3.57
Winter 2025/26	163	141.28	13.33

Source: SRE modelling

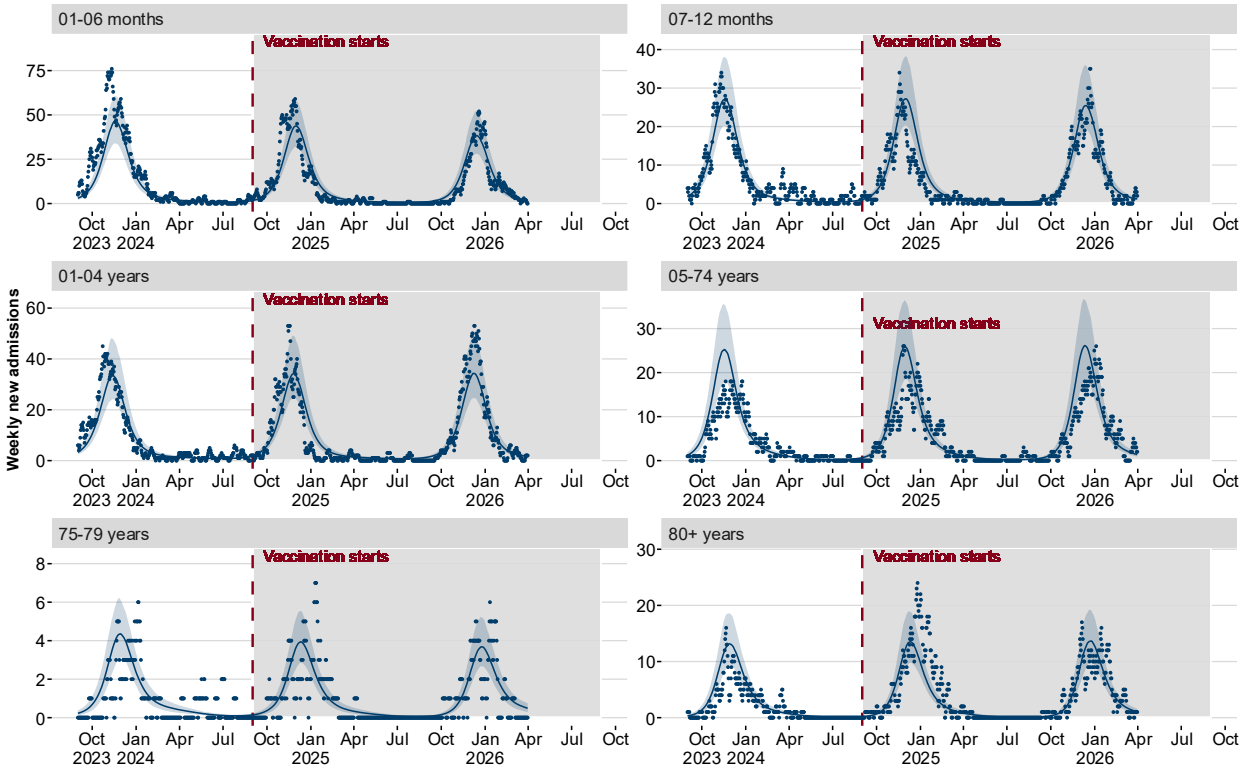
Table 4: Comparison of the observed peak timings with the median peak timing estimated by the model

Season	Observed peak date	Peak date (estimated by the model)	Difference
Winter 2023/24	11 November 2023	18 November 2023	7 days
Winter 2024/25	29 November 2024	30 November 2024	1 days
Winter 2025/26	19 December 2025	13 December 2025	-6 days

Source: SRE modelling

The age-specific model fits showed similar patterns: they accurately estimated peak height and timing, but their interval coverage was consistently low for all groups, especially within the 50% intervals (**Figure 4**).

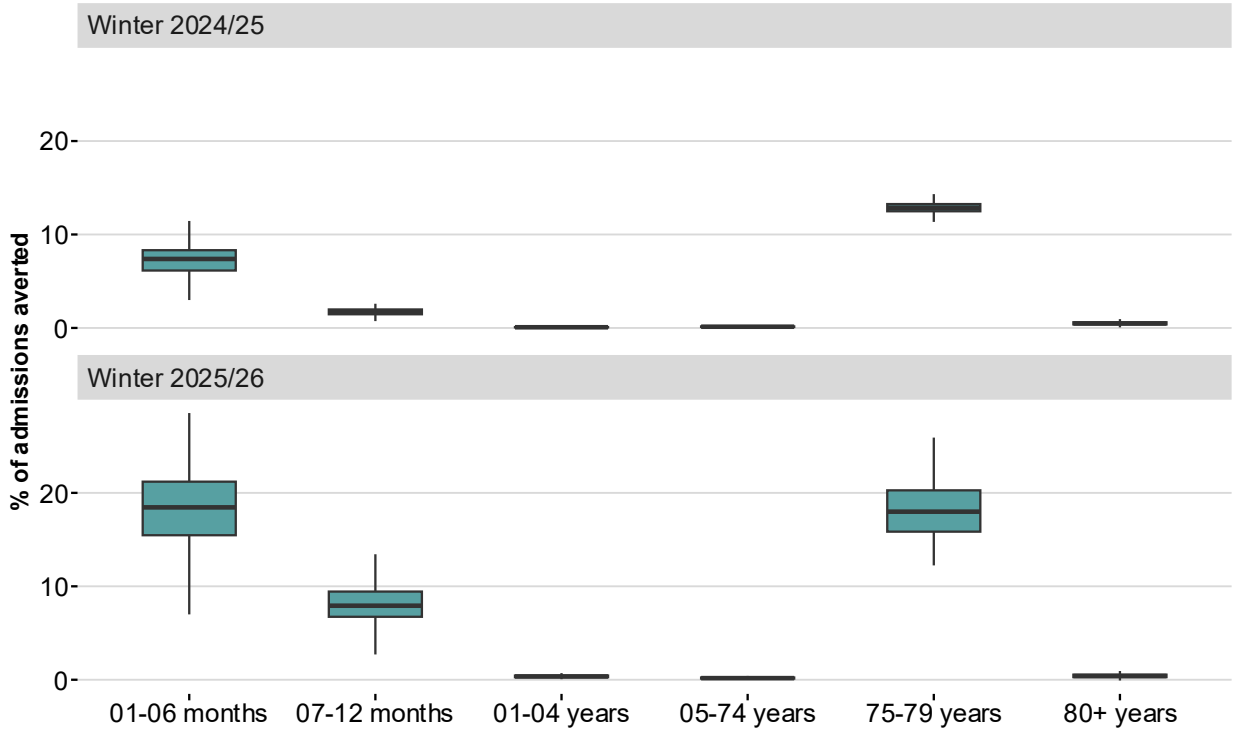
Figure 4: Comparison of model fit and observed RSV admissions between September 2023 and March 2026, in Wales, by age group.



Source: SRE modelling

Estimated percentage of RSV admissions prevented

Figure 5: Estimation of the percentage RSV admissions prevented by the vaccination during the Winter 2024/25 and Winter 2025/26, in Wales, by age group.



Source: SRE modelling

To quantify the number of RSV-associated hospital admissions averted by vaccination, a counterfactual no-vaccination scenario was created by setting vaccine uptake values to zero and comparing the resulting admissions with those estimated under observed uptake. As expected, no vaccine-attributable reduction in admissions was estimated in winter 2023/24 before programme implementation. In the first winter post-implementation (2024/25), the model estimated that 7.38% (95%CI: 3.36% - 10%) of admissions among infants aged 1–6 months and 1.75% (95%CI: 0.83% - 2%) among infants aged 7–12 months were averted. In the second winter (2025/26), the estimated reductions were larger for infants, with admissions 18.45 % (95%CI 8.30% - 25%) lower

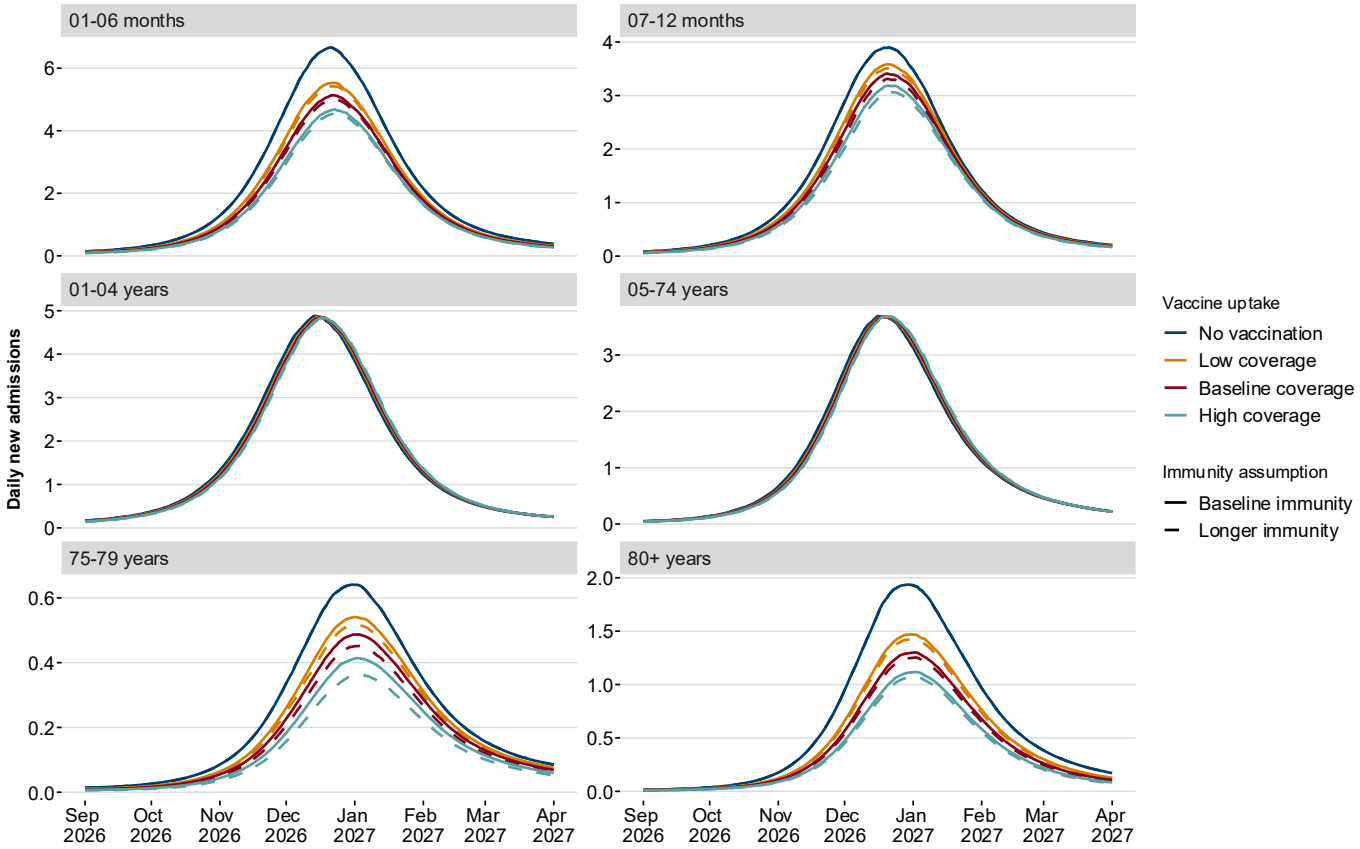
among those aged 1–6 months and 7.92% (95%CI: 3.53% - 12%) lower among those aged 7–12 months. Among adults aged 75–79 years, 12.86% (95% CI:11.65%-14%) of admissions were prevented in 2024/25 and 17.99% (95% CI: 13.16% - 25%) in 2025/26.

In summary, the modelling estimates reductions in RSV admissions in the vaccinated age groups in the past 2 winter seasons since the RSV vaccination programme started. The reductions in RSV admissions were more pronounced in the second year following RSV vaccinations compared with the first.

Projections for winter 2026/27

In this section, projections are presented as daily admissions rather than weekly admissions, as this is more helpful for planning purposes. RSV admissions scenarios were generated by varying assumptions regarding vaccine uptake and the duration of vaccine-derived immunity **(Figure 6).** Occupancy scenarios were then calculated using the projected admissions and age-specific lengths of stay due to RSV observed in the winter of 2025/26 **(Figure 8).**

Figure 6: Winter modelling admissions scenarios for 2026/27 winter in Wales, by age.



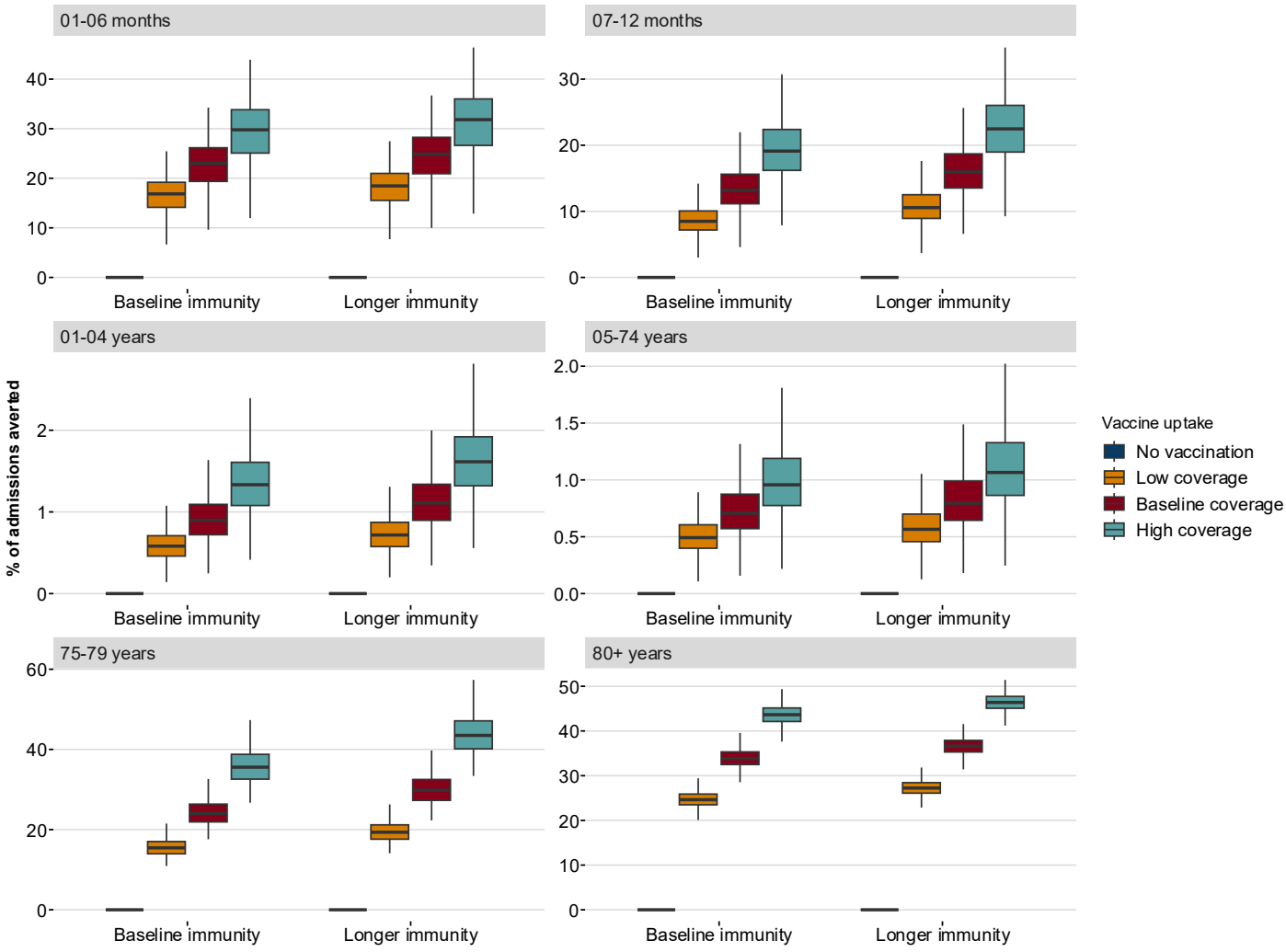
Source: SRE modelling

Table 5: Range of admission peak height and dates estimated by the model

Age group	Range of peak dates	Range of peak height	Total admissions
01-06 months	21 Dec 2026 - 23 Dec 2026	4.6 - 6.7	333.1 - 481.5
07-12 months	20 Dec 2026 - 21 Dec 2026	3.1 - 3.9	219.2 - 283
01-04 years	14 Dec 2026 - 17 Dec 2026	4.8 - 4.9	349.6 - 354.6
05-74 years	16 Dec 2026 - 21 Dec 2026	3.7 - 3.7	257.7 - 260.1
75-79 years	31 Dec 2026 - 03 Jan 2027	0.4 - 0.6	28.3 - 51
80+ years	30 Dec 2026 - 02 Jan 2027	1.1 - 1.9	74.9 - 139.1

Source: SRE modelling

Figure 7: Estimation of RSV admissions averted during the 2026/27 winter in Wales, by age group and scenario.



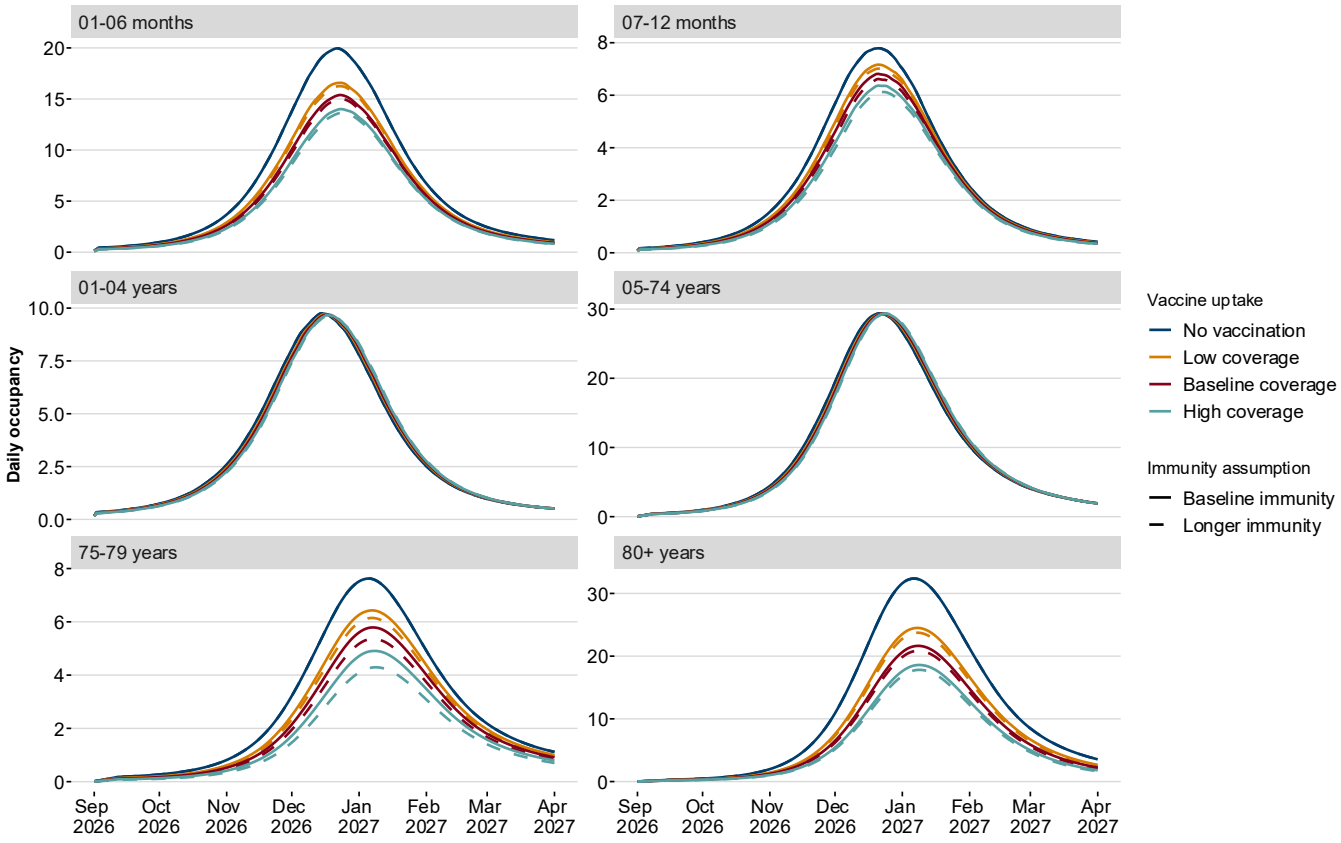
Source: SRE modelling

Admission scenarios indicate that peak daily admissions for infants aged 1–6 months are projected to range between 5 and 7 admissions, occurring between 21–23 December. For infants aged 7–12 months, peak admissions are lower, estimated at 3-4, occurring slightly later between 20-21 December (**Table 5**).

Among older adults, peaks are projected to occur later in the season. Admissions among those aged 75–79 years are expected to peak between 31st December - 3rd January, while those aged 80+ years are projected to peak between 30th December –

2nd January **(Table 5)**. The model estimates that between 24.6% and 46.4% of admissions in adults aged 80 years and over may be prevented (**Figure 7**).

Figure 8: Winter modelling occupancy scenarios for 2026/27 winter in Wales, by age group.



Source: SRE modelling

Occupancy scenarios estimate peak bed demand of 14–20 beds among infants aged 1–6 months and 6-8 beds among infants aged 7–12 months, occurring between 22nd-24th December and on 21 December. Occupancy is expected to peak at 4–8 beds among adults aged 75–79 years between 5-9th January and 18–32 beds among adults aged 80 years and over between 5-9th January and 6-9th January **(Table 6).**

Table 6: Range of occupancy peak height and dates estimated by the model.

Age group	Range of peak dates	Range of peak occupancy height
01-06 months	22 Dec 2026 - 24 Dec 2026	13.6 - 20
07-12 months	21 Dec 2026 - 21 Dec 2026	6.1 - 7.8
01-04 years	15 Dec 2026 - 18 Dec 2026	9.7 - 9.7
05-74 years	22 Dec 2026 - 24 Dec 2026	29.3 - 29.4
75-79 years	05 Jan 2027 - 09 Jan 2027	4.3 - 7.6
80+ years	06 Jan 2027 - 09 Jan 2027	17.8 - 32.4

Source: SRE modelling

Discussion

We developed a compartmental transmission model to estimate RSV hospital admissions. Compared to the previous version, the updated model incorporates age-specific contact patterns derived from a new Reconnect survey, changes in waning of vaccine-induced immunity, the explicit separation of vaccine effectiveness against infection and against hospital admission and model calibration using the most recent data. Model parameters were estimated using a Bayesian framework, with calibration via Markov Chain Monte Carlo (MCMC) methods to three seasons of RSV hospital admissions data, two of which followed the implementation of the maternal and older adult vaccination programme.

Overall, the model was able to reproduce both the magnitude and timing of peak RSV admissions with good fidelity. Counterfactual “no vaccination” scenarios were used to estimate the number of hospital admissions averted during the first two winters[15] of

[15] Defined as September - March

programme implementation. The estimated impact was modest in the first year, which is consistent with expectations given the timing of programme introduction in September 2024. In particular, there was an inherent delay between maternal vaccination uptake and the subsequent birth of infants who benefit from vaccine-derived protection, resulting in only partial population coverage in the first season. In contrast, the estimated impact in the second winter was substantially greater. This reflects the programme having been in place for a full year, allowing a larger proportion of infants to be protected at birth by the time the RSV epidemic begins to grow.

Several studies have estimated the potential impact of maternal RSV vaccination on infant hospitalisations. For example, modelling work by Hogan et al. 2017 assumes partial temporary immunity has projected reductions in hospital admissions ranging from 6% to 37% among infants aged 0–2 months and from 30% to 46% among those aged 3–5 months.[16] Similarly, Pan-Ngum et al. estimated that maternal vaccination could reduce RSV-related hospitalisations among infants aged under 12 months by 7% to 15%.[17] Our model estimates 18.45% of admissions were averted among those aged 1–6 months and 7.92% among those aged 7–12 months after the second year of its implementation. While direct comparisons are challenging due to differences in model structure, assumptions, and epidemiological context, the magnitude of impact observed in this analysis falls within the range reported in these studies.

Finally, the model was used to generate projections for the 2026/27 winter season, incorporating the effects of vaccinating adults aged 80 years and over. Using various vaccine uptake scenarios in this group, the model estimates that vaccination could avert between 24.6% and 46.4% of RSV hospital admissions in this age group during winter 2026/27. This is much higher that what will be observed in ages 75-79 years.

As with all modelling studies, the results are contingent on several assumptions, including contact patterns, vaccine efficacy, and completeness of ICD-10 coding. These

[16] **Potential impact of a maternal vaccine for RSV: A mathematical modelling study - ScienceDirect**

[17] **Predicting the relative impacts of maternal and neonatal respiratory syncytial virus (RSV) vaccine target product profiles: A consensus modelling approach - ScienceDirect**

assumptions introduce uncertainty and should be considered when interpreting the findings. The effects of vaccinating residents in care homes have not been considered. Therefore, the model outputs should be viewed as indicative rather than definitive and as an estimation of what might happen rather than a prediction of what will happen.

Annex

Model Assumptions:

1. **Disease progression**: Infected individuals pass through a latent (exposed) period during which they are infected but not infectious, before becoming infectious. Following the infectious period, individuals recover and are removed from further transmission. There are two compartments for exposed and infectious stages to get a gamma distributed average time rather than an exponentially distributed average waiting time within these stages. Within each compartment, individuals are assumed to be homogeneous.

2. **Vaccination:** Vaccinated individuals are either: effectively vaccinated and moved to R_{ev}/M, or ineffectively vaccinated (and moved to S_v-R_v), following the same disease pathway as vaccinated individuals. The rate of transition to vaccinated compartments is dependent on time dependent vaccine uptake rate and vaccine efficacy.

3. **Waning immunity:** Vaccine-induced immunity against infection wanes according to an Erlang-3 distribution including three delay states before becoming susceptible again ($M1 - M3$ or $R1_{ev} - R3_{ev}$).

4. **Closed population** (fixed population size): The total population size is fixed over the modelled period, but aging rates are included.

5. **Age stratification with non-random mixing:** The population is stratified by age. Contacts between age groups are governed by fixed, age-specific contact rates from Reconnect survey rather than assuming random mixing. These contact rates are not further stratified by time or setting.

Data quality issues

Hospitalisation data: Admissions due to RSV were identified using a narrow set of ICD-10 codes: B97.4, J12.1, J20.5 and J21.0. Reliance on these codes may lead to an underestimation of RSV hospital admissions as they only include patients who were tested for RSV, potentially excluding those who were not tested or whose diagnosis has not yet been coded in clinical records. In addition, there may be patients with RSV who have not been clinically coded at the time the data is received. The ICD-10 coding process can experience delays of several months, resulting in incomplete coding and, consequently, incomplete data regarding RSV admissions.

Reconnect survey: The survey included contacts which were face-to-face conversations or physical touch and may not account for all close encounters, such as those in crowded transport or elevators. Self-reported contacts could be affected by recall bias, and brief interactions with strangers may have been overlooked.

Differential equations

Differential equations for the compartmental model are as follows:

$$\frac{dS_{n,i}}{dt} = -\lambda_i(t)S_{n,i} - \mu(t)S_{n,i} + \omega 0 R_{n,i} + \omega 2 S_{v,i} + 3\omega 1 M2_i + 3\omega 2 R_{ev2,i} + \tau_{in}S_{n,i-1} + \tau_{out}S_{n,i}$$

$$\frac{dE1_{n,i}}{dt} = \lambda_i(t)S_{n,i} - 2\epsilon E1_{n,i} - \mu(t)E1_{n,i} + \omega 2 E1_{v,i} + \tau_{in}E1_{n,i-1} + \tau_{out}E1_{n,i}$$

$$\frac{dE2_{n,i}}{dt} = 2\epsilon E1_{n,i} - 2\epsilon E2_{n,i} - \mu(t)E2_{n,i} + \omega 2 E2_{v,i} + \tau_{in}E2_{n,i-1} + \tau_{out}E2_{n,i}$$

$$\frac{dI1_{n,i}}{dt} = 2\epsilon E2_{n,i} - 2\gamma I1_{n,i} - \mu(t)I1_{n,i} + \omega 2 I1_{v,i} + \tau_{in}I1_{n,i-1} + \tau_{out}I1_{n,i}$$

$$\frac{dI2_{n,i}}{dt} = 2\gamma I1_{n,i} - 2\gamma I2_{n,i} - \mu(t)I2_{n,i} + \omega 2 I2_{v,i} + \tau_{in}I2_{n,i-1} + \tau_{out}I2_{n,i}$$

$$\frac{dR_{n,i}}{dt} = 2\gamma I2_{n,i} - \mu(t)R_{n,i} - \omega 0 R_{n,i} + \omega 2 R_{v,i} + \tau_{in}R_{n,i-1} + \tau_{out}R_{n,i}$$

$$\frac{dS_{v,i}}{dt} = -\lambda_i S_{v,i} + \mu(t)(1-\alpha)S_{n,i} + \omega 0 R_{v,i} - \omega 2 S_{v,i} + \tau_{in}S_{v,i-1} + \tau_{out}S_{v,i}$$

$$\frac{dE1_{v,i}}{dt} = \lambda_i S_{v,i} - 2\epsilon E1_{v,i} + \mu(t)E1_{n,i} - \omega 2 E1_{v,i} + \tau_{in}E1_{v,i-1} + \tau_{out}E2_{v,i}$$

$$\frac{dE2_{v,i}}{dt} = 2\epsilon E1_{v,i} - 2\epsilon E2_{v,i} + \mu(t)E2_{n,i} - \omega 2 E2_{v,i} + \tau_{in}E2_{v,i-1} + \tau_{out}E2_{v,i}$$

$$\frac{dI1_{v,i}}{dt} = 2\epsilon E2_{v,i} - 2\gamma I1_{v,i} + \mu(t)I1_{n,i} - \omega 2 I1_{v,i} + \tau_{in}I1_{v,i-1} + \tau_{out}I1_{v,i}$$

$$\frac{dI2_{v,i}}{dt} = 2\gamma I1_{v,i} - 2\gamma I2_{v,i} + \mu(t)I2_{n,i} - \omega 2 I2_{v,i} + \tau_{in}I2_{v,i-1} + \tau_{out}I2_{v,i}$$

$$\frac{dR_{v,i}}{dt} = 2\gamma I2_{v,i} + \mu(t)R_{n,i} - \omega 0 R_{n,i} - \omega 2 R_{v,i} + \tau_{in}R_{v,i-1} + \tau_{out}R_{v,i}$$

$$\frac{dR1_{ev,i}}{dt} = \mu(t)\alpha S_{n,i} - 3\omega 2 R1_{ev,i} + \tau_{in}R1_{ev,i-1} + \tau_{out}R1_{ev,i}$$

$$\frac{dR2_{ev,i}}{dt} = 3\omega 2 R1_{ev,i} - 3\omega 2 R2_{ev,i} + \tau_{in}R2_{ev,i-1} + \tau_{out}R2_{ev,i}$$

$$\frac{dR3_{ev,i}}{dt} = 3\omega 2 R2_{ev,i} - 3\omega 2 R3_{ev,i} + \tau_{in}R3_{ev,i-1} + \tau_{out}R3_{ev,i}$$

$$\frac{dM1_i}{dt} = \xi(t)\alpha Births - 3\omega 1 M1_i + \tau_{in}M1_{i-1} + \tau_{out}M1_i$$

$$\frac{dM2_i}{dt} = 3\omega 1 M1_i - 3\omega 1 M2_i + \tau_{in}M2_{i-1} + \tau_{out}M2_i$$

$$\frac{dM3_i}{dt} = 3\omega 1 M2_i - 3\omega 1 M3_i + \tau_{in}M3_{i-1} + \tau_{out}M3_i$$

The equations below describe the counters used in hospitalisations calculations

$$\frac{dH_{1,i}}{dt} = 2\gamma\eta\left(I1_{n,i} + I1_{v,i}\big(1-\alpha(H)\big)/(1-\alpha)\right)$$
$$\frac{dH_{2,i}}{dt} = 2\kappa\big(H_{1,i} - H_{2,i}\big)$$
$$\frac{dH_i}{dt} = 2\kappa H_{2,i}$$

The ordinary differential equations were written using R package Odin and solved numerically using the Euler method.

Model parameters

Table S1: Fixed parameters and priors used in the model

Parameter	Description	Value/Prior	Reference
$1/\varepsilon$	Latent period	$Gamma(7.111,0.563)$days	Hodgson 2020[18]
$1/\gamma$	Infectious period	$W(4.137,8.303)$days	Hodgson 2020
$1/\omega 0$	Natural immunity period	$Normal(135,35)$days	Hodgson 2020
$1/\omega 1$ and $1/\omega 2$	Vaccine-induced immunity period	$Normal(180,30)$days	-
$1/\kappa$	Delay between infection and hospitalization	$Gamma(3,2)$days	-
α	Vaccine efficacy against infection	$1 - LogNormal(-0.61,0.29)$	van Leeuwen et al. 2025 [19]

[18] **Evaluating the next generation of RSV intervention strategies: a mathematical modelling study and cost-effectiveness analysis | BMC Medicine | Springer Nature Link**

[19] **Influenza hospital admissions prevented by vaccination: a transmission dynamic analysis of the 2022/2023 and 2023/2024 programmes in England**

Parameter	Description	Value/Prior	Reference
b_0	Baseline transmissibility	$U(0,1)$	-
b_1	Seasonal forcing factor	$U(0,1)$	-
ϕ	Phase difference	$U(-pi, pi)$	-
ψ	Period of seasonality	$Normal(365,20)$days	-
σ	Susceptibility	$U(0,1)$	van Leeuwen et al. 2023[20]
η	Infection to hospitalisation ratio	$U(0,0.2)$	-
p^{sus}	Proportion susceptible	$Beta(5,5)$	-
$p^{infected}$	Proportion infected	$Beta(2,20)$	-
k	Dispersion	$Beta(2,100)$	-
k	Time delay between vaccine administration and antibodies generation	14 days	Jordan et al. 2023[21]
k	Vaccine effectiveness (infants)	82.2	McLachlan et al. 2026[22]
k	Vaccine effectiveness (adults)	83.3	Symes et al. 2026[23]

[20] **The interplay between susceptibility and vaccine effectiveness control the timing and size of an emerging seasonal influenza wave in England - ScienceDirect**

[21] **Reduced Respiratory Syncytial Virus Load, Symptoms, and Infections: A Human Challenge Trial of MVA-BN-RSV Vaccine - PMC**

[22] **Effectiveness of the maternal RSVpreF vaccine against severe disease in infants in Scotland, UK: a national, population-based case-control study and cohort analysis - PubMed**

[23] **Vaccine effectiveness of a bivalent respiratory syncytial virus (RSV) pre-F vaccine against RSV-associated hospital admission among adults aged 75–79 years in England: a multicentre, test-negative, case–control study - The Lancet Infectious Diseases**

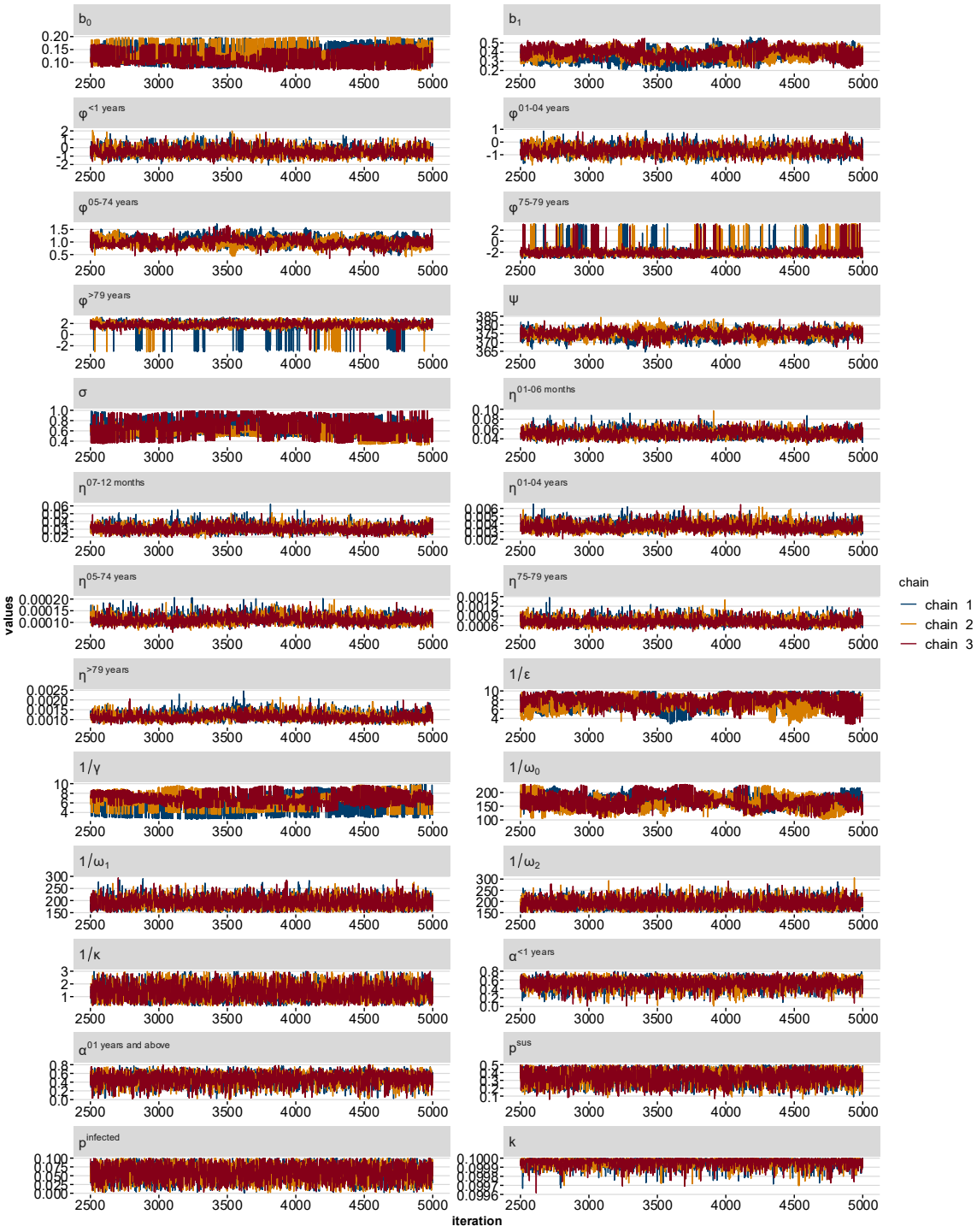
Table S2: Summary statistics of the posterior samples obtained through model fitting

Parameters	median+ 95%CrI
$\alpha^{<1\text{ years}}$	0.55532 [0.25122,0.73605]
$\alpha^{01\text{ years and above}}$	0.49769 [0.1671,0.70382]
b_0	0.12329 [0.07434,0.19268]
b_1	0.37725 [0.2483,0.50726]
$\eta^{01–06\text{ months}}$	0.04999 [0.03624,0.06639]
$\eta^{07–12\text{ months}}$	0.02977 [0.02275,0.04073]
$\eta^{01–04\text{ years}}$	0.00354 [0.0027,0.00501]
$\eta^{05–74\text{ years}}$	0.00011 [8e-05,0.00015]
$\eta^{75–79\text{ years}}$	0.00073 [0.00052,0.00098]
$\eta^{>79\text{ years}}$	0.00113 [0.00082,0.0016]
$1/\gamma$	6.80253 [2.91116,9.36948]
k	0.09997 [0.09981,0.1]
$1/\epsilon$	7.77307 [4.4801,9.7972]
$1/\omega 0$	165.55872 [123.12863,215.86071]
$\phi^{<1\text{ years}}$	-0.53391 [-1.4512,0.74696]
$\phi^{01–04\text{ years}}$	-0.68742 [-1.38664,0.27549]
$\phi^{05–74\text{ years}}$	1.00211 [0.66079,1.37853]
$\phi^{75–79\text{ years}}$	-2.16916 [-3.02992,2.9517]
$\phi^{>79\text{ years}}$	1.78993 [0.85523,2.79365]
$p^{infected}$	0.058 [0.00842,0.09834]
p^{sus}	0.35012 [0.16111,0.48982]
ψ	375.3857 [369.86366,379.65146]
σ	0.60672 [0.37103,0.95862]

$1/\kappa$	1.27048 [0.34971,2.72456]
$1/\omega 2$	189.43045 [155.35289,247.57287]
$1/\omega 1$	191.83003 [153.8347,242.19025]

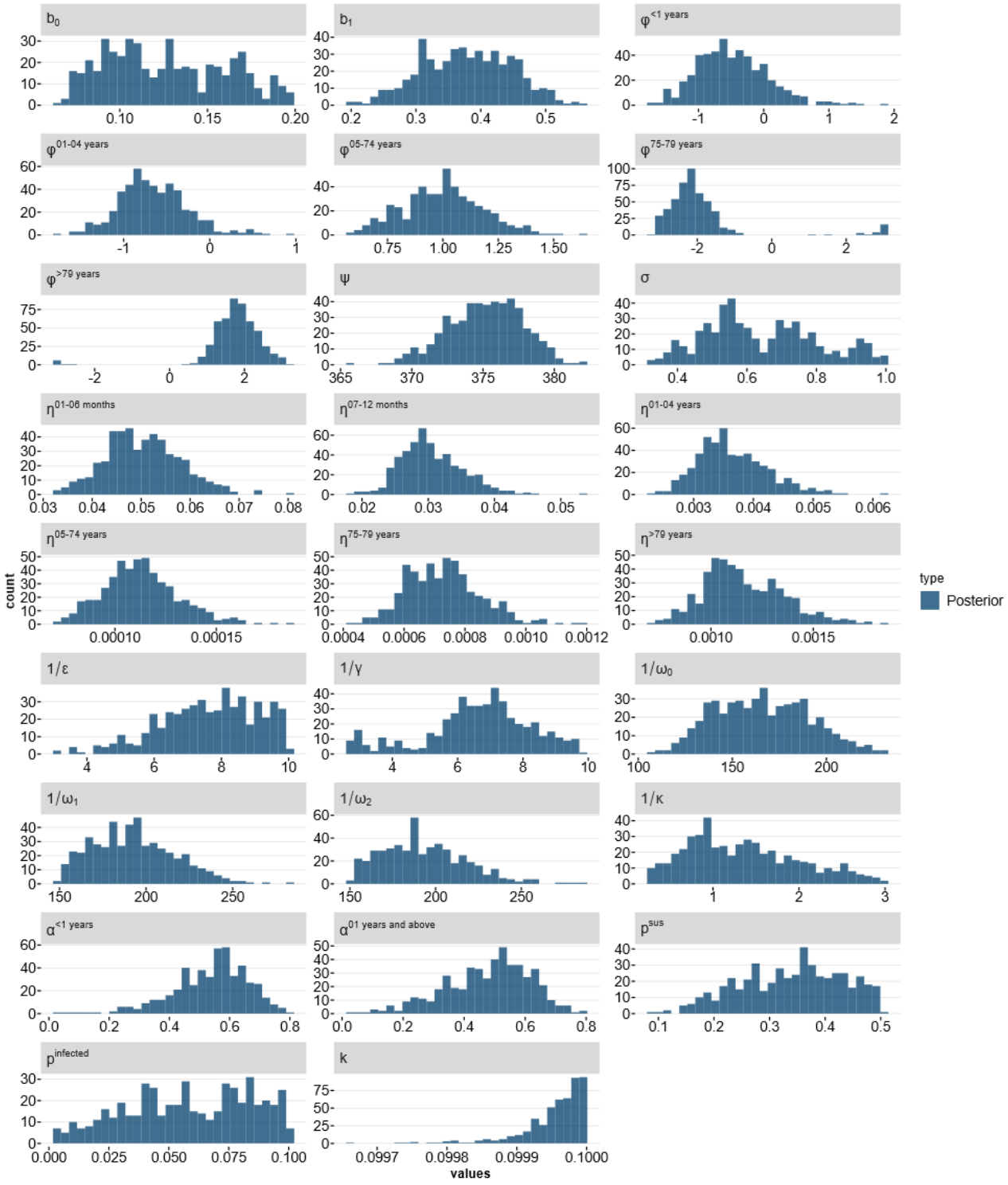
MCMC diagnostics

Figure S1: Trace plot of MCMC runs during sampling phase.



Source: SRE modelling

Figure 3: Histogram of posterior samples derived from the MCMC run



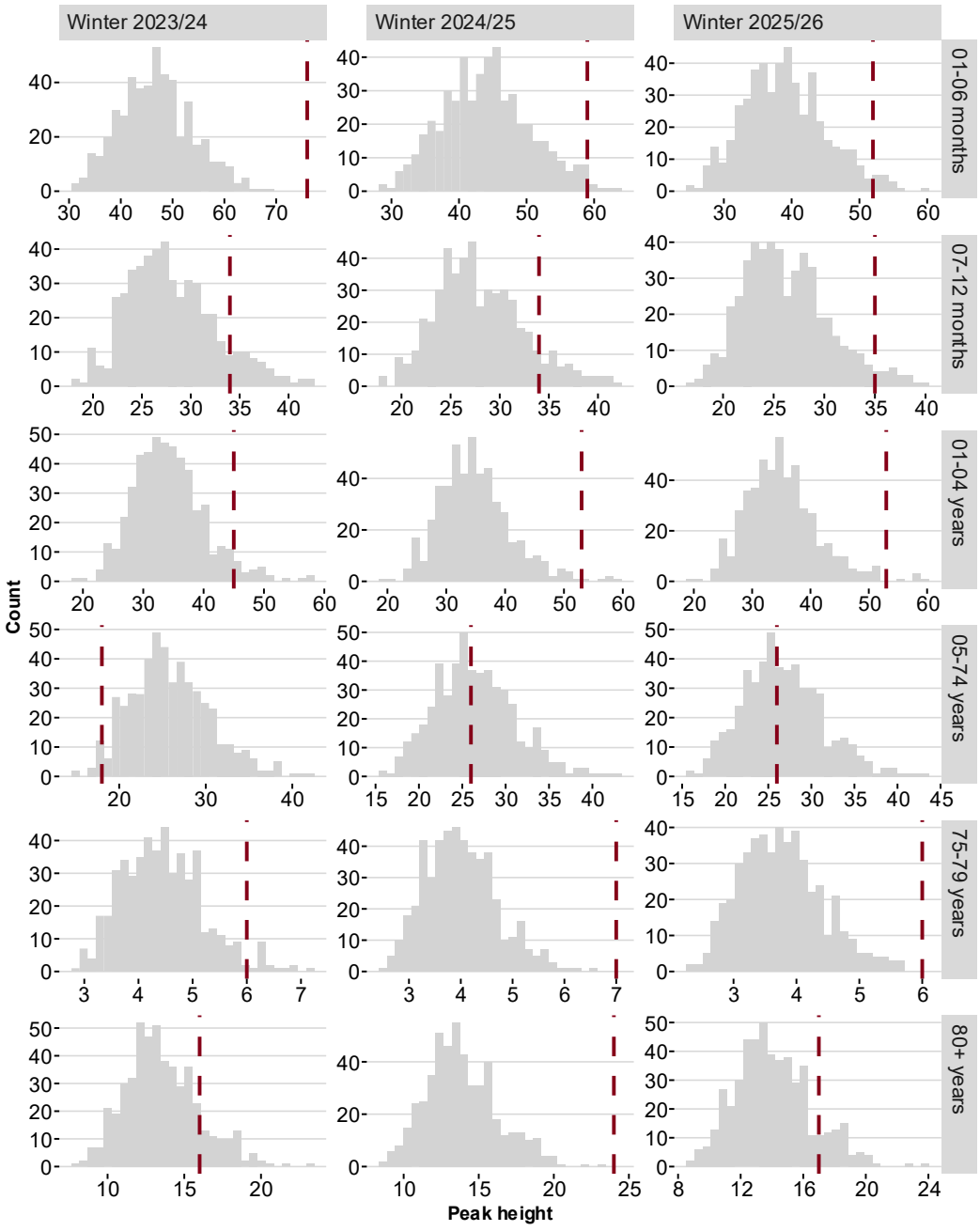
Source: SRE modelling

Table S3: Diagnostic parameters of MCMC run

Parameters	Gelman Rubin diagnostic	Effective sample size
$\alpha^{<1\text{ years}}$	1.00	3897.12
$\alpha^{01\text{ years and above}}$	1.00	4025.41
b_0	1.09	207.09
b_1	1.06	105.04
$\eta^{01–06\text{ months}}$	1.01	1624.87
$\eta^{07–12\text{ months}}$	1.01	1023.50
$\eta^{01–04\text{ years}}$	1.01	870.58
$\eta^{05–74\text{ years}}$	1.02	568.34
$\eta^{75–79\text{ years}}$	1.01	1300.05
$\eta^{>79\text{ years}}$	1.03	584.41
$1/\gamma$	1.07	222.64
k	1.00	5439.46
$1/\epsilon$	1.03	288.52
$1/\omega 0$	1.04	132.88
$\phi^{<1\text{ years}}$	1.00	2455.15
$\phi^{01–04\text{ years}}$	1.00	1394.64
$\phi^{05–74\text{ years}}$	1.03	341.29
$\phi^{75–79\text{ years}}$	1.00	1011.32
$\phi^{>79\text{ years}}$	1.00	1114.57
$p^{infected}$	1.00	3578.71
p^{sus}	1.00	2939.71
ψ	1.01	736.74
σ	1.07	173.37

$1/\kappa$	1.00	3648.23
$1/\omega 2$	1.00	4122.26
$1/\omega 1$	1.00	3783.64

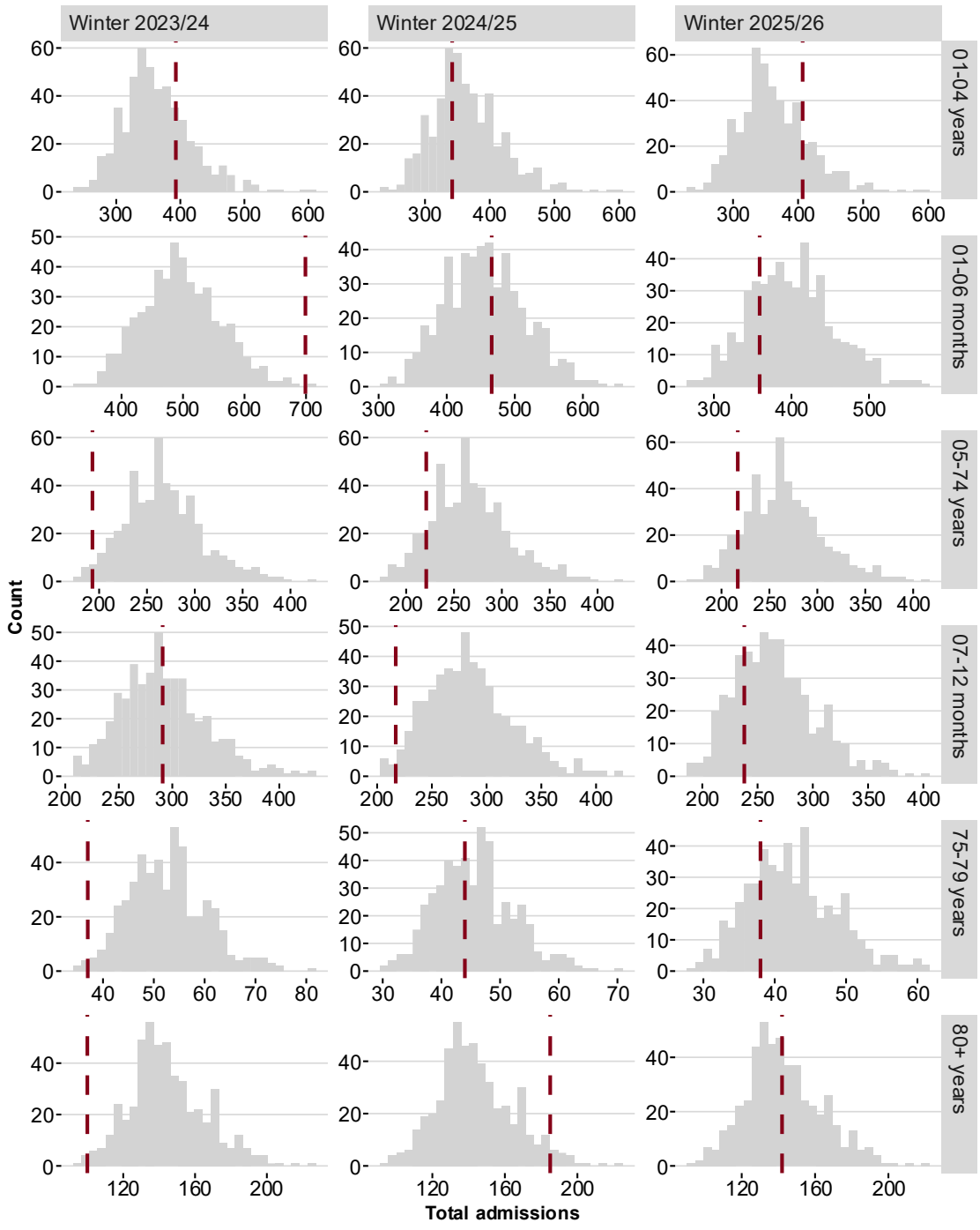
Figure S3: Comparison of peak height of RSV admissions estimated by the model and observed data, in Wales, by age group and season [Note 1].



[Note 1]: The red line shows the observed data while the histogram shows the model estimates.

Source: SRE modelling

Figure S4: Comparison of total number of RSV admissions estimated by the model and observed data, in Wales, by age group and season [Note 1].



[Note 1]: The red line shows the observed data while the histogram shows the model estimates.

Source: SRE modelling