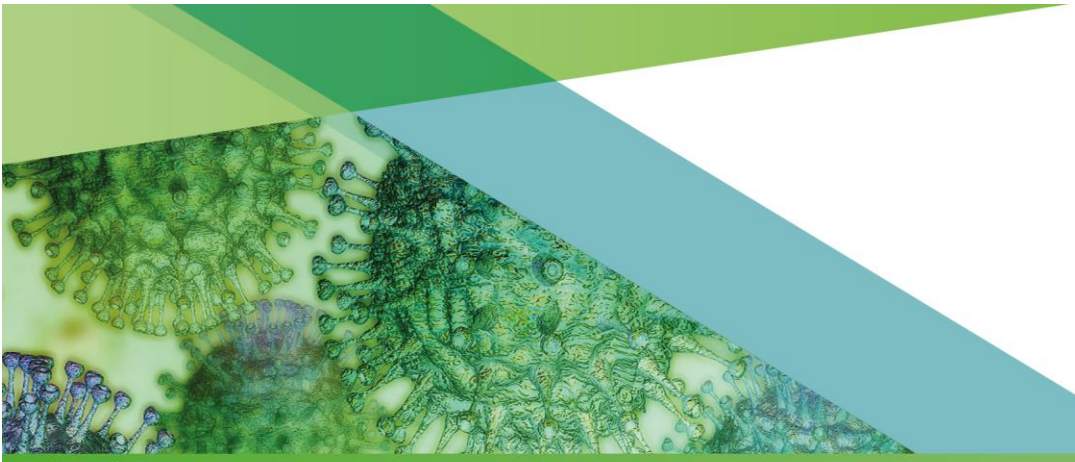

TECHNICAL REPORT

Preliminary public health considerations for COVID-19 vaccination strategies in the second half of 2022

18 July 2022

Key messages

- In the current post-acute phase of the pandemic, the introduction and emergence of new SARS-CoV-2 variants with increased transmissibility and/or immune escape capacity, together with waning protection against infection and severe disease from natural or vaccine-induced immunity, can result in new waves of virus transmission and surges of COVID-19 cases with a subsequent rise in hospitalisations, ICU admissions and deaths.
- As of 10 July 2022, the overall notification rates of COVID-19 cases in the EU/EEA remain high and have been increasing for the past five weeks. Case rates among people aged 65 years and over increased in 23 of the 27 reporting countries. These increases are still relatively recent, and they signal the start of a widespread wave driven by the BA.4 and BA.5 variants of concern.
- As of 3 July 2022, based on GISAID or the European Surveillance System (TESSy) data, Omicron BA.4 or BA.5 are the dominant circulating SARS-CoV-2 variants (>50%) in 18 EU/EEA countries, and, based on projections, the proportion of all COVID-19 cases due to infection with BA.4 or BA.5 will exceed 95% in most EU/EEA countries by end-July 2022.
- The increasing transmission among older age groups is starting to translate into severe disease, and, as of 10 July 2022, 12 countries reported an increasing trend in either hospital or ICU admissions/occupancy compared with the previous week. At the same time, even though the EU/EEA death rate has remained stable for the last five weeks, the forecast for the period up to 31 July indicates that both case notification rates and death rates will increase.
- As of 10 July 2022, the cumulative uptake of the primary COVID-19 vaccination course in the total population in the EU/EEA reached 72.8%, and 52.9% for the first booster dose. Among individuals aged 60 years and older, vaccine uptake is higher, 90.8% and 83.1% for the primary course and the first booster respectively, but still with significant disparities across EU/EEA countries.
- Currently, 20 countries recommend the administration of a second booster dose, mostly for age groups from 60+ to 80+ years and for long-term care facility (LTCF) residents, with a time interval after the first booster dose varying between three to five months. Approximately 16.5 million second booster doses have been administered so far (data reported to TESSy by 21 countries), the majority among those 60+ (88%), and with a median uptake of 11.6% among 60+ (range: <0.1-59.5%) and 20% among 80+ (range: 0.1-80.1%).

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- Published literature indicates that vaccine effectiveness (VE) against severe outcomes caused by Omicron remains high, including among older age groups, with continued strong protection generally around 80–90% around two to three months after receiving the first booster, albeit with the balance of evidence indicating gradual waning after three to six months (VE estimates in the range 53-100%). A second mRNA booster dose restores VE against severe disease, which remains stable for up to 10 weeks, but longer follow-up times are not yet available. Only limited data are available on VE against Omicron sub-lineages BA.4 and BA.5. A preliminary analysis from Portugal suggests that the VE may be reduced against infection with BA.5 as compared to infection with BA.2, while data from South Africa indicate that high VE against severe disease has been maintained during the BA.4/BA.5 dominant period.
- The analysis of severe outcomes of disease among COVID-19 cases having received a first booster dose (TESSy data) shows that hospitalisation and death are rare in this group (0.6% and 0.1% respectively); nevertheless, the adjusted risk of hospitalisation and death is higher in those who received the first booster dose more than three months previously, older age groups (80+ and 60 to 79) and males.
- Mathematical modelling shows that for countries with an uptake of >40% for the first booster in the whole population, a second booster rollout among 60+ can have a substantial impact on restoring vaccine-induced protection against hospitalisation in this population from mid-July to the end of 2022, with an expected median absolute increase of 17% (95% UI 6-34%) on 1 November 2022. For countries with an uptake of <40% for the first booster in the whole population, closing the vaccination coverage gaps of the primary series and the first booster has a larger overall effect than a second booster rollout, with an expected median absolute increase of population-level vaccine-induced protection against hospitalisation of 16% (95% UI 10-41%) and 5% (95% UI 1-24%) on 1 November 2022, respectively. Furthermore, an earlier second booster rollout among 60+ in mid-July 2022 results in a larger vaccine-induced protection against hospitalisation for the rest of 2022 compared to a later second booster rollout. The benefit in terms of vaccine-induced protection against hospitalisation in the population 60+ decreases the more the starting date of the second booster rollout is moved later (we evaluate a starting date in July, August, September, or October).

Public health considerations

Considering the above, the following public health considerations provide some guidance for vaccination strategies and the use of additional booster doses of mRNA vaccines in the second half of 2022:

- At this stage of the pandemic, the objective of COVID-19 vaccination campaigns continues to be to reduce COVID-19 hospitalisation, severe disease and death, and to protect health systems.
- Improving vaccine uptake of the primary course and first booster dose in eligible individuals who are yet to receive them remains a priority, especially for population groups at higher risk of severe outcomes and for countries with lower uptake of primary course and first booster dose.
- An early second booster rollout, not only among 80+, but also for adults between the ages of 60 and 79 years and individuals with underlying comorbidities regardless of age, should now be considered to prevent severe disease and safeguard health system capacity, and countries should consider a rapid deployment. This would be particularly relevant and impactful in countries where the BA.4/BA.5 wave is starting or has not yet peaked. Second boosters could be administered at least four months after the previous one, with a focus on people who received a previous booster more than six months ago.
- At the moment, for immunocompetent individuals below 60 years of age, unless they have underlying comorbidities, there is no clear epidemiological evidence to support the administration of a second booster.
- The early administration of a second booster dose with currently available vaccines to healthcare workers (HCW) and personnel working in LTCFs for infection control purpose, is likely to offer only modest benefits in terms of limiting the risks of transmission to vulnerable people in their care, and be of limited duration. HCW and LTCF personnel may receive a second booster for their own protection if they belong to any prioritised population group based on age or underlying comorbidities. It should be ensured that LTCF residents receive the recommended booster doses; non-pharmaceutical interventions (NPIs) in healthcare settings including LTCFs remain effective measures to protect vulnerable individuals; and access to therapeutics is an additional key measure for the protection of LTCF residents from severe outcomes.
- In addition, in anticipation of further waves of infection that may arrive in the autumn/winter season, countries should consider the need for rollout of further additional booster doses of mRNA vaccines for population groups at risk of severe disease (e.g. 60+,individuals with underlying comorbidities, immunocompromised individuals and pregnant women) later in the year, possibly combining campaigns for vaccination against COVID-19 and influenza, taking into account any new evidence available at that time on the benefit/risk profile of repeated boosters and the impact on the capacity of health systems to deliver vaccinations in the context of other competing public health priorities in the post-pandemic phase.
- The boosting of HCW and LTCF personnel should also be considered for this later rollout. If adapted, vaccines will show increased neutralisation against Omicron variants, indicating a possible higher effect against infection and transmission, they may be used to provide both direct and indirect protection.

- The need for, and optimal timing of further additional booster doses in autumn/winter may vary across countries, especially depending on the timing of rollout of second boosters in spring/summer 2022 and emerging evidence of continued protection against severe disease in those that have received a second booster dose.
- Updated Omicron-adapted vaccines will likely be authorised for use in the EU in September and possibly available sometime during the last trimester of 2022, however the distribution timeline and available supplies are currently being defined with manufacturers. Nevertheless, it is important to continue the efforts to increase vaccination rates with available vaccines for groups at high risk of severe disease in a timely manner, and not to wait for the new Omicron-adapted vaccines.
- Future vaccination strategies may also differ depending on the availability of the updated vaccines and their characteristics. Countries may have to use different types of vaccines for different strategies and population groups depending on the characteristics of the updated vaccines compared to first-generation ones and considering emergence of new variants.
- Communication initiatives to promote uptake of additional vaccine doses, and to promote completion of the primary series by those who have not yet done so face recurring and emerging challenges. These include complacency towards the threat of COVID-19, the need to provide evidence-based reassurances to address lower confidence in vaccine effectiveness and concerns about side effects, as well as potential confusion in the public as to how boosters will be offered in the coming months, timelines for adapted vaccines, who should receive these and when. This context stresses the importance of understanding and addressing individuals' and communities' beliefs, concerns and expectations regarding the vaccine and the disease. Clear information should be provided around the rationale for recommendations, and the benefits of the primary course and boosters for different population groups, including for those who already had the disease.

These public health considerations are based on current scientific evidence and epidemiological trends, and will be periodically reassessed. The scope of these considerations is focused on the second half of 2022, with an emphasis on the case for booster vaccination and closing the primary vaccination gap in the late summer/early autumn, and not for longer term COVID-19 vaccination strategies. National Immunisation Technical Advisory Groups (NITAGs) will ultimately make national decisions on the use of COVID-19 vaccines, taking into account the previous vaccination uptake and the epidemiological situation in their countries.

Background and rationale

Over half of the European Union/European Economic Area (EU/EEA) countries are already recommending and rolling out second booster doses of COVID-19 vaccines, mainly to older population groups. Some countries are also recommending or discussing the introduction of second booster doses in certain other vulnerable population groups, as well as healthcare workers. Furthermore, EU/EEA countries are now discussing their future COVID-19 vaccination strategies and the need for additional booster doses before the autumn/winter season when another wave and health service pressures related to other respiratory viruses may be expected.

Scope of this document

This document offers an overview of the available scientific and epidemiological evidence and provides public health considerations to support decisions on the implementation of additional booster doses of COVID-19 vaccine. It aims to provide some preliminary considerations and inputs to EU/EEA countries for evidence-based decision-making when planning vaccination campaigns, both at present and during the coming months, ahead of the next autumn/winter season. This ECDC technical report builds upon and complements the previous one on public health considerations and evidence to support decisions on the implementation of a second mRNA COVID-19 vaccine booster dose published on 28 April 2022 [1]. The public health considerations presented in this document are based on the assessment of current epidemiological trends and available scientific evidence. As such, they are preliminary and subject to change as more data become available. The scope of these considerations is also focused on the second half of 2022, with an emphasis on the case for booster vaccination and closing the primary vaccination gap in late summer/early autumn, and not for longer term COVID-19 vaccination strategies. National Immunisation Technical Advisory Groups (NITAGs) will ultimately make national decisions on the use of COVID-19 vaccines, taking into account the previous vaccination uptake and the epidemiological situation in their countries.

Target audience

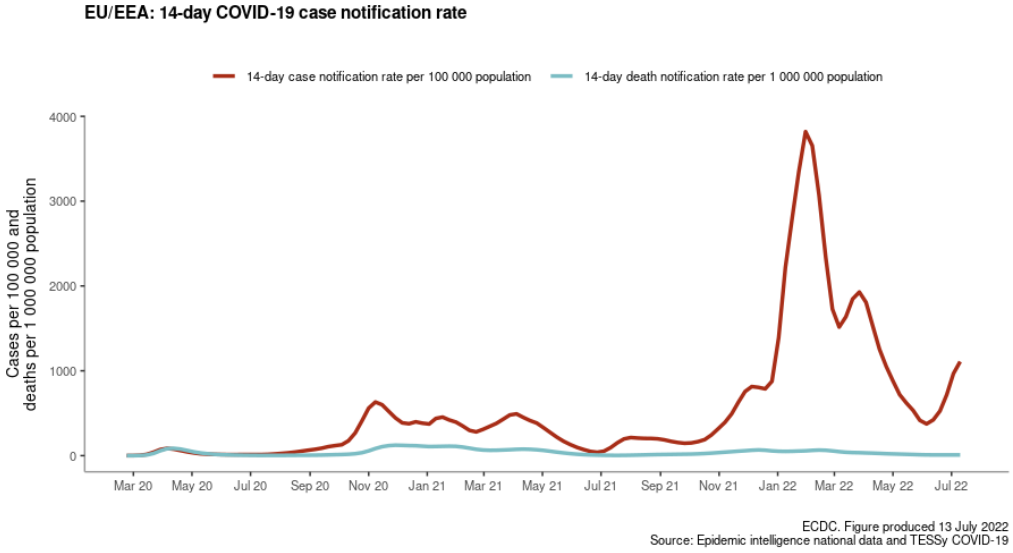
The target audiences for this document are the EU/EEA NITAGs, national public health institutes and ministries of health in the EU/EEA, as well as public health experts and decision-makers at national and subnational level.

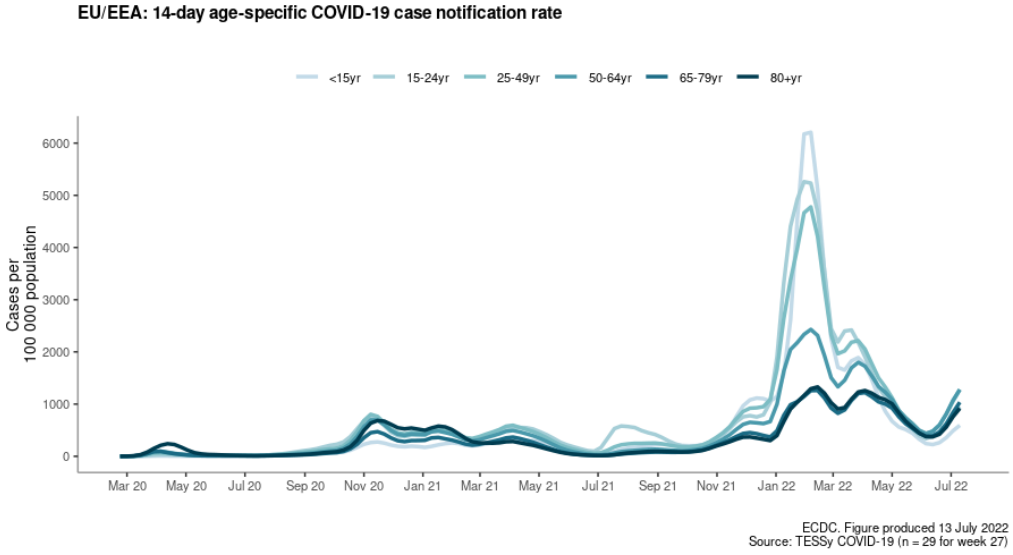
Epidemiological overview based on European surveillance data

COVID-19 case notifications in the EU/EEA

In the post-acute phase of the SARS-CoV-2 pandemic, the introduction and emergence of new SARS-CoV-2 variants with increased transmissibility and/or immune escape capacity, together with waning protection against infection and severe disease from natural or vaccine-induced immunity, can result in new waves of virus transmission and surges of COVID-19 cases [2]. The emergence of Omicron – bearing the most significant profile of SARS-CoV-2 mutations evading existing immunity to-date – in November 2021 resulted in a sharp increase in reported COVID-19 cases in the EU/EEA, reaching a peak in February 2021 (Figure 1, upper panel). The early surge in cases was largely attributable to Omicron sub-lineage BA.1 [3]. The subsequent decline in reported cases observed between February and May 2022 was interrupted by a short period of resurgence between March and April 2022, primarily driven by the replacement of Omicron sub-lineage BA.1 with the more transmissible sub-lineage BA.2, in combination with widespread relaxation of public health response measures [1,4]. Following a sustained period of decline in April and May 2022, the EU/EEA 14-day COVID-19 case notification rate has steadily increased in June 2022, with increases reported across all age groups (Figure 1, lower panel). As of week 27, 2022 (week ending 10 July), the overall case notification rate in the EU/EEA was 1 109 cases per 100 000 population, corresponding to an 11% increase compared to the previous week.

Figure 1. EU/EEA 14-day COVID-19 case notification and death rates (upper panel) and age-specific 14-day case notification rates (lower panel) (up to 10 July 2022)





BA.4 and BA.5 in the EU/EEA

On 13 June 2022, ECDC published an epidemiological update on the implications of the emergence and spread of SARS-CoV-2 variants of concern BA.4 and BA.5 for the EU/EEA [5]. In this update, ECDC reported that whilst most EU/EEA countries had detected low proportions of the SARS-CoV-2 variants BA.4 and BA.5, the estimated growth advantage of BA.4 and BA.5 over other circulating strains would lead to these variants becoming dominant throughout the EU/EEA. BA.4 or BA.5 are the dominant (>50%) circulating SARS-CoV-2 variants in 18 EU/EEA countries (Austria, Belgium, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovenia, Sweden) according to data submitted to GISAID or TESSy up to 03 July 2022 (Table 1) [6,7].

Table 1. EU/EEA SARS-CoV-2 variant proportions as reported to GISAD or TESSy

Country	Weeks of data	Data source	Number of cases	Sequencing volume			Total known variants detected	BA.4/BA.5		BA.2		BA.2+L452X		BA.1		B.1.617.2		Other	
				n	%	Category		n	%	n	%	n	%	n	%	n	%	n	%
Austria	25-26	TESSy	131844	43652	33.1	L1a	43652	34303	78.6	8769	20.1			152	0.3	2	0	426	1
Belgium	25-26	TESSy	68481	2139	3.1	L1b	2139	1748	81.7	251	11.7			1	0			139	6.5
Bulgaria	26	TESSy	3123	88	2.8	L2	88	7	8	81	92								
Croatia		TESSy	9547		0	No data	0												
Cyprus	25	TESSy	24735	78	0.3	L2	78	70	89.7	8	10.3								
Czechia	25-26	GISAID	10133	12	0.1	L2	12	7	58.3	2	16.7	3	25						
Denmark	25-26	TESSy	19375	8514	43.9	L1a	8514	7258	85.2	1255	14.7							1	0
Estonia	25-26	TESSy	2143	521	24.3	L1c	521	195	37.4	319	61.2			2	0.4			5	1
Finland	25	TESSy	10145	4968	49	L1a	4968	4968	100										
France	25-26	TESSy	1210313	7531	0.6	L1a	7531	5687	75.5	1160	15.4	661	8.8	6	0.1			17	0.2
Germany	25-26	TESSy	1188593	10636	0.9	L1a	10636	9210	86.6	1426	13.4								
Greece	25-26	TESSy	178941	351	0.2	L2	351	239	68.1	111	31.6			1	0.3				
Hungary	25	TESSy	3042	137	4.5	L2	137	7	5.1			124	90.5	6	4.4				
Iceland		TESSy	5605		0	No data	0												
Ireland	25-26	TESSy	27171	336	1.2	L2	336	300	89.3	27	8	9	2.7						
Italy	25-26	GISAID	899833	213	0	L2	213	159	74.6	35	16.4	18	8.5	1	0.5				
Latvia	25-26	TESSy	4932	773	15.7	L1c	773	119	15.4	652	84.3					2	0.3		
Liechtenstein		GISAID	287		0	No data	0												
Lithuania		GISAID	3657		0	No data	0												
Luxembourg	25-26	TESSy	12711	495	3.9	L2	495	414	83.6	69	13.9	12	2.4						
Malta		TESSy	7020		0	No data	0												
Netherlands	25	TESSy	32546	719	2.2	L1b	719	604	84	63	8.8	52	7.2						
Norway	25-26	TESSy	20405	1245	6.1	L1b	1245	858	68.9	270	21.7			3	0.2			114	9.2
Poland	25-26	TESSy	5241	63	1.2	L2	63	36	57.1	22	34.9							5	7.9
Portugal	25-26	TESSy	142728	881	0.6	L1c	881	852	96.7	16	1.8	13	1.5						
Romania	25-26	TESSy	11274	232	2.1	L2	232	58	25	153	65.9	2	0.9	2	0.9			17	7.3
Slovakia		TESSy	6224		0	No data	0												
Slovenia	25	TESSy	4194	84	2	L2	84	84	100										
Spain	25-26	TESSy	283991	347	0.1	L2	347	146	42.1	47	13.5			2	0.6			152	43.8
Sweden	25-26	TESSy	7205	1175	16.3	L1b	1175	985	83.8	190	16.2								

Note: BA.4/BA.5 means BA.4 or BA.5 cannot be distinguished from each other, as reported to TESSy by some countries using non-sequencing methods and/or a recoding of S-gene target failure (SGTF) reported to TESSy since week 20, 2022. Level 1a: Variant proportion estimate with sufficient precision at a variant prevalence of 1% or lower. Level 1b: Variant proportion estimate with sufficient precision at a variant prevalence of >1% to 2.5%. Level 1c: Variant proportion estimate with sufficient precision at a variant prevalence of >2.5% to 5%. Level 2: Not able to estimate a variant proportion with sufficient precision at a variant prevalence of 5%.

COVID-19 severity indicators in the EU/EEA

In the context of recent changes to testing practices amongst younger age groups, ECDC currently considers case rates among people aged 65+ years to be the most reliable indicator of changes in disease transmission, and ICU occupancy and ICU admissions the most reliable indicators of severity in the current context. Importantly, lags and delays in reporting, as well as varying and low levels of reporting by different countries affect the quality of these indicators.

In Portugal, the emergence and subsequent dominance of BA.5 has occurred earlier than in other EU/EEA countries. After emerging in early April (week 13, 2022), BA.5 was the dominant (>50%) variant in circulation by mid-May (week 20, 2022). This increase in BA.5 circulation was associated with a surge in COVID-19 incidence, observed across all age groups, that peaked in early June at approximately 25% of the previous peak incidence recorded earlier in the Omicron wave in late January 2022. Whilst there is currently no indication of any significant change in severity for BA.4 or BA.5

compared to previous Omicron sub-lineages [8], increased BA.5 circulation was associated with an observed increase in hospitalisations and ICU admissions in Portugal, peaking in early June at a lower level than was observed in the previous peak earlier in the Omicron wave. BA.5 associated increases in hospitalisations and ICU admissions have primarily been driven by those aged 60 years and over [9]. The BA.4/BA.5 wave has peaked in Portugal, which has reported a sharply decreasing trend in case rates among people aged 65 years and over for the last five weeks.

The emergence of BA.4 and BA.5 in other EU/EEA countries can be expected to result in increases in COVID-19 cases as observed in Portugal in recent months. The extent of the increase will depend on various factors, including immune protection against infection, the timing and coverage of COVID-19 vaccination and the extent, timing and variant landscape of previous SARS-CoV-2 pandemic waves. In line with trends observed in Portugal, as of week 27, 2022 (week ending 10 July), case rates among people aged 65 years and older have increased in 23 of the 27 countries reporting these data to TESSy, corresponding to a 23% increase at the EU/EEA level compared to the previous week, reaching 78.2% of the highest case rates during the pandemic (Table 2). Increasing transmission among older age groups is starting to translate into severe disease. Of 34 countries with data on hospital or ICU admissions/occupancy, 12 (Austria, Belgium, Cyprus, France, Greece, Ireland, Luxembourg, Malta, the Netherlands, Romania, Slovenia and Spain) reported an increasing trend in at least one of these indicators compared with the previous week. Austria, Belgium, France, Greece, Ireland, and Spain reported increases in both hospital and ICU indicators. Compared to maximum values observed during the pandemic, current levels of ICU indicators are much lower (highest 20% in France) than hospital indicators (highest 57% in Greece) (Figure 2).

Table 2. Current trends in epidemiological indicators for EU/EEA; reporting week 27, 2022 (up to 10 July)

Indicator	Previous week	Reporting week	Change compared to previous week (%)	Number of countries with increasing trend	Percentage of pandemic maximum
Tests per 100 000 people	2 036	2 260	11	9	22.1
14-day case notification rate per 100 000	967	1 109	15	24	29
Test positivity (%)	25.1	24.2	-3.5	12	20.9
14-day case rate per 100 000 (65+ years)	816	1 002	23	23	78.2
Hospital admissions per 100 000	8.8	9.4	6.3	4	39
Hospital occupancy per 100 000	12.6	14.6	16	10	32.8
ICU admissions per 100 000	0.6	0.7	17	2	14.6
ICU occupancy per 100 000	0.8	0.9	12	6	15.5
14-day death rate per million	8.5	8.3	-2.2	7	6.8

Figure 2. Summary of epidemiological indicators; reporting week 27, 2022 (up to 10 July)

Summary of epidemiological indicators: current value as of 10 July 2022 and observed trend (▲ or ▼) compared to the previous week

	Tests per 100k	14-day case rate per 100k	Test positivity (%)	14-day case rate per 100k (65+ years)	Hospital admissions per 100k	Hospital occupancy per 100k	ICU admissions per 100k	ICU occupancy per 100k	14-day death rate per million
EU/EEA	2 260 ▲	1 109 ▲	24.2	1 002 ▲	9.4	14.6 ▲	0.7 ▲	0.9 ▲	8.3
Austria	9 729	1 629 ▲	8.5	1 177 ▲		10.4 ▲		0.6 ▲	5.8 ▼
Belgium	1 321	812 ▲	35.1 ▲	731 ▲	8.5 ▲	14.2 ▲		0.7 ▲	10.1 ▲
Bulgaria	423 ▲	115 ▲	16.5 ▲			6.1		0.5	2.9
Croatia	1 037 ▲	339 ▲	18.4	330 ▲					14.1 ▲
Cyprus	13 102 ▲	4 422 ▼	13.1 ▼	3 476 ▼		10.8 ▲		0.1	10.0 ▼
Czechia	279 ▼	117 ▲	20.6 ▲	156 ▲	2.9	2.6	0.2	0.2	1.8
Denmark	1 210 ▲	393 ▲	17.3	500 ▲		5.6		0.2	11.1 ▲
Estonia	491	188 ▲	17.8	209 ▲	5.3 ▼	6.6	0.2	0.2	12.0 ▲
Finland		289 ▼				8.7		0.2 ▼	1.1
France	4 054 ▲	2 445 ▲	33.3	1 671 ▲	12.9 ▲	25.9 ▲	1.2 ▲	1.5 ▲	10.9 ▲
Germany		1 404 ▼		722				1.2	3.3 ▼
Greece	8 556	2 135 ▲	13.5	1 682 ▲	21.5 ▲		0.5 ▲		27.9 ▲
Hungary	172	131 ▲	48.0 ▲	148 ▲					3.5
Iceland	1 191 ▼	1 733 ▲	72.8 ▲	2 191 ▲		10.7 ▼		0.3	70.5
Ireland	786	571 ▲	36.0	508 ▲	20.2 ▲	18.2 ▲	0.5 ▼	0.3 ▲	3.0
Italy	4 082 ▲	1 696 ▲	19.5 ▼	1 595 ▲	6.2 ▼				13.6
Latvia	910	384 ▲	22.4	267 ▲	7.3		0.2	0.2	8.5 ▼
Liechtenstein	1 160 ▲	927 ▲	46.1 ▼	1 099 ▲	5.1				0.0
Lithuania	241	172 ▲	37.6 ▲	152 ▲		3.4			1.4
Luxembourg	2 252	2 275 ▲	50.3	1 416 ▲		4.5 ▲		0.0	0.0 ▼
Malta	1 797 ▼	1 477 ▲	40.6 ▲	1 565 ▲	15.5 ▼			0.8 ▲	36.8
Netherlands	408	459 ▲	59.2	370 ▲	2.8 ▼	4.6 ▲	0.2	0.2	1.5
Norway	215 ▼	172 ▼	17.5 ▼	305 ▼	5.1 ▼		0.2 ▼		25.0 ▲
Poland	86.3	24.6 ▲	18.2 ▲			1.2			1.0
Portugal	1 325 ▼	1 172 ▼	39.2	1 218 ▼	0.0				24.9 ▼
Romania	461 ▲	113 ▲	16.2 ▲	125 ▲		6.1 ▲		0.3	1.7
Slovakia	370 ▼	152 ▲	22.5 ▲	212 ▲		5.5		0.4	1.3
Slovenia	1 548 ▲	698 ▲	26.6 ▲	670 ▲	4.0	4.5 ▲	0.4	0.5	6.6
Spain	675 ▼	606	40.5 ▲	1 365 ▲	11.3 ▼	25.0 ▲	0.4 ▼	1.1 ▲	14.2 ▼
Sweden	182	80.5 ▲	22.5	117 ▲				0.3	1.5

Level of current value, coloured by class breaks defined per indicator:
- 14-day case notification rate per 100k: <40, 40-<100, 100-<300, 300 or higher
- Test positivity (%): <2%, 2-<4%, 4-<10%, 10% or higher
- 14-day case rate per 100k (65+ years): <20, 20-<50, 50-<150, 150 or higher
- Hospital or ICU admissions per 100k (as % of historical country peak rate): <10%, 10-<25%, 25-<50%, 50% or higher
- Hospital or ICU occupancy per 100k (as % of historical country peak rate): <25%, 25-<50%, 50-<75%, 75% or higher
- 14-day death rate per million: <20, 20-<40, 40-<100, 100 or higher

1 (lowest) 2 3 4 (highest) Not applicable

Age-specific notification rate of hospitalised COVID-19 cases

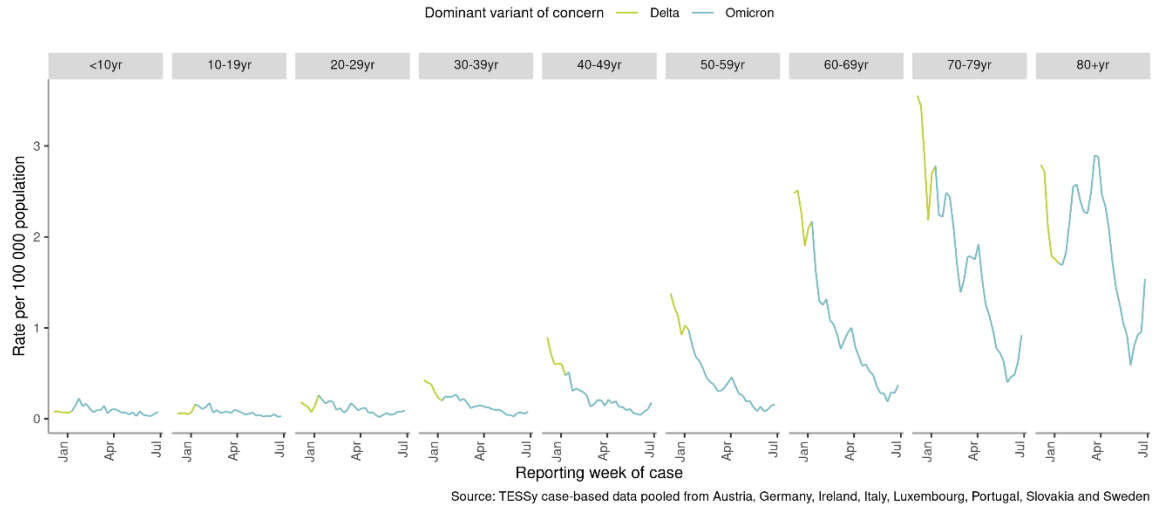
Pooled analysis of case-based data reported to TESSy by eight EU/EEA countries with sufficient data completeness from week 48, 2021, to week 25, 2022, show that after the decrease observed in rates of severely ill cases in hospital (requiring admission to ICU and/or ventilation and/or extracorporeal membrane oxygenation) since Jan-Feb 2022, an increase in trend is seen in recent weeks. This effect is more substantial among those aged 60 years and above (Figure 3a).

The same trend is observed looking at the notified cases requiring hospitalisation, based on pooled data from eight countries (Figure 3b). The interpretation of this is made difficult by the considerable uncertainty concerning the proportion of cases hospitalised due to or with COVID-19. It is not normally possible to make this distinction in routine surveillance data submitted to TESSy.

Since completeness of vaccination status reported to TESSy is limited for this pool of countries, we are unable to attribute the observed increases to individuals with a particular level of vaccination.

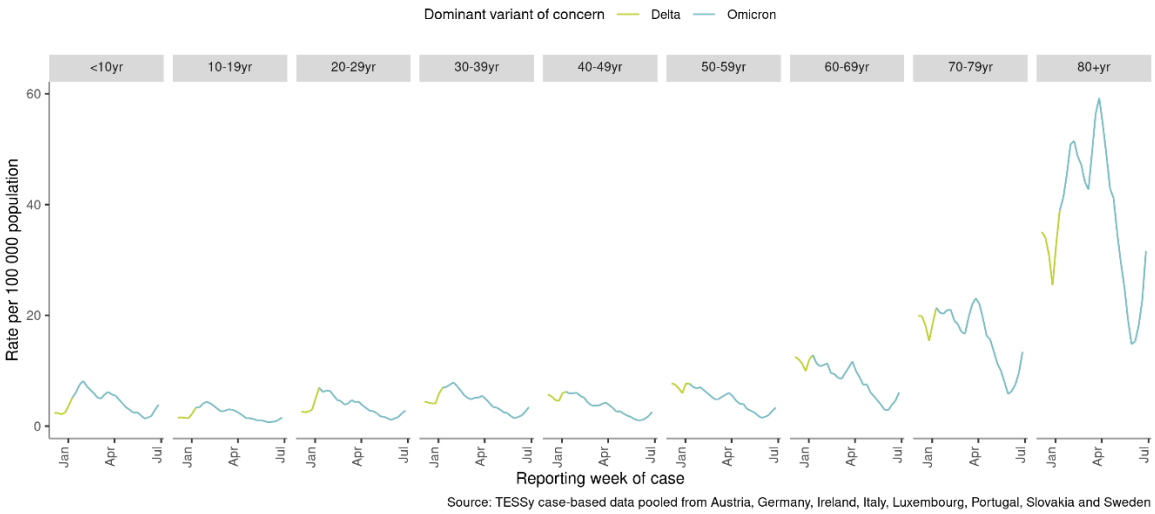
Figures 3a and 3b. Age-specific notification rate of cases admitted to ICU and/or requiring ventilation and/or extracorporeal membrane oxygenation (3a) and age-specific notification rate of hospitalised cases (3b), week 48, 2021 to week 25, 2022

Age-specific notification rate of cases admitted to ICU and/or requiring ventilation and/or extracorporeal membrane oxygenation, week 48, 2021 to week 25, 2022



Source: TESSy case-based data pooled from Austria, Germany, Ireland, Italy, Luxembourg, Portugal, Slovakia and Sweden

Age-specific notification rate of hospitalised cases, week 48, 2021 to week 25, 2022



Source: TESSy case-based data pooled from Austria, Germany, Ireland, Italy, Luxembourg, Portugal, Slovakia and Sweden

Risk of hospitalisation and death post-first COVID-19 booster dose

For this analysis, cases were considered for all adult individuals aged 18 years and older with laboratory-confirmed symptomatic SARS-CoV-2, as reported to TESSy by EU/EEA countries from 1 December 2021 to 29 May 2022 for hospitalisation and from 1 December 2021 to 19 June 2022 for case fatality, with disease onset at least two weeks after receiving their first booster dose. Individuals were then divided into groups who had received their first booster less than or more than three months prior to the COVID-19 onset data. Unknown hospitalisation status and unknown deaths were recoded as 'No'. We believe that a very small proportion of unknown could be categorized as 'Yes', and misclassified observations are very likely to be equally distributed among the groups under comparison. The proportion of hospitalisation and deaths could therefore be slightly underestimated. The risk of hospitalisation and death was compared between groups defined by sex, age (18–59, 60–79, 80+ years) and time from booster dose (less than or 3+ months), adjusted by onset month.

Negative binomial models were run to calculate the Relative Risks (RR) and the 95% Confidence Interval (95% CI) of hospitalisation and death.

Table 3. Main characteristics of COVID-19 cases who had a disease onset at least two weeks after receiving their first COVID-19 vaccine booster dose, by hospitalisation status, 1 December 2021–29 May 2022 (N=398 414)

	Total		Not hospitalised		Hospitalised	
Characteristic	Number of cases	Proportion of cases (%)	Number of cases	Proportion of cases (%)	Number of cases	Proportion of cases (%)
	398 414	100	396 101	99.4	2 313	0.6
Booster vaccination						
Booster dose <3 months	288 648	72.5	287 231	99.5	1 417	0.5
Booster dose >=3 months	109 766	27.5	108 870	99.2	896	0.8
Sex						
Female	223 786	56.2	222 748	99.5	1 038	0.5
Male	174 534	43.8	173 259	99.3	1 275	0.7
Age at diagnosis (years)						
18-59	238 870	60.0	238 471	99.8	399	0.2
60-79	132 900	33.4	131 648	99.1	1 252	0.9
80+	26 644	6.7	25 982	97.5	662	2.5
Onset month						
December 2021	8 257	2.1	8 064	97.7	193	2.3
January 2022	107 960	27.1	107 425	99.5	535	0.5
February 2022	137 739	34.6	137 004	99.5	735	0.5
March 2022	115 771	29.1	115 084	99.4	687	0.6
April 2022	23 714	5.9	23 589	99.5	125	0.5
May 2022	4 973	1.2	4 935	99.2	38	0.8

Cases are from Estonia (735), France (4), Ireland (49), Luxembourg (46 863), Malta (2 996), Norway (877) Poland (346 873), Romania (17).

The main results for hospitalisation data are presented in Table 3. Of 398 414 individuals who acquired COVID-19 between 1 December 2021 and 29 May 2022 at least two weeks after receiving a first COVID-19 booster dose, 0.6% required hospitalisation. This proportion was higher for the individuals who, at the time of onset, had received their booster dose more than three months before their diagnosis of COVID-19 (0.8%), compared to those who had received their booster dose less than three months before (0.5%). The proportion was also higher for males (0.7%) than females (0.5%), and by age group, but remains quite stable in 2022, with the exception of an increase in May.

Table 4. Main characteristics of COVID-19 cases who had disease onset at least two weeks after receiving their first COVID-19 vaccine booster dose, by case fatality, 1 December 2021−19 June 2022 (N= 321 664)

	Total		Survived		Died	
Characteristic	Number of cases	Proportion of cases (%)	Number of cases	Proportion of cases (%)	Number of cases	Proportion of cases (%)
	321 664	100	321 327	99.90	337	0.10
Booster vaccination						
Booster dose <3 months	244 783	76.1	244 649	99.95	134	0.05
Booster dose >=3 months	76 881	23.9	76 678	99.74	203	0.26
Sex						
Female	179 529	55.8	179 368	99.9	161	0.09
Male	142 065	44.2	141 889	99.88	176	0.12
Age at diagnosis (years)						
18-59	190 578	59.3	190 571	100.0	7	0.00
60-79	109 112	33.9	109,023	99.92	89	0.08
80+	21 974	6.8	21,733	98.90	241	1.10
Onset month						
December 2021	4 860	1.5	4 836	99.51	24	0.49
January 2022	40 726	12.7	40 653	99.82	73	0.18
February 2022	97 151	30.2	97 076	99.92	75	0.08
March 2022	134 727	41.9	134 614	99.92	113	0.08
April 2022	30 929	9.6	30 886	99.86	43	0.14
May 2022	8 179	2.5	8 171	99.90	8	0.10
June 2022	5 092	1.6	5 091	99.98	1	0.02

Cases are from Estonia (735), France (4), Ireland (49), Luxembourg (46 863), Malta (2 996), the Netherlands (271 000), Romania (17).

The main results for case fatality data are presented in Table 4. Of 321 664 individuals who acquired COVID-19 between 1 December 2021 and 19 June 2022 at least two weeks after receiving a first COVID-19 booster dose, 0.10% died. This proportion was higher for individuals who, at the time of onset, had received their booster dose more than three months before (0.26%), compared to those who had received their booster dose less than three months before (0.05%). The proportion was also higher for males (0.12%) than females (0.09%) and increased by age group while there was no clear trend over time by month of onset in 2022.

Table 5. Adjusted relative risk of hospitalisation and death by time from booster vaccination, sex, age group ***

	Adjusted relative risk of hospitalisation (95% CI) [&]	Adjusted relative risk of death (95% CI) [$]
Booster vaccination		
Booster dose <3 months	Ref	Ref
Booster dose >=3 months	1.17 (1.04-1.32) *	4.81 (3.64-6.36) *
Sex		
Female	Ref	Ref
Male	1.49 (1.37-1.62) **	1.39 (1.12-1.73) **
Age at diagnosis (years)		
18-59	Ref	Ref
60 to 79	5.32 (4.75-5.97) **	20.80 (9.61-45.01) **
80	13.71 (12.02-15.64) **	204.31 (95.60-436.64) **

** P-value<0.01 ** P-value<0.001 *** Further adjusted by onset month.*
[&] Cases are from Estonia (735), France (4), Ireland (49), Luxembourg (46 863), Malta (2 996), Norway (877) Poland (346 873), Romania (17).
$ Cases are from Estonia (735), France (4), Ireland (49), Luxembourg (46 863), Malta (2 996), the Netherlands (271 000), Romania (17).

The main results for the Relative Risks (RR) and the 95% Confidence Interval (95% CI) of hospitalisation and death are shown in Table 5: the adjusted risk of hospitalisation increases by 17% for those having received a booster dose three months or more before diagnosis of COVID-19, compared to less than three months before. A significant increase in the adjusted risk of hospitalisation is seen also among men compared to women (RR=1.49, 95% CI: 1.37−1.62) and among older age groups. Regarding the adjusted risk of death, those who received the booster dose three months or more before their diagnosis of COVID-19 have a 4.8-fold increase in the risk of dying after COVID-19 onset compared to those who received it less than three months before. A significant increase in the adjusted risk of death is also seen for men (RR=1.39, 95% CI: 1.12−1.73) and older adults.

Update of data on vaccine effectiveness and duration of protection following booster doses against the Omicron variant

The recently published ECDC technical report on the second mRNA COVID-19 vaccine booster dose, published on 28 April 2022, included a review of the available scientific evidence on vaccine effectiveness against the Omicron variants BA.1 and BA.2 [1]. The updated overview of COVID-19 vaccine effectiveness (VE) in this section of the report is largely based on an ongoing systematic review of COVID-19 vaccine effectiveness studies conducted by the International Vaccine Access Center, John Hopkins Bloomberg School of Public Health and the World Health Organization (WHO) [10], with the latest update provided on 23 June 2022, and also through regular monitoring of published and preprint literature up to 4 July 2022.

Since the previous document, additional studies have been published that are included in the summaries below [11-19].

Vaccine effectiveness against infection over time with the Omicron variant

Studies have found that VE against infection with the Delta and Omicron variant wanes over time, starting from around two to three months after completing the primary series [1]. Similarly, the effectiveness against documented infection wanes after administration of a first mRNA vaccine booster dose, from estimates within the range of 45−66% in the first 0 to three months, to around 25−45% between three to six months after the booster dose [20-26]. Estimates for symptomatic infection (as compared to documented infection that also includes asymptomatic infection) are in a slightly higher range, but direct comparisons between studies should be avoided due to different study designs, study population, settings, etc [27-30]. The majority of these studies were conducted during the period where the Delta or Omicron subvariants BA.1 and BA.2 were dominant.

Vaccine effectiveness against transmission with the Omicron variant

Studies conducted in the UK investigating VE against transmission of Omicron and Delta variants in household and non-household settings have found that transmission is less likely from cases receiving a booster dose compared to those receiving only primary vaccination [31,32], but that the protective effect is less pronounced for Omicron compared to Delta [31]. In summary, the studies suggest that booster doses in general have a modest effect and limited duration in preventing Omicron transmission in the population [31-33].

Vaccine effectiveness against severe disease due to the Omicron variant by time since first booster

Several studies conducted during the period when the Omicron subvariants BA.1 and BA.2 were dominant have estimated vaccine effectiveness against severe disease or hospitalisation at sequential time points after the administration of a first booster dose (third dose) [1]. In summary, these studies suggest that vaccine effectiveness against severe outcomes is high following the administration of a booster dose, with estimates of around 77−94% protection for up to two to three months after receiving it [12,16,19,28,29,34-38]. Studies with a follow-up period of three to six months after the first booster dose are heterogenous, but generally show a gradual decrease in effectiveness against severe COVID-19 outcomes (VE estimates in the range of 53-100%) [34,35].

Few studies with a follow-up time longer than six months are available, but a nationwide cohort study from Slovenia estimated the unadjusted vaccine effectiveness against severe acute respiratory infection (SARI) COVID-19 to be 96% (95% CI 90-99%) in 65-year-olds and above at six months or more after administration of a first booster dose [17]. The corresponding effectiveness in younger age groups (18–49 and 50–64-year-olds) was estimated to be 100% at the same follow-up time, but the number of cases were small in these groups and no confidence interval could be calculated. In addition, a preprint study from Israel estimated the relative effectiveness of a first booster dose of Comirnaty to be 68% for hospitalisation and death at six to seven months after the administration of the booster, but this was in comparison to primary vaccination [11].

The available studies indicate that a first booster dose provides strong protection against severe disease in all the investigated age groups, and there are no clear signs of a more rapid waning in elderly groups. In a nationwide study from Finland, the effectiveness against hospitalisation among 70 years old and above was estimated to be 90% (95% CI 87-93%) at 61 or more days after a first booster dose [12], and studies of age groups above 60 or 65 years old have provided estimates in the range 67-96% at three months or more after the first booster [11,15,16,29,37]. Nationwide data from UK reported higher vaccine effectiveness against hospitalisations for 65 years and older (peak estimate of

92.4% and dropping to 76.9% at 15 or more weeks) compared to 18-64 year olds (82.4% and dropping to 53.6%) after administration of a first booster dose, but the observed discrepancy may be explained by younger age groups being more likely to be hospitalised with COVID-19 as an incidental finding [25]. Similarly, a nationwide study from Denmark reported slightly higher estimates in 60 years or older (94%, 95% CI 93-96%, dropping to 77%, 95% CI 71-82%, at 4+ months) compared to 12-59 year olds (90%, 95% CI 88-91, dropping to 33%, 95% CI 1-55%) after administration of a booster dose [15]. The nationwide cohort study from Slovenia also reports similar or higher VE for 65-year-olds and above compared to younger age groups, although the number of cases are relatively few in the younger age groups [17].

These results are in agreement with summarised evidence on VE after primary vaccination suggesting that the waning of protection proceeds more rapidly in older age groups with regards to documented or symptomatic infection, but rates of waning appear to be more consistent, and not as rapid, across age groups for severe disease [39].

Vaccine efficacy and effectiveness of a second booster dose against infection and severe disease

Data on the efficacy and effectiveness of a second mRNA vaccine booster (fourth dose) are still scarce at this point, with little evidence on duration of protection due to short follow-up times of the available studies. In addition, most of the estimates provided so far are mainly calculated as a relative benefit compared to a third dose given three or four months earlier, rather than against those who are unvaccinated. The Canadian study by Grewal et al shows that vaccine effectiveness against infection and severe outcomes ≥7 days after administration of a second booster dose was higher by around 20-40 percentage points when using the unvaccinated as reference group instead of those given a first booster dose [16].

From the evidence available so far, a second booster seems to restore the humoral immune response to levels similar to those shortly after the first booster dose as seen in an open-label non-randomised clinical study from Israel [40].

A second booster improves VE against infection, but this seems to wane rapidly as seen within the short follow-up period available so far after the second booster dose. Studies on vaccine effectiveness against Omicron infection after the second booster dose are heterogenous with regards to study design and follow-up time after the last dose, with estimates ranging from 18 to 81%, comparing those that received a second booster dose with those that only received the first booster dose [16,41-46]. A study from Israel that estimated the effectiveness at sequential time points reports a peak of 64% shortly after receiving the second booster dose, declining to 30% at 10 weeks post second booster dose [43]. VE against severe disease remains high (in the range of 62-77% depending on the specific outcome and study) during the short follow-up period covered in the studies available so far, and seemingly restore the slightly reduced protection seen four months after the first booster dose [16,41,43,44,46,47]. A recent preprint from Israel found that in addition to a maintained high effectiveness of a first booster dose in preventing severe disease (during a seven month follow-up), a second booster dose provides additional protection (assessed during Omicron BA.1 and BA.2 sublineage dominance) [11]. To summarise, the benefit of a second booster dose against infection appears short-lived and limited. The protection of a first booster dose against severe outcomes wanes gradually with time, and a second booster dose seemingly restores the protection against severe disease, hospitalization and deaths.

Effect of vaccination and previous infection on Omicron sub-lineages

It is not fully understood to what extent the different sub-lineages of Omicron influence vaccine effectiveness. A case control study from the southern part of Sweden reported on a rapid decline in vaccine effectiveness against severe COVID-19 that coincided with the transition from Omicron BA.1 to BA.2 dominance in the region [48]. The decline was observed among persons who had received two vaccine doses only, while the effectiveness from the first booster (three doses) remained stable. Other studies from Qatar and the UK have reported similar vaccine effectiveness estimates for the sub-lineages BA.1 and BA.2 in relation to symptomatic infection [28,49], and hospitalisation or death [21].

At present, there are only limited data available on vaccine effectiveness against different clinical outcomes for Omicron sub-lineages BA.4 and BA.5. There is preliminary analysis provided by the UK Health Security Agency that indicate that the vaccination status of cases infected with BA.4 and BA.5 is not significantly different to that of cases infected with BA.2 (adjusted odd ratio- aOR 1.13; 95% CI 0.88-1.44 and aOR 0.83; 95% CI 0.88-1.44, respectively). The authors observe that these early data do not indicate a difference in vaccine effectiveness against BA.4 or BA.5 as compared to BA.2 at this stage, however a test-negative case control vaccine effectiveness study will be carried out when data are available [8]. A study from South Africa that investigated clinical outcomes of Omicron BA.4/BA.5 infections reported that strong protection against severe COVID-19 conferred by prior infection and vaccination was retained in the BA.4/BA.5 wave, with three homologous doses of Janssen or Comirnaty or a heterologous combination of these providing 83% protection (95% CI 60 to 93%) against severe COVID-19 hospitalisation or death [50]. In addition, a preliminary analysis from Portugal comparing reinfections and vaccination breakthrough infections in BA.2 and BA.5 cases have suggested that BA.5 has higher immune evasion from previous infections, and that the vaccine effectiveness against infection with BA.5 is reduced compared to infection with BA.2 (preliminary information from unpublished study).

Some recent studies have investigated previous infection, vaccination and protective effect focusing on the Omicron subvariant BA.4 and BA.5. A recent pre-print from Qatar found that the protection conferred by a previous infection

against BA.4/BA.5 infection was modest when the previous infection involved a pre-Omicron variant, but strong when the previous infection involved the Omicron BA.1 or BA.2 subvariant. Importantly, the protection from previous infection was lower against BA.4/BA.5 than against BA.1/BA.2, consistent with BA.4/BA.5's greater capacity for immune-system evasion. Sensitivity analyses, adjusting for vaccination status in conditional logistic regression, showed similar results [51]. As described above, the recent pre-print study from South Africa found that disease severity was similar amongst confirmed COVID-19 cases in the BA.4/BA.5 and BA.1 periods in the context of growing immunity against SARS-CoV-2, due to prior infection and vaccination, both of which were strongly protective. Prior confirmed infection was strongly protective against severe hospitalisation or death (aHR 0.29; 95% CI 0.24; 0.36) as was vaccination with aHR (95% CI) of 0.17 (0.07; 0.40); 0.37 (0.33; 0.42) and 0.26 (0.21; 0.32) for 'first booster dose', 'two doses' and 'single dose', respectively. Strong protection against severe COVID-19 conferred by prior infection and vaccination was retained in the BA.4/BA.5 wave [50].

Evidence on the protective effect of hybrid immunity

Decision-making around the need for, and timing of additional vaccine doses requires careful consideration of the level of immunity against SARS-CoV-2 in those populations targeted for vaccination. Population immunity can be broadly estimated by measuring both vaccination coverage and the proportion of the population that has experienced prior infection. Due to the recent exposure of large numbers of the population to the Omicron BA.1 and BA.2 variants, hybrid immunity—developed via a combination of full primary course vaccination and at least one prior infection—is likely to play an increasingly important role in protection at population level [52-54]. Hybrid immunity results in the improved induction of site-specific, mucosal IgA (binds to virus/virus expressing host cells) and tissue-resident CD4 and CD8 T cells (lyse infected host cells), which are not induced by injectable vaccines, and which may not be effectively induced by mild natural infections [55]. In the context of Omicron, hybrid immunity has been shown to confer better protection against both SARS-CoV-2 infection and severe outcomes (hospitalisation and death) when compared to vaccine-induced or infection-induced immunity alone [18,19,21,24,53,54]. Evidence to-date also indicates that variant-specific protection against infection and severe disease conferred by hybrid immune responses wane more slowly than protection conferred by vaccine-induced or infection-induced immunity alone [18,54].

As yet, no absolute serum antibody titre threshold has been established as a correlate of protection against SARS-CoV-2 infection, and immune correlates have not been established for protection against severe disease [56,57]. However, serum neutralising antibody titres are well-established predictors of protection against SARS-CoV-2 infection [57]. Nationally representative, age-stratified sero-epidemiological studies provide a basis for estimating the proportion of the population with SARS-CoV-2-specific antibodies in a given country. These, in turn, provide a basis for estimating projected disease burden and evaluating the potential benefit of additional booster doses during periods of increased viral circulation. Such studies are particularly informative when they use quantitative assays to determine the level of both natural and vaccine-induced antibodies in participating individuals to estimate the contribution of natural, vaccine-derived and hybrid immunity in the population [58,59]. Given that serum antibodies wane over time [60], longitudinal or repeated studies with the same sampling strategy and common testing methodology are essential for understanding temporal trends and risks, as is continued vigilance for the immune escape capabilities of newly emerging variants.

Population serosurveys estimating the proportion of the population experiencing prior infection before, during and after the emergence of Omicron, show that despite observed increases in all age groups, older age groups appear less likely to be exposed to or experience Omicron infections. In contrast to younger adults, persons 60 years of age or older face the highest rates of hospitalisation and death, whilst having the lowest rates of combined infection and vaccination [58,61]. These age-specfic trends caution against the assumption that hybrid immunity is developed uniformly across the population.

Evidence from studies looking at the combined effect of naturally-acquired immunity and vaccine-induced immunity clearly point to an extra layer of protection for those with hybrid immunity. However, the scale of natural-acquired immunity in populations is difficult to quantify due to issues such as the under-ascertainment of COVID-19 cases and reinfections, the lack of unbiased, longitudinal seroprevalence data, and the waning profiles of protection. In addition, few vaccine effectiveness studies disaggregate results by prior infection status. For those that do, direct comparison between studies is challenging, owing to heterogeneity (type of study, study population, type of vaccine, follow-up time, sequence of infection/vaccination).

Current recommendations on a second booster dose in the EU/EEA

There are currently 20 EU/EEA countries recommending a second booster dose in immunocompetent individuals (Austria, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Sweden). The second booster dose is under discussion in three countries (Latvia, Lithuania, Spain). Twenty countries recommend a second booster for those in the 60+ to 80+ years age group; 11 counties for long-term care facilities residents and four countries for healthcare workers or personnel working in LTCFs. Other population groups are also included in some countries (home care; chronic diseases or underlying conditions; Down syndrome; vaccinated with Jcovden – previously COVID-19 vaccine Janssen). The time interval after the first booster dose differs among countries from an earliest time of three months up to five months (six months for healthcare workers) (see Table A1 in Annex 2 for more details on country recommendations for booster doses).

Uptake of primary vaccination, first and second booster doses in the EU/EEA

As of 10 July 2022, the uptake of the primary vaccination course against COVID-19 in the total EU/EEA population had reached 72.8% (range: 29.8 – 86.4%) and is levelling off with very limited progression over the last month. The uptake of the first booster dose[1] has reached 63.8% (range: 11.2 – 85.9%) among adults aged 18 years and above and is increasing very slowly (average 0.1% weekly increase in the last month). The uptake of the first booster dose is still showing some increase among younger adults aged 18−24 years (average 0.2% of weekly increase in the last month) (Figure 4). Among individuals above 60 years of age, the median uptake of the primary course and first booster dose has reached 90.8% (range: 38.3-100%) and 83.1% (range: 13.5 – 97.5%) respectively (Figure 5). Overall, the progress in vaccine uptake remains uneven across EU/EEA countries (Figure 6). [3].

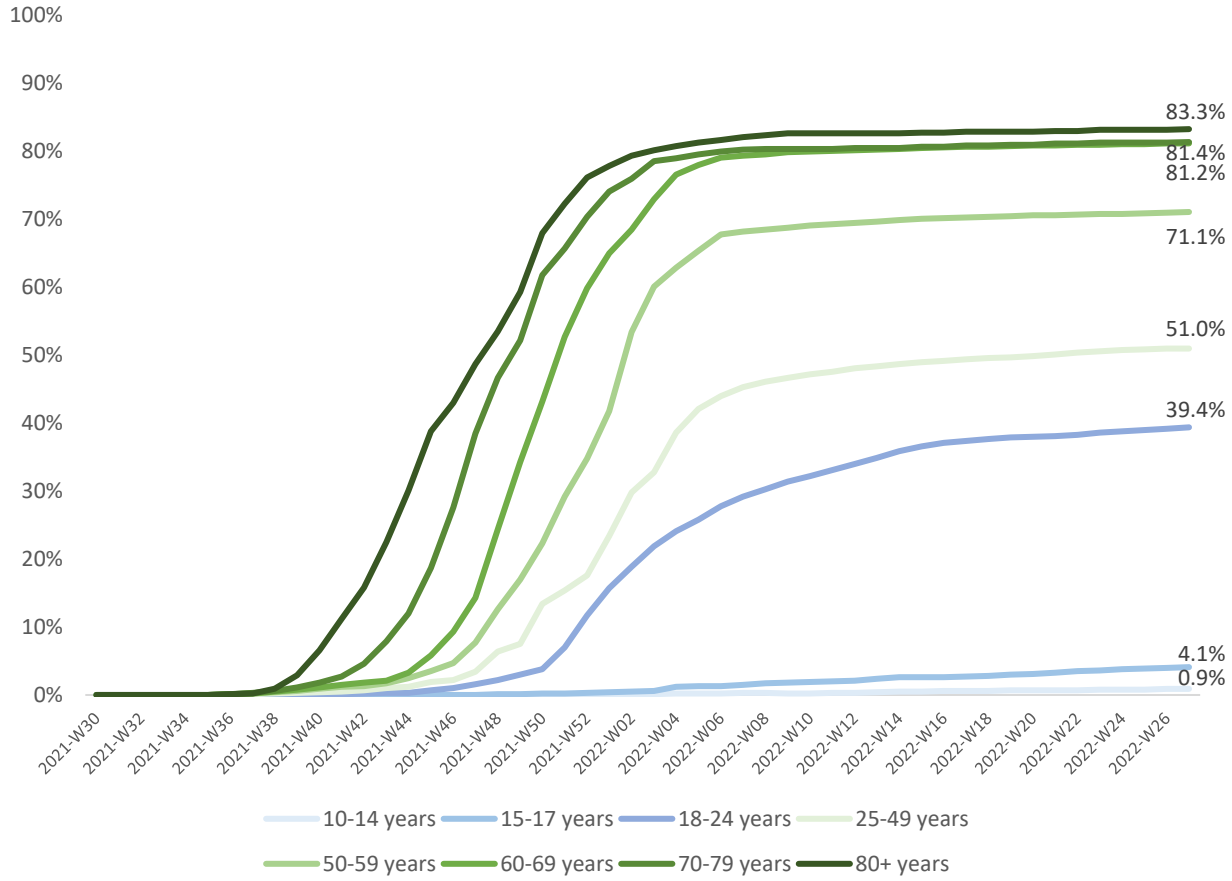
Based on preliminary data reported to TESSy by 19 EU/EEA countries, ~16.5 million second booster doses[2] have been administered to adults 18+ years of age and 88% of them have been administered to those 60+ years of age. The cumulative uptake of the second booster dose among reporting countries is 4.5% in 18+ years olds (range: <0.1-19.8%), 11.6% in those 60+ years old (range: <0.1-59.5%) and 20% in those 80+ years old (range: 0.1-80.1%) [62]. The uptake among 60+ is still low in most countries (only four countries exceeded 25% of 60+ as of week 27: 59.5% in Sweden; 48.8% in the Netherlands; 40.9% in Ireland and 35% in Malta).

Table 6 summarises the uptake of the primary course, first and second booster dose by selected age group as of 10 July 2022. More information on COVID-19 vaccine doses administered and vaccine uptake rates can be found in the ECDC Vaccine Tracker.

[1] For surveillance purposes, this refers to the first additional dose of COVID-19 vaccine administered after the standard primary course. Therefore, the count and uptake estimates may include both first booster doses administered to immunocompetent persons and additional primary course doses administered to immunocompromised individuals.

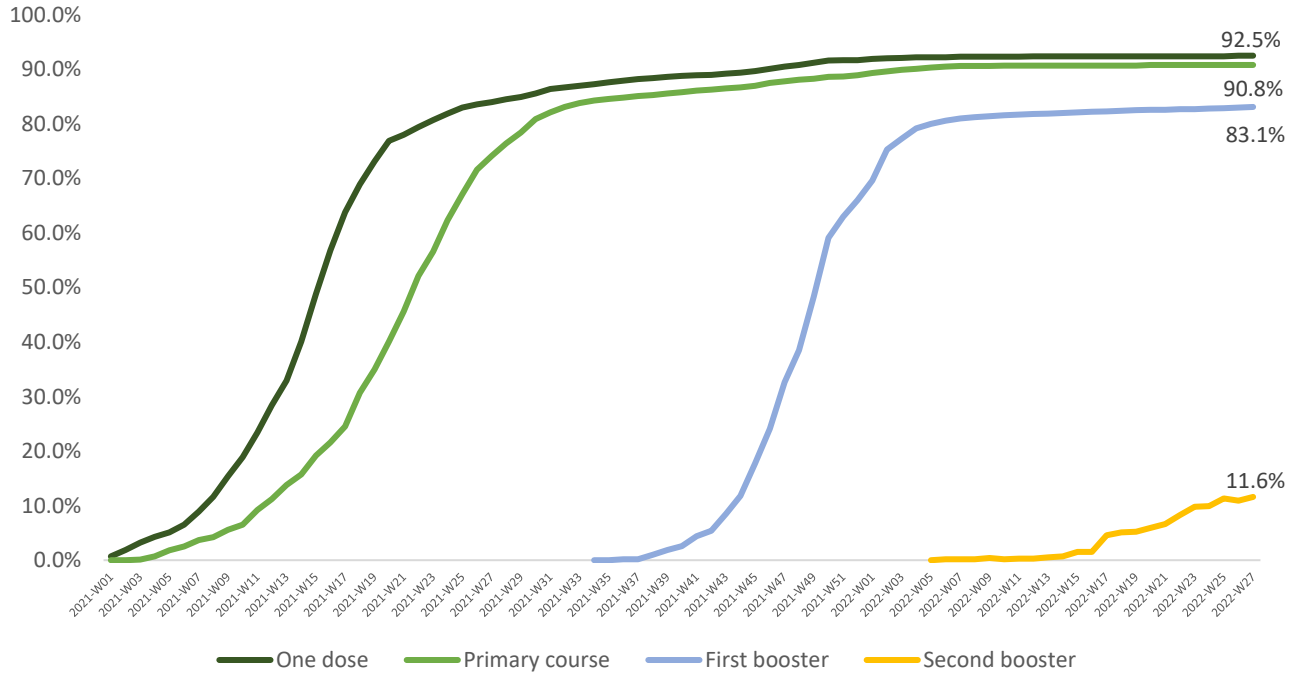
[2] For surveillance purposes, this refers to the second additional dose of COVID-19 vaccine administered after the standard primary course. Therefore, the count and uptake estimates may include both second booster doses administered to immunocompetent persons and second additional doses administered to immunocompromised individuals after a standard primary course.

Figure 4. Median cumulative uptake of first booster dose of COVID-19 vaccine by age group in the EU/EEA (as 10 July 2022)



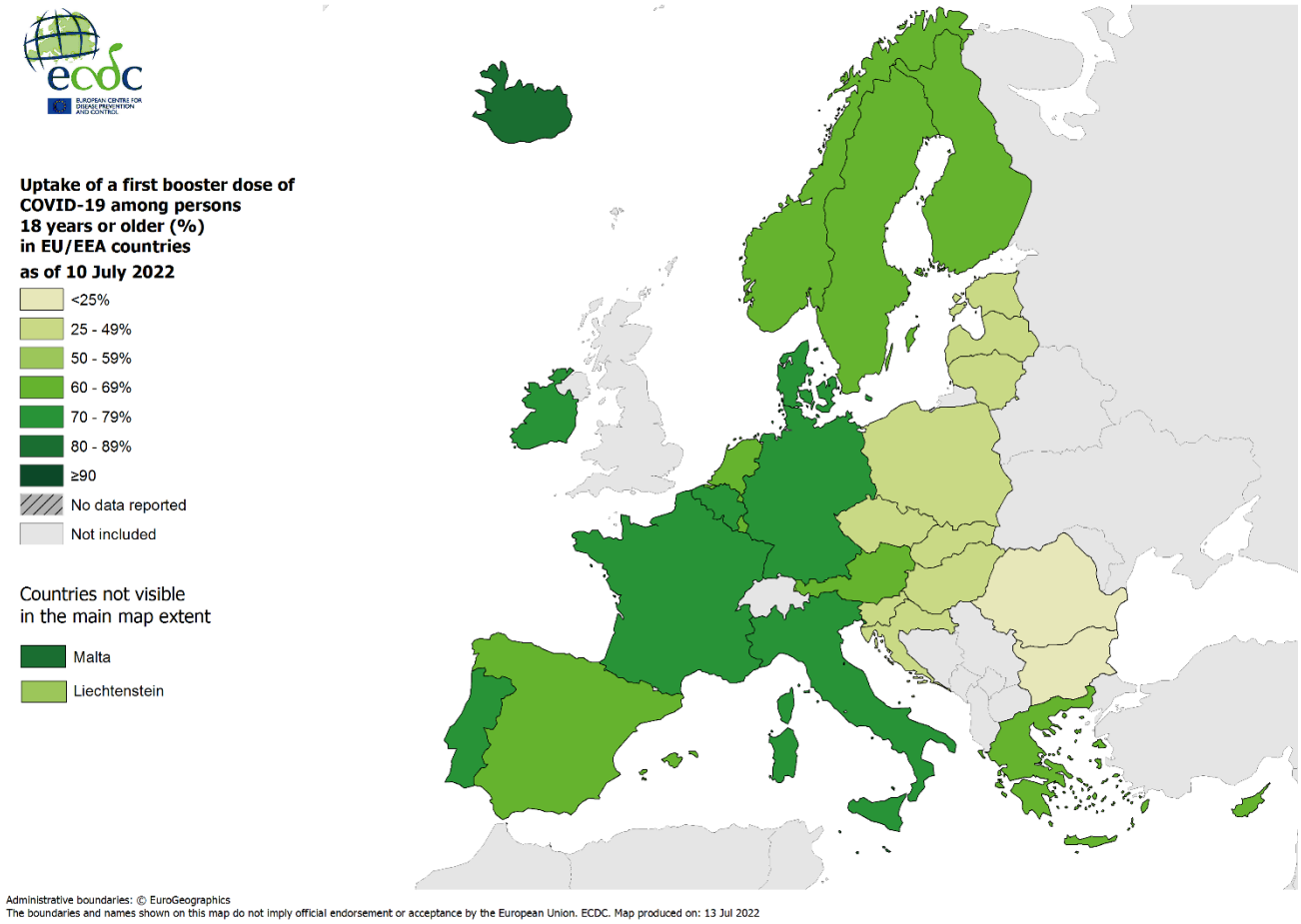
Source: TESSy data reported by 30 countries.

Figure 5. Median cumulative uptake of one dose, primary course first and second booster of COVID-19 vaccine among 60+ in the EU/EEA (as of 10 July 2022)



Source: Cumulative uptake of the primary vaccination course based on the dosing schedule authorised in the EU/EEA. Numbers of countries reporting to TESSy: 30 for uptake primary course and first booster, 21 for second booster.

Figure 6. Uptake of first booster dose of COVID-19 vaccine among adults aged 18 years and above in EU/EEA countries (as of 10 July 2022)



Source: TESSy data reported by 30 countries.

Table 6. Summary table of COVID-19 vaccine uptake (as of 10 July 2022)

Population group	Uptake of primary course (range)	Uptake of the first booster dose (range)	Uptake of the second booster dose (range)
Total population	72.8% (29.8-86.4%)	52.9% (9.1-69.1%)	3.7% (<0.1-15.6%)
Adults (18+)	83.6% (35.6-94.5%)	63.8% (11.2-85.9%)	4.5% (<0.1-19.8%)
Persons aged 60+*	90.8% (38.3-100%)	83.1% (13.5-97.5%)	11.6% (<0.1-59.5%)
Persons aged 80+*	94.1% (26.2-100%)	83.3% (8.0-100%)	20% (0.1-80.1%)

Note: cumulative uptake of the primary vaccination course based on the dosing schedule authorised in the EU/EEA. Numbers of countries reporting: 30 for uptake primary course and first booster in total population and 18+, 21 for second booster; 30 for uptake primary course and first booster in 60+, 21 for second booster; 29 for uptake primary course and first booster in 80+ (missing Germany), 21 for second booster.

**Median uptake among reporting countries.*

Plans for autumn/winter vaccination campaigns in EU/EEA countries

Several EU/EEA countries are currently discussing their future COVID-19 vaccination strategies and the need for additional booster doses before the autumn/winter period when another wave may arrive. The planning of future vaccination strategies and campaigns for the autumn is based on each country's epidemiological situation, the effectiveness of previously administered vaccinations, the potential availability of new, updated and more effective vaccines, and the identification of risk groups. A few EU/EEA countries have already published recommendations for their autumn/winter vaccination campaigns:

- The Belgian Superior Health Council has published recommendations that all risk groups should be vaccinated with an additional booster by the end of September 2022 at the latest and that the campaign should be 'as compact as possible' to maximise the benefits of vaccinating against COVID-19 (the interval should be at least three months, but preferably six months for the administration of an additional booster dose). For the autumn/winter season 2022-2023 a proactive mass vaccination campaign will target adults 65 years of age and older, any patient with immune suppression due to disease or treatment, any patient with at least one comorbidity, all pregnant women, all 'persons active in the care sector' in and outside care institutions, and people living in the same household as people at high risk of severe disease [63].
- The Danish Health Authority has provided preliminary recommendations for an autumn vaccination campaign starting from 15 September for residents in LTCF and other vulnerable elderly people. From the 1 October, all individuals over 50 years of age and those who are severely immunocompromised (regardless of age) will be offered vaccination. Final recommendations are expected in August [64].
- The French Haute Autorité de Santé (HAS) has published recommendations to anticipate the organisation of a vaccination booster campaign for autumn 2022 for the population groups most at risk of severe forms of the disease (immunocompromised, people 65+ years old and/or with comorbidities), with consideration of vaccination of healthcare professionals. The vaccination campaign against COVID-19 will be combined with the one for influenza. In addition, as soon as updated vaccines obtain their marketing authorisation, HAS will assess them, specify their inclusion in the vaccine strategy and indicate, where applicable, the preferred type of vaccine to be used for each population according to their characteristics [36].
- The Portuguese Directorate-General of Health published interin recommendations for the next autumn-winter 2022-2023 COVID-19 vaccination strategy. It is planned that, at the beginning of September, a new dose/booster of COVID-19 vaccine will be given to: nursing home residents; people aged 65 and over; people aged 18 years and over with comorbidities that have a risk for COVID-19; healthcare and nursing home professionals. The inclusion of other priority groups is under discussion. Portugal plans to use the best available vaccine for the variants in circulation (country communication).
- The Swedish Public Health Agency has provided new recommendations for the autumn COVID-19 vaccination campaign starting from 1 September 2022, to adults 65 years of age and older and people in risk groups from the age of 18 years (including among others pregnant women, people with weakened immune systems, people with heart and lung disease). For adults 18-64 years of age, the recommendation remains for one booster dose, however anyone can take a second booster in this age group if they request it [65].

Updated COVID-19 vaccines

The mRNA technology is the only platform that can deliver updated versions of approved vaccines in time for vaccination campaigns for this autumn/winter. Currently under investigation are monovalent Omicron BA.1 vaccines and bivalent Omicron BA.1 and original strain vaccines from both Pfizer/BioNTech and Moderna. Following a recent FDA statement, vaccines incorporating BA4/5 are expected to be developed as well [66].

On 15 June 2022, EMA started a rolling review of an Omicron-adapted Comirnaty COVID-19 vaccine [67]. The review will initially focus on chemistry, manufacturing and controls (CMC), which relate to the manufacturing of the vaccine. As the company makes progress in the development of its adapted vaccine, EMA will receive more data, including data on the immune response to the vaccine as well as data on neutralisation of Omicron subvariants, including BA4/5. On 17 June 2022, EMA started a rolling review for a bivalent Spikevax COVID-19 vaccine adapted to provide better protection against two strains of SARS-CoV-2, the original strain and the BA.1 Omicron variant of concern [68].

On 17 June 2022, the WHO Technical Advisory Group on COVID-19 Vaccination Composition (TAG-CO-VAC) issued an interim statement on the composition of current COVID-19 vaccines and concluded that, given the uncertainties of further evolution, it may be prudent to pursue the additional objective of COVID-19 vaccination of achieving a greater breadth in the immune response against circulating and emerging variants, while retaining protection against severe disease and death. Available data indicate that the inclusion of Omicron in an updated vaccine composition may be beneficial if administered as a booster dose to those who have already received a COVID-19 vaccination primary series [69].

An International Coalition of Medicines Regularity Authorities (ICMRA) workshop took place on 30 June to discuss with international regulators whether vaccines need to be updated and how. ICMRA members and WHO agreed that authorised COVID-19 vaccines continue to offer protection against severe disease, hospitalisation and death and encouraged their use, where available, both as primary series and as booster doses. Global regulators however also acknowledged that the continuous evolution of SARS-CoV-2 reduces the protection offered by the approved vaccines against infection and mild disease. Although the Omicron BA.4 and BA.5 subvariants seem to be taking over in many parts of the world, experience has shown that new variants may emerge rapidly and replace the currently circulating ones after short-lived waves. Preliminary data indicate that adapted mRNA vaccines, which incorporate an Omicron variant strain, can increase and extend protection, when used as a booster. Additionally, according to emerging data, a bivalent mRNA vaccine targeting two strains of SARS-CoV-2, one of which should be an Omicron strain, may provide some advantages in widening the immune response. Bivalent vaccines could be considered initially for use as boosters. Their use for primary vaccination might be supported in the future when further data become available [70].

Additionally, there are new candidate vaccines that contain the Beta variant strain that are currently under assessment by the EMA and they might represent an additional modality for booster doses, if an approval is confirmed before autumn.

Estimating the impact of future COVID-19 vaccination campaigns on the hospitalisation risk in individuals aged older than 60 years by mathematical modelling

Modelling approach and parameters to estimate the vaccine effectiveness against infection and hospitalisation at population level

We estimate vaccine induced protection against infection and against severe disease based on available data of vaccine effectiveness (VE) measured against Omicron subvariant BA.1. We assume that VE against infection wanes following a functional shape based on decaying antibody titers [71]. We use this relationship to back-calculate VE at full vaccine effect (two weeks post administration), which we denote as VE0. For Corminaty we estimate VE0=0.76 [27,34,72], for Spikevax we estimate VE0=0.87 [72], for Vaxzevria we estimate VE0=0.46 [72], and due to lack of data we assume the same VE0 for COVID-19 Vaccine Janssen as for Vaxzevria.

Given the large uncertainty around the waning of immune protection from vaccines, we assume an optimistic and pessimistic waning scenario of the VE against infection. In the optimistic scenario, the relative VE against infection decreases by 60% after 35 weeks, and in the pessimistic scenario the relative VE against infection decreases by 60% after only 13 weeks. Assuming the functional waning shape based on antibody titers [71], immunity keeps declining beyond those time points. For VE against hospitalisation we assume the same protection from all vaccine types, which we estimate as VE0=0.92 [73,74]. Across scenarios we assume that VE against severe outcome wanes four times slower compared to VE against infection. This captures waning of the relative VE against severe outcome by 7% to 24% after six months (for the optimistic and pessimistic scenario, respectively).

We assume that the VE after a first or second booster is independent of the vaccine products used in the primary vaccination series, and we do not differentiate between a Comirnaty or Spikevax booster. We assume the protection of a first booster against infection to be VE0=0.86 [35,73,75], and against hospitalisation to be VE0=0.94 [76]. We assume that the vaccine-induced protection following the booster decays the same way as following the primary vaccination schedule, both for the vaccine-induced protection against infection and against severe outcomes. We assume that a second booster dose restores the vaccine-induced protection against infection and severe disease of the first booster, and has the same waning profile.

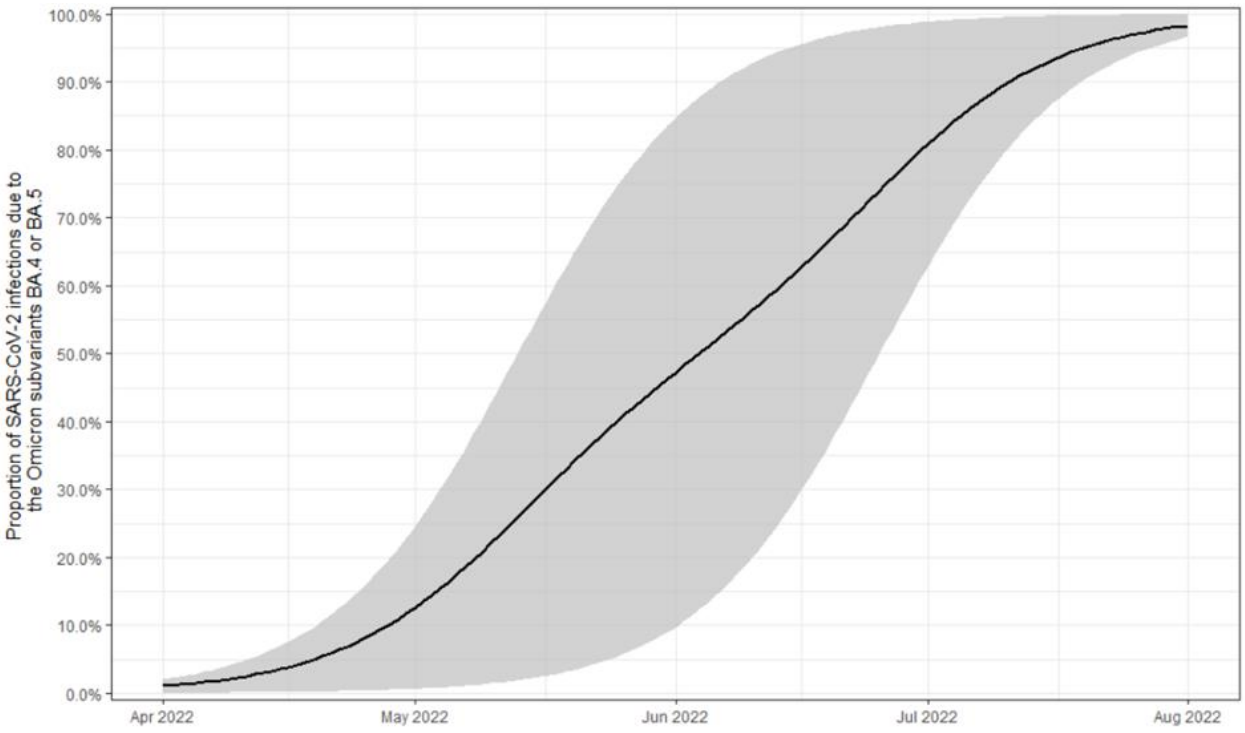
Due to lack of data, we assume no increased transmissibility of BA.4 and BA.5 in comparison to previous Omicron subvariants. Hence, we consider that the growth advantage of BA.4 and BA.5 is due to an increase of immune escape of vaccine-induced and naturally-acquired protection. In Figures 8 and 9 below, we vary the immune escape of vaccine-induced protection against infection due to BA.4 and BA.5 in comparison to previous Omicron subvariants from 0-20%. This range is in agreement with preliminary data that was shared with us confidentially. As there is currently no other indication, we assume the same severity for BA.4 or BA.5 as compared to previous Omicron lineages.

Model predictions of the future BA.4 and BA.5 proportions and the vaccine-induced protection against infection in the EU/EEA

Sequencing data from GISAID of COVID-19 cases until early June 2022 indicate that the Omicron subvariants BA.4 and BA.5 are quickly taking over in countries throughout the EU/EEA [7]. We predict the future combined BA.4 and BA.5 proportion for every country in the EU/EEA for which sufficiently reliable and recent sequencing data is available in GISAID (at least 100 Omicron sequences on 16 May or later, altogether 16 countries). For each of these EU/EEA countries, we fit a logistic curve to the past sequencing data, which matches the observed data well and yields predictions of the future proportion of BA.4 and BA.5. As shown in Figure 7, by end-July 2022 the vast majority of all COVID-19 cases (>95%) in the EU/EEA are predicted to be due to BA.4 or BA.5. We emphasise that the predicted proportion of BA.4/BA.5 infections in Figure 7 is obtained directly from fitting to observations of sequencing data, which does not require the transmissibility or immune-evasion of BA.4 and BA.5.

We note that, as with any extrapolation, there are major uncertainties that may affect the accuracy of our predictions in Figure 7. First, only a subset of EU/EEA countries provided sufficiently reliable and recent sequencing data (16 of 30 countries). Hence, the predictions in Figure 7 are applicable to the whole EU/EEA only under the assumption that a similar trend holds also for countries for which sufficiently reliable or recent sequencing data was not available. Indeed, the estimated proportion of BA.4 and BA.5 for countries with sufficient sequencing data varied less than 1.8% from the mean prediction at the end of July 2022. Second, also for the subset of countries with available sequencing data, the predictions are subject to uncertainties due to country-specific testing and sequencing practices, which have been changing over time, as well as the viral characteristics of the Omicron subvariants BA.4 and BA.5, including changes in the rates of asymptomatic cases and PCR test sensitivities.

Figure 7. Predicted proportion of SARS-CoV-2 infections in the EU/EEA caused by the Omicron subvariants BA.4 or BA.5

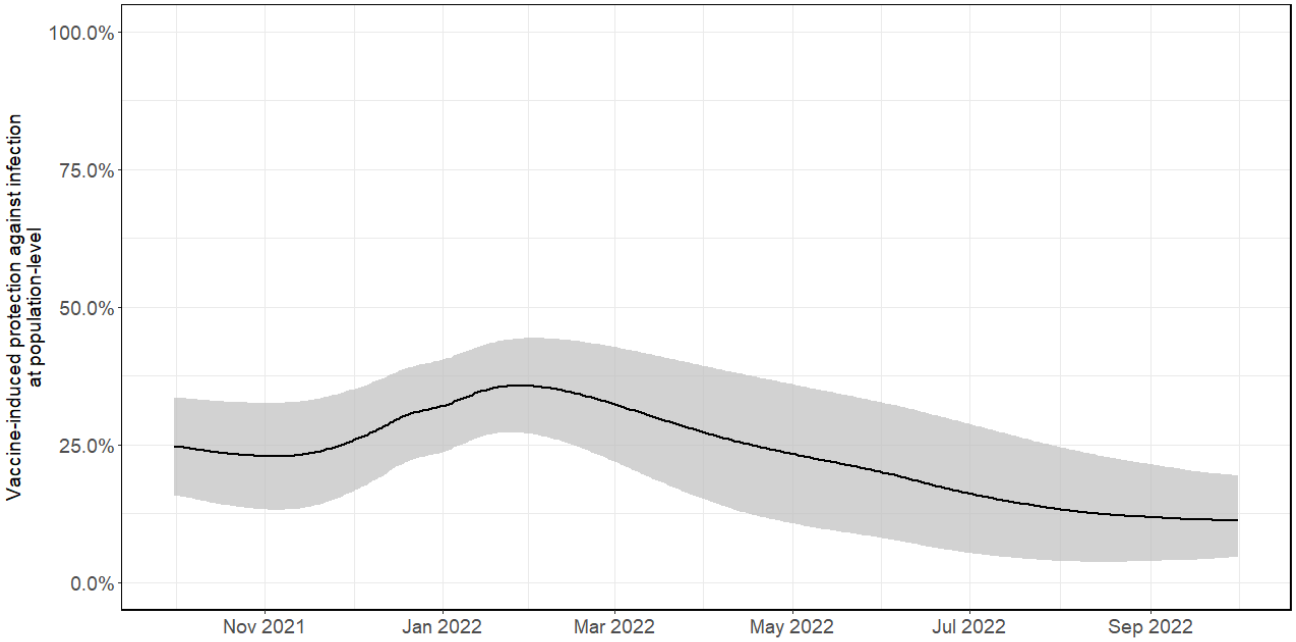


Note: The predictions for each considered EU/EEA country fall within the grey shaded area, and the solid black line is the mean across the predictions of the considered EU/EEA countries.

Preliminary data suggest that BA.4 and BA.5 may result in a substantial reduction of the population-level vaccine protection against infection (the vaccine effectiveness against infection, averaged over the whole population including non-vaccinated individuals) and an increased probability of reinfections. Additionally, the population-level vaccine protection against infection from the primary vaccination course and the first booster dose is likely to have waned substantially by July 2022. We emphasise that, in contrast to the potential reduction of the vaccine effectiveness against infection due to BA.4 or BA.5, there is currently no indication of a decrease in vaccine effectiveness against severe outcome due to BA.4 or BA.5 in comparison to previous Omicron lineages; hence, we assume the same vaccine-induced protection against severe outcomes for BA.4 and BA.5 as for earlier Omicron lineages.

Figure 8 presents estimates of the reduction of vaccine protection against infection at the population-level; we build upon the predictions of the BA.4 and BA.5 proportion shown in Figure 7 and assume that the vaccine effectiveness against infection is reduced by 0%-20% due to BA.4 and BA.5, as compared to previous Omicron sublineages (due to the current lack of evidence, we assume that both BA.4 and BA.5 result in the same reduction of the vaccine effectiveness).

Figure 8. Predicted vaccine effectiveness against infection (averaged across the whole EU/EEA population, and based on assumptions of increasing proportion of BA.4/5 infections from April onwards)



Note: The predictions for each EU/EEA country and for each uncertain spreading parameter fall within the grey shaded area, and the solid black line is the mean across the predictions of the considered EU/EEA countries and parameter uncertainties. Note that the vaccine-induced protection against infection at a population-level does not include protection against infection from prior infections which would increase the population level protection against infection.

Figure 8 shows that, after a peak due to the first booster rollout in early 2022, the vaccine-induced protection against infection at population-level, taking into account the estimated increasing proportion of BA.4 and BA.5 infections during the summer, has been decreasing steadily. By September 2022, the estimated vaccine effectiveness against infection, averaged across the whole population of the respective countries, is reduced to 3%-20% in the EU/EEA. The broad range of the predictions reflect substantial uncertainties regarding crucial parameters, including the waning of the vaccine effectiveness against infection, the current and future proportion of BA.4 and BA.5 and the reduction of the vaccine effectiveness against infection due to BA.4 and BA.5. The estimated substantial waning of the vaccine effectiveness against infection is consistent with the recent rise of COVID-19 notifications rates in the EU/EEA in the past three weeks. Further circulation of SARS-CoV-2 across the EU/EEA is probable in autumn and winter 2022, which results in continued exposure for at-risk groups. We emphasise that Figure 8 considers the vaccine effectiveness against infection, the vaccine effectiveness against severe disease is considered further below.

Scenarios for vaccination campaigns in summer and autumn

To assess the risk of a continued exposure of risk groups to SARS-CoV-2 infection, we conduct scenario analyses until the end of December 2022, for which we explore different vaccination strategies for countries that have not started a rollout of the second booster. In the following, we consider scenarios of rolling out a second booster to elderly individuals and closing the gaps in vaccination by increasing coverage of the primary course and/or first booster dose, as given in detail below:

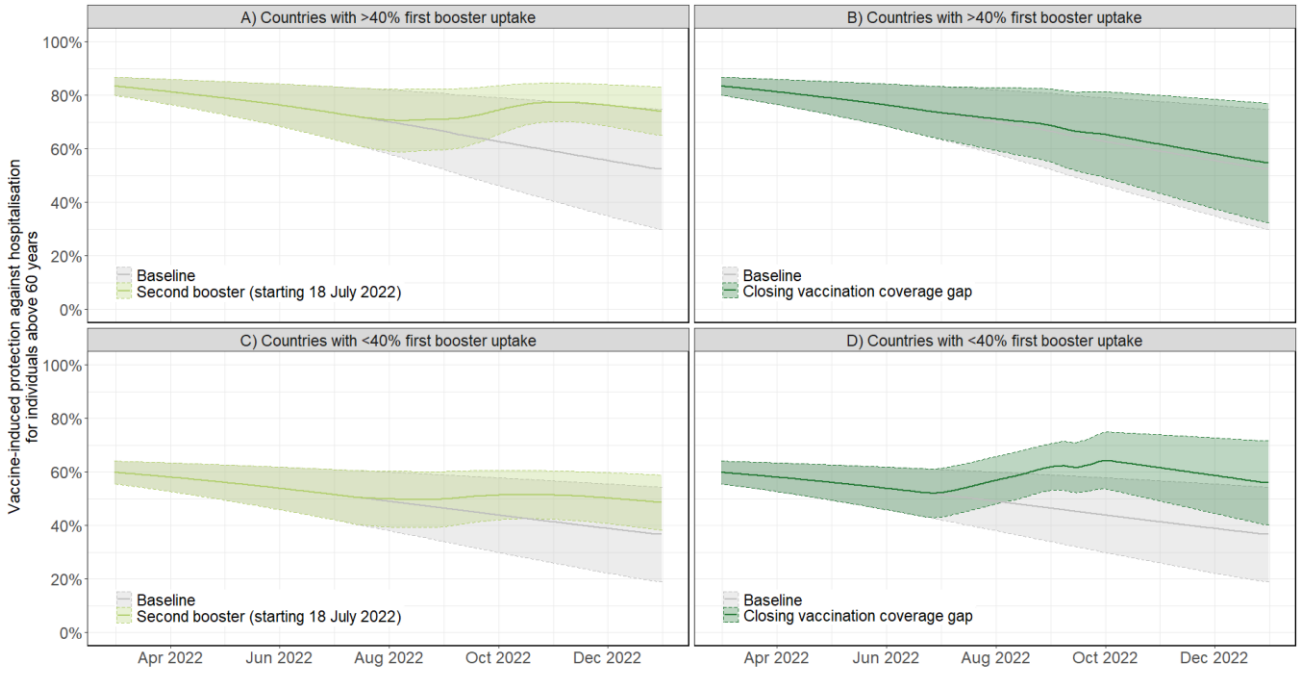
- **Second booster dose rollout.** In this scenario, we consider a rollout of a second booster to individuals older than 60 years who already received a first booster dose. We consider an eventual uptake of 75% of the second booster dose among individuals older than 60 who received a first booster. We consider that the rollout starts on 18 July 2022, and we assume the same speed of the second booster rollout as observed for the past first booster rollout. In Annex 1, we also evaluate the impact of a different start date of the second booster rollout (1 August 2022, 1 September 2022, or 1 October 2022) and the impact of a faster booster rollout, where the eventual uptake of 75% is attained in six weeks. Our modelling focuses explicitly on vaccine effectiveness and second boosters given to individuals of a certain age category (older than 60 years) since vaccine coverage or other data is available by age group.
- **Closing the coverage gaps of the first booster and primary vaccination series.** We consider an optimistic scenario of reducing the vaccination coverage gap for the first booster dose by 50% for individuals between 18 and 59 years and by 75% for individuals older than 60 years by 1 October 2022. Additionally, we consider that the coverage gap for the primary vaccination series for individuals older than 18 years is reduced by 50% by 1 October 2022.
- **Baseline scenario.** In this scenario, we consider that there are no new vaccine campaigns, while current vaccination uptake trends continue.

To capture the uncertainty concerning future viral circulation, we assess each of these intervention scenarios for a range of parameter settings relating to the waning of protection against infection and severe disease, as well as uncertainties relating to the spread of BA.4 and BA.5 and the resulting reduction in vaccine effectiveness against transmission. The results are presented as ranges of estimates across these different settings.

Model predictions of the future hospitalisation risk and conclusions

Figure 9 shows the estimated vaccine effectiveness against hospitalisation over time, averaged over all individuals above 60 years, for the three different vaccination scenarios. The results show that a second booster rollout has a substantial effect on the protection of individuals older than 60 years against hospitalisation, which is particularly large for countries with a high uptake of the first booster dose. More specifically, the expected median absolute increase (in percentage points) of the vaccine-induced protection against hospitalisation on 1 November 2022 due to a second booster rollout starting on 18 July 2022 is 17% (95% UI 6-34%) for countries with a high first booster uptake (see Figure 9A), and 5% (95% UI 1-24%) for countries with a low first booster uptake (see Figure 9C). Furthermore, countries with a low first booster uptake would benefit strongly from a vaccination campaign that aims to reduce the vaccination gap of the primary vaccination series and the first booster (see Figure 9D). The expected median absolute increase (in percentage points) of the vaccine-induced protection against hospitalisation on 1 November 2022 due to closing the vaccination coverage gaps for countries with a low first booster uptake is 16% (95% UI 10-41%) for countries with a low first booster uptake (see Figure 9D).

Figure 9. Predicted vaccine effectiveness against hospitalisation, averaged across all individuals older than 60 years.



Note: the left two subplots compare the baseline scenario with the second booster scenario (starting on 18 July 2022), and the right two subplots compare the baseline scenario with the scenario of closing the vaccination coverage gaps. The top and bottom rows correspond to countries with a high and low first booster uptake (of more or fewer than 40% of the total population, respectively, on 1 July 2022). The predictions for each EU/EEA country and for each uncertain spreading parameter fall within the respective shaded area, and the solid line is the respective mean across the predictions of the considered EU/EEA countries and parameter uncertainties. The expected median absolute increase (in percentage points) of the vaccine-induced protection against hospitalisation on 1 November 2022 due to a second booster rollout starting on 18 July 2022 is 17% (95% UI 6-34%) for countries with a high first booster uptake (see Figure 9A), and 5% (95% UI 1-24%) for countries with a low first booster uptake (see Figure 9C). The expected median absolute increase (in percentage points) of the vaccine-induced protection against hospitalisation on 1 November 2022 due to closing the vaccination coverage gaps is 3% (95% UI 0-10%) for countries with a high first booster uptake (see Figure 9B), and 16% (95% UI 10-41%) for countries with a low first booster uptake (see Figure 9D).

In countries who began second booster vaccination before 18 July 2022, at a similar rollout speed as for the first booster dose, the vaccine-derived protection is expected to be induced earlier than shown in Figure 9, with the curve shifting to the left. In settings with a slow uptake speed before 18 July 2022, the results are not expected to materially change.

Furthermore, we evaluate the impact of different timings of the second booster rollout on the future hospitalisation risk. Figure A1 in Annex 1 shows that there is a considerable advantage of an earlier second booster rollout (18 July) as compared to a later rollout (starting on 1 August 2022, 1 September 2022 and 1 October 2022, respectively). More specifically, Figure A1 shows that the predicted averaged vaccine effectiveness against hospitalisation of the earlier second booster rollout is larger for almost the entire period from 18 July 2022 until 31 December 2022, although the uncertainty intervals are overlapping.

The speed of the second booster rollout in Figure 9 is based on the speed of country-specific first booster rollouts observed historically. The uncertainty bands shown in that figure thus contain both slower and faster rollouts. However, to reflect on the potential advantages of achieving an even faster uptake in second booster vaccines, Figure A2 in Annex 1 shows the effect of an accelerated second booster rollout, which we assumed to reach the eventual uptake plateau of 75% within six weeks. While noting the large uncertainties, a faster second booster rollout starting on 1 September 2022 results in a comparable vaccine effectiveness against hospitalisation by November as the second booster rollout shown in Figure 9 (starting 18 July 2022). However, given the rise in case numbers due to BA.4 and BA.5 at the moment, and if expectations are that a 75% uptake may not be reached within six weeks, then it would be prudent to start the rollout now. Furthermore, a faster second booster rollout starting on 1 October 2022 results in lower vaccine effectiveness against hospitalisation during September/October relative to the second booster rollout shown in Figure 9 (see Figure A2, Annex 1).

We emphasise that Figures 8, 9, A1 and A2 focus on the decrease of vaccine-induced protection against infection and hospitalisation, respectively, due to waning over time and the potential increase of immune-escape of BA.4 and BA.5, while we are not considering additional immunity from previous infections in the population. Naturally-acquired protection does have a considerable impact on the protection against infection and hospitalisation, but the precise extent of naturally-acquired protection in the population is unclear due to substantial uncertainties, which include the under-ascertainment of COVID-19 cases and reinfections, the lack of unbiased and recent seroprevalence data, and the waning profiles of natural, vaccine-induced and hybrid protection. The substantial change in vaccine-induced protection in Figures 8, 9, A1 and A2 suggests a considerable reduction of the protection of individuals above 60 years who have not recently been infected by SARS-CoV-2. Due to fewer human-to-human contacts in general, higher uptakes of the primary vaccination series and first booster doses, and more cautious behaviour, the likelihood of having acquired past infection as a result of exposure in recent months may be particularly low amongst this group.

We summarise the conclusions from ECDC's mathematical modelling as:

- There is a substantial, steady decrease of the vaccine-induced protection against infection at population-level due to waning, and this trend might be exacerbated due to BA.4 and BA.5 Omicron subvariants (based on preliminary evidence). In contrast, there is currently no indication that BA.4 or BA.5 lead to a decrease in vaccine-induced protection against severe outcomes in comparison to previous Omicron lineages.
- For countries with an uptake of >40% of the first booster among the whole population, a second booster rollout can have a substantial impact on restoring protection against hospitalisation in individuals older than 60 years in autumn 2022. The expected median absolute increase (in percentage points) of the vaccine-induced protection against hospitalisation in individuals older than 60 years due to a second booster rollout starting on 18 July 2022 is 17% (95% UI 6-34%) on 1 November 2022.
- For countries with an uptake of <40% of the first booster among the whole population, closing vaccination coverage gaps of the primary vaccination series and the first booster has a larger effect than a second booster rollout, with an expected median absolute increase (in percentage points) of the vaccine-induced protection in individuals older than 60 years of 16% (95% UI 10-41%) and 5% (95% UI 1-24%) on 1 November 2022, respectively.
- An earlier second booster rollout (mid-July 2022) results in a larger protection against hospitalisation in the population above 60 years for the rest of 2022 compared to a later second booster rollout. The benefit in terms of vaccine-induced protection against hospitalisation in the population 60+ decreases the more the starting date of the second booster rollout is moved to a later starting date (we evaluate a starting date in July, August, September or October).

The predictions from mathematical modelling are subject to substantial uncertainties for assessing different vaccination campaigns, including the effectiveness of vaccines against BA.4 and BA.5, the prevalence and severity of BA.4 and BA.5, the associated effectiveness of the vaccine including the speed of waning, the effect of BA.4 and BA.5 on the probability of reinfections, the emergence of new SARS-CoV-2 variants, and the effect of hybrid immunity. Naturally-acquired protection from previous SARS-CoV-2 infections significantly complements the vaccine-induced protection against infection and hospitalisation in Figures 8 and 9, respectively. The level of naturally-acquired protection is uncertain due to lack of epidemiological evidence and data, including under-ascertainment of SARS-CoV-2 infections, lack of recent and unbiased seroprevalence data in the EU/EEA, waning profiles of naturally- and vaccine-induced protection, and the cross-protection and immune escape of different SARS-CoV-2 variants.

Public health considerations for vaccination strategies and campaigns

Considerations on additional booster doses, target groups and timing

Based on current projections, SARS-CoV-2 Omicron variants BA.4 and BA.5 are expected to become dominant across EU/EEA countries and by the end of July 2022 most COVID-19 cases (>95%) in the EU/EEA will be due to BA.4 or BA.5. As of 10 July 2022, the overall notification rates of COVID-19 cases in the EU/EEA remain high and have been increasing for the past five weeks, and case rates among people aged 65 years and over increased in 23 of the 27 reporting countries. These increases are still relatively recent, and they signal the start of a widespread wave driven by the BA.4 and BA.5 variants of concern, although with a growth rate likely slower than observed during the earlier emergence of BA.1 and BA.2. The increasing transmission among older age groups is starting to translate into severe disease, and twelve countries reported an increasing trend in at least one indicator of either hospital or ICU admissions/occupancy compared with the previous week. At the same time, even though the EU/EEA death rate has remained stable for the last five weeks, the forecast for the period up to 31 July indicates that both case notification rates and death rates will increase [77].

Current evidence shows that protection against infection due to Omicron variant (BA.1 and BA.2) starts waning two to three months after completing the primary series, is largely lost after six months and also wanes rapidly after the first booster dose. Protection is stronger and more durable against severe disease, although the balance of the evidence indicates gradual waning three to six months after the first booster dose. A second mRNA booster dose seemingly restores VE against severe disease, which remains stable for up to 10 weeks. Vaccine effectiveness data against BA.4 and BA.5 associated outcomes are still very limited, but thus far there is no evidence of reduced vaccine effectiveness against severe outcomes from BA.4 or BA.5 in comparison to previous Omicron lineages. However, as in previous waves, an overall increase in COVID-19 cases can result in a rise in hospitalisations, ICU admissions and deaths. Some signals in this direction are starting to emerge in a few countries with earlier progression towards dominance of BA.4 and BA.5 and corresponding waves with increased rates of infection.

In April 2022, ECDC assessed that in anticipation of future waves, it was expected that the administration of a second booster dose of mRNA vaccine would avert a significant number of hospitalisations and deaths and be needed for those groups most at risk of severe disease, such as adults 60 years and older and individuals with underlying comorbidities, with clearest public health benefit for those aged 80 years and above [1]. Such additional doses would be of greatest value if administered closer to expected periods of increased viral circulation, but before virus circulation reaches high levels. The age of 60 years as a cut-off for the recommendation was based on the higher observed age-specific notification rates of hospitalisation and ICU admission, increased adjusted risk of hospitalisation and death post first booster dose, and projected reduction in cumulative predicted deaths and SARS-CoV-2 cases by a second booster rollout in this population group.

Based on the new mathematical modelling presented in this document, for countries with an uptake of >40% of the first booster among the whole population, a second booster rollout among 60+ can have a substantial impact on restoring vaccine-induced protection against hospitalisation in this population from mid-July to the end of 2022 and an earlier second booster rollout among 60+ in mid-July 2022 results in a larger vaccine-induced protection against hospitalisation for the rest of 2022 compared to a later second booster rollout. There are currently twenty EU/EEA countries with recommendations on the use of a second booster in age group varying from 60+ to 80+ years, but as of 10 July 2022, the uptake of the second booster is still low in the EU/EEA (20% among 80+; 11.6% among 60+) and uneven across countries.

General considerations

Considering that with currently available vaccines, protection against infections rapidly wanes and effectiveness on transmission is modest, at this stage of the pandemic the objective of COVID-19 vaccination campaigns continues to be to reduce COVID-19 hospitalisation, severe disease and death, and to protect health systems.

Improving COVID-19 vaccine uptake of the primary course and first booster dose in eligible individuals who are yet to receive them remains a priority, especially for population groups at higher risk of severe outcomes and for countries with lower uptake of primary course and first booster dose.

Considerations for vaccination strategies in the summer

In light of the projection of a widespread wave driven by BA.4 and BA.5, waning protection against infection, and the current signal of increased rates of infection and severe disease in several countries, an early second mRNA vaccine booster rollout, not only among 80+ but also for adults between the ages of 60 and 79 years and individuals with underlying comorbidities regardless of age (including moderately to severely immunocompromised individuals), should now be considered to prevent severe disease and safeguard health system capacity, and countries should consider a rapid deployment. This would be particularly relevant and impactful in countries where the BA.4/BA.5 wave is starting or has not yet peaked. Second booster doses could be administered at least four months after the previous one, with a focus on people who received a previous booster more than six months ago. Continued close epidemiological and vaccine effectiveness monitoring continues to be essential to rapidly detect signals of waning protection and tailor the deployment of additional booster doses among population groups most at risk based on local data.

At the moment, for immunocompetent individuals below 60 years of age, unless they have underlying comorbidities, there is no clear epidemiological evidence to support the administration of a second booster dose, even though a certain degree of waning protection against severe outcomes may be expected overtime. The extension of the indication for additional booster doses to younger age groups will need to be reassessed based on epidemiological trends, emerging vaccine effectiveness evidence, performance and availability of future updated vaccines.

Considering the low and rapidly waning protection against infection and modest effect on transmission obtained with COVID-19 vaccines currently available, the early administration of a second booster dose to HCW and personnel working in LTCF for infection control purpose is likely to offer only modest benefits in terms of limiting the risks of transmission to vulnerable people in their care and be of limited duration. HCW and LTCF personnel may receive a second booster dose for their own protection if they belong to any prioritised population group based on age or due to underlying comorbidities. It should be ensured that LTCF residents receive the recommended booster doses, as they are effective in reducing morbidity and mortality in this group. In addition, NPIs in healthcare settings including LTCFs and other health care settings, such as use of face masks, remain effective measures to protect the vulnerable populations in these settings. Finally, access to therapeutics is an additional key measure for the protection of LTCF residents from severe outcomes. LTCFs should ensure the early detection and containment of outbreaks, as larger outbreaks are linked to lower protection by vaccines against infection presumably due to repeated exposure SARS-CoV-2 [78].

Considerations for vaccination strategies in the autumn/winter

Further waves of infection may be expected, including in the autumn/winter season of this year. The key drivers for further waves will be a combination of waning protection from vaccines and natural immunity, further evolution and emergence of variants, and, during autumn/winter months, increased indoor activity, among other factors. In anticipation of this, countries should consider the need for the rollout of further additional booster doses to be administered to population groups at risk of severe disease (e.g. 60+,individuals with underlying comorbidities, immunocompromised individuals and pregnant women), including later in this year. If further boosters are to be offered in the autumn/winter, countries should consider the need for combined campaigns for vaccination against COVID-19 and influenza, since such a combined approach provides efficiencies in administration logistics and costs. The boosting of HCW and LTCF personnel should also be considered for this later rollout. If adapted vaccines will show increased neutralisation against Omicron variants, indicating a possible higher effect against infection and transmission, they may be used to provide both direct and indirect protection. The need for, and the optimal timing of, further additional booster doses in autumn/winter may vary across countries, especially depending on the timing of the rollout of second boosters in spring/summer 2022 and emerging evidence of continued protection against severe disease in those that have received a second booster dose.

In addition, updated Omicron-adapted vaccines will likely be authorised for use in the EU in September and possibly available some time during the last trimester of 2022, however, the exact distribution timeline and available supplies of new vaccines are currently being defined with manufacturers. Efficacy data are currently under evaluation by EMA [67]. Future vaccination strategies may therefore also differ depending on the availability of these updated vaccines and their characteristics, and countries may have to use a mix of current and new vaccines depending on the timing of their availability and distribution. Nevertheless, it is important to continue the efforts to increase vaccination rates with available vaccines for groups at high risk for severe disease in a timely manner, and not to wait for the new Omicron-adapted vaccines. Depending on available supplies, different types of vaccines may therefore be used for different strategies and population groups depending on the characteristics of the updated vaccines compared to first-generation ones and the potential emergence of further new variants.

Furthermore, the frequency of re-vaccination needs to be carefully considered to allow that enough time has elapsed since previous vaccination. Data on the safety of a fourth dose of mRNA COVID-19 vaccine are limited, but so far the adverse events are mostly similar to those following previous doses and are short-lived [40,79]. Data emerging from the use of the second booster will continue to be assessed to determine if repeated boosters show any difference with respect to the overall safety profile.

These public health considerations are based on available scientific evidence and current epidemiological trends, and will be periodically reassessed. Considering that COVID-19 vaccination strategies and uptake, extent and timing of pandemic waves, circulation and timing of dominance of variants, among other factors, may differ across EU/EEA countries, NITAGs will ultimately make national decisions on the use of COVID-19 vaccines, taking into account previous vaccination uptake and epidemiological situation in their countries.

The scope of these considerations is focused on the second half of 2022, with an emphasis on the case for booster vaccination and closing the primary vaccination gap in late summer/early autumn, and not for longer term COVID-19 vaccination strategies. The administration of additional booster doses, both in the second half of 2022 as well as for the longer term COVID-19 vaccination strategy, may have a significant impact on the capacity of health systems to deliver COVID-19 vaccinations in the context of other competing public health priorities in the post-pandemic phase and already overburdened health services. At population level, vaccination fatigue could also undermine efforts to deliver vaccines to groups at higher risk of severe disease. Long-term vaccination strategies, including frequency of boosters, type of vaccines and target population groups, will need to balance scientific evidence and epidemiological trends with health system and economic implications, including investments in capacity to respond to future health service pressure of COVID-19, influenza and other respiratory viruses.

Future COVID-19 vaccination strategies will need to adapt to the evolving epidemiological situation, the possible emergence of new variants and subvariants of concern, potential seasonality, changing seasonal behaviour and future waves. In addition, the speed and degree of waning protection against infection and severe outcomes from both vaccine-induced and natural immunity, vaccine effectiveness against BA.4 and BA.5 or new emerging variants, efficacy, characteristics and available supplies of new adapted vaccines, safety considerations around repeated boosting, all play an important role in determining future long-term vaccination strategies, optimal frequency of revaccination and target groups.

Communication, vaccination acceptance and uptake considerations for the rollout of vaccination campaigns

Communication initiatives to promote uptake of additional vaccine doses and to promote completion of the primary series by those who have not yet done so, face several challenges. Some of these challenges are similar to those previously faced, while others are new:

- **Complacency regarding the threat of COVID-19:** With restrictions lifted throughout the EU/EEA, many people may perceive that the pandemic is over. Further, COVID-19 is regarded as a 'mild' disease for most people, in particular in the context of the Omicron variant, and this can add to perceptions that vaccination is not necessary [80]. The fact that many people not yet vaccinated will have undergone an infection can also contribute to lower vaccination intentions, as this may lead them to underestimate the risk of severe disease if they only faced mild to moderate symptoms. It is also possible that they might assume that they are permanently immune as a result of their earlier infection, and/or that they cannot transmit the disease to others [81].
- **Lower confidence in the effectiveness of the vaccines, and concerns about side effects:** Since early 2022, due to both the circulation of the highly transmissible Omicron variant and waning immunity, the number of COVID-19 cases in vaccinated people has increased, although with lower rate of severe disease compared to those unvaccinated [1]. As reflected in media coverage [82] and surveys [83], this can lead people to question the value of COVID-19 vaccines. Such views may be further amplified by misinformation circulating through social media that interprets these data as confirmation that vaccines do not work [84]. Further, surveys indicate that people who have experienced adverse events of varying degrees after primary vaccination, or who have friends or family members who had such experiences, may be less inclined to receive a booster [85].
- **The potential offer of variant-adapted vaccines, and the accompanying timelines, may be confusing for the public** [86] **and recurrent boosting faces acceptability challenges:** Variant-adapted vaccines are currently expected to become available during the last trimester of 2022 [87], although the timeline of distribution and number of doses that will be available are currently being defined with manufacturers. These uncertainties could lead to some vaccines being perceived as 'better', or people may decide to adopt a 'wait and see' approach to vaccination. Further, the public may be unclear about who should receive additional boosters when and with which vaccine, as well as what are the timelines for newer variant-specific vaccines. There are also media reports on the need for vaccines that offer more durable protection, while also cautioning that a strategy of booster shots given every few months is not sustainable [88]. Members of the US Advisory Committee on Immunization Practices (ACIP) cautioned in April 2022, when discussing US strategies for future doses, that for every COVID-19 vaccine dose recommended, uptake has declined – as shown in vaccine uptake data. ACIP members raised the issue of 'booster fatigue' and how it threatens confidence in the vaccination programme. The impact of each COVID-19 vaccine recommendation on vaccine confidence and uptake needs to be considered. Further, ACIP discussions highlighted the importance of

'communicating with one voice' and using common language to explain scientific complexity and uncertainty, in order to not contribute to the public's confusion [89].

Within this context, it continues to be very important to monitor vaccine uptake and the associated drivers and barriers to vaccination in order to understand where, why, and in which population groups and communities immunity gaps persist. As highlighted in previous ECDC reports [1], successful COVID-19 vaccination programmes can only be built on an understanding of, and a proper response to individuals' and communities' beliefs, concerns and expectations regarding the vaccine and the disease. The '5Cs' model – Confidence, Constraints, Complacency, Calculation, and Collective responsibility – can be used as a framework for understanding these concerns and designing strategies to facilitate COVID-19 vaccination acceptance and uptake [90].

To address the public's doubts about the value of vaccination, clear information should be provided around the rationale for the recommendations [91] as well as around the benefits of the primary course and boosters for different population groups (including for those who already had the disease). Given the evolving nature of the evidence, uncertainty should be acknowledged where it exists [92]. Communication should highlight the protection given by vaccines against the most severe outcomes of COVID-19, such as hospitalisation and death, which has direct benefits for the individual while also limiting the burden on healthcare services. In addition, messaging could also emphasise how vaccination can contribute to limiting the need for any possible re-imposition of restrictions [64]. Further, clear information is needed on which population groups shall receive boosters, as well as details on the optimal timing (for example, in relation to if/when they received a previous booster dose). Targeted communication should be provided to the specific groups being recommended for the boosters, as well as to healthcare workers so they can give reccomendations to their patients. This can also include information on the possibility for combining uptake of COVID-19 vaccine with the seasonal influenza vaccine. Information voids or misunderstandings regarding the types of vaccines that are available along with possible timelines for the availability of adapted vaccines need to be addressed. Barriers to uptake, specifically including those related to physical access, also need to be identified and addressed. Planning of future campaigns should be based on good practices identified during earlier phases of the vaccination programme.

Throughout the vaccination programme, countries have reported adopting a range of strategies to reach individuals and population groups with low vaccination uptake. These have included measures related to addressing, among other issues, access, misinformation, distrust, or a lack of clear and suitably adapted information. For example, access has been facilitated through use of mobile and pop-up vaccination teams/clinics; targeted communication strategies have been adopted; reminders have been sent; outreach initiatives and intersectoral partnerships for community-based interventions have been implemented; and vaccine ambassadors have been used to promote vaccination within their own communities [93].

Knowledge gaps and research priorities

Further or continued research in the following areas should be a matter of public health priority:

- Studies and collection of real-life data on longer-term duration of protection and patterns of waning protection against severe outcomes following first and second booster doses in different population groups, especially in older age groups (in response to currently circulating BA.4/BA.5 and potential future SARS-CoV-2 variants) as well as immunosuppressed individuals, and those with underlying conditions associated with more severe COVID-19 outcomes;
- Nationally representative, age-stratified sero-epidemiological studies provide a basis for estimating the proportion of the population with pathogen-specific antibodies in a given country. Such studies are particularly informative when they apply functional (neutralising titres) or quantitative assays to determine the level of both natural and vaccine-induced antibodies in participating individuals in order to estimate the contribution of natural, vaccine-derived and hybrid immunity in the population. Given that serum antibodies wane over time, longitudinal or repeated studies with the same sampling strategy and common testing methodology are essential for understanding temporal trends. High-quality studies on the current sero-epidemiological situation in different EU/EEA countries will be crucial for high-quality modelling predictions, including an understanding of optimal rollout timing for future vaccine boosters.
- Kinetics of the antibody response to repeated COVID-19 vaccine doses in different populations;
- Effectiveness of eventual future variant-specific vaccines compared to currently available vaccines;
  - Continuous monitoring of safety following additional booster doses;
  - Vaccine effectiveness studies that disaggregate findings by prior infection status;
- Vaccine effectiveness for individuals receiving mRNA vaccine booster doses following administration of a primary vaccine series with another type of vaccine (i.e. viral vector) and for boosters with non-mRNA vaccines.

Consulted experts (in alphabetical order)

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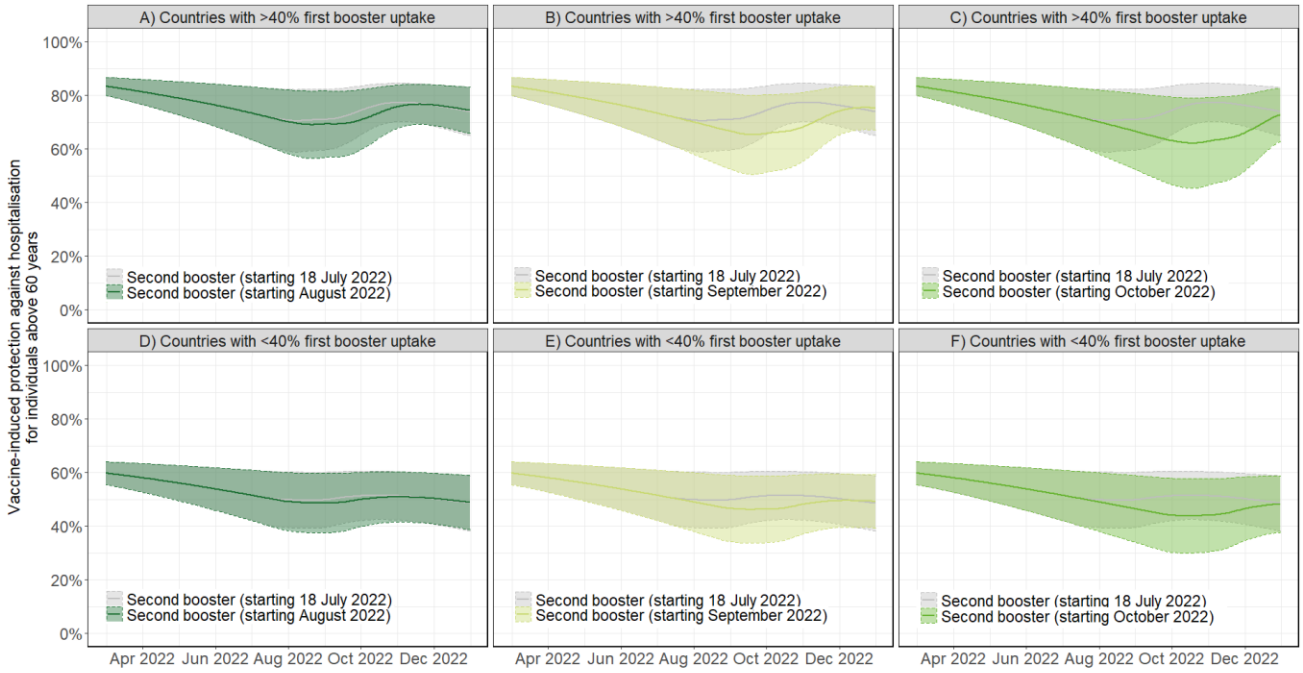
Annex 1. Evaluating the impact of later and/or faster second booster rollout scenarios

Figure A1. Comparison of the second booster rollout scenario starting on 18 July 2022 and later second booster scenarios (starting on 1 August 2022, 1 September 2022 and 1 October 2022, respectively) with respect to the predicted vaccine effectiveness against hospitalisation, averaged across all individuals older than 60 years



The top and bottom rows correspond to countries with a high and low first booster uptake (of more or less than 40% of the total population, respectively, on 1 July 2022). The predictions for each EU/EEA country and for each uncertain spreading parameter fall within the respective shaded area, and the solid line is the respective mean across the predictions of the considered EU/EEA countries and parameter uncertainties.

Figure A2. Comparison of the booster rollout scenario starting on 18 July 2022, where the eventual second booster uptake is attained in the same time as for the first booster uptake of the respective country, and fast booster rollouts that achieve the eventual second booster uptake within six weeks (from 1 September 2022 to 15 October 2022, and from 1 October 2022 to 15 November 2022, respectively) with respect to the predicted vaccine effectiveness against hospitalisation, averaged across all individuals older than 60 years

The top and bottom rows correspond to countries with a high and low first booster uptake (of more or less than 40% of the total population, respectively, on 1 July 2022). The predictions for each EU/EEA country and for each uncertain spreading parameter fall within the respective shaded area, and the solid line is the respective mean across the predictions of the considered EU/EEA countries and parameter uncertainties.

Annex 2 – Policies on additional and booster doses in EU/EEA countries

Table A1. Recommendations for additional and booster doses in EU/EEA countries (n=30)

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
Austria	**Recommendation**: Additional dose plus one booster dose (four doses) for individuals ≥12 years (extended primary three-dose vaccination series plus a booster dose 3+1 schedule). **Timing**: Additional dose is given at least 28 days after second dose. At least four weeks later, testing of neutralising antibodies is recommended to find out whether any immune response has occurred. If no neutralising antibodies can be detected after the additional third dose, an additional fourth dose is recommended at least four weeks after the third dose (off-label). In the event of a negative neutralising antibody test at least four weeks after the third dose, administration of an additional fourth dose is recommended (off-label).	**Recommendation**: One booster dose for individuals ≥5 years (primary two-dose vaccination series plus a booster dose). Two booster doses for individuals aged ≥80 years; for persons with underlying health conditions or at risk for severe disease (from 12 years) and those 65-79 years according to a medical individual benefit -risk assessment or at the explicit request of the person to be vaccinated (two dose primary vaccination series plus two booster doses). **Timing**: Individuals aged five years and above: booster given as of six months after the second dose; After one dose with COVID-19 Vaccine Janssen a second dose is recommended 28 days after the first dose (preferably with mRNA-vaccine), COVID-19 Vaccine Janssen can also be used again for the second dose, in this case an interval of at least two months between the first two doses is recommended and a third dose at the above-indicated intervals (six months) is also recommended for people vaccinated with COVID-19 Vaccine Janssen. Two booster doses (fourth doses) can be considered four months after the third dose at the earliest, but in any case, six months after the third dose for those ≥80 years. For people aged ≥65 years and persons regardless of age (12 years or older) with pre-existing conditions and circumstances that may place them at increased risk for severe disease of COVID-19, in whom an earlier waning of immunity is to be expected - six months after the first booster (third dose)– off-label	Bundesministerium für Soziales Gesundheit Pflege und Konsumentenschutz. COVID-19-Impfungen: Anwendungsempfehlungen des Nationalen Impfgremiums. 2021. Available at: https://www.sozialministerium.at/Corona-Schutzimpfung/Corona-Schutzimpfung---Fachinformationen.html
Belgium	**Recommendation**: Additional dose for individuals aged 5-11 years (extended primary three-dose vaccination series). One booster dose (fourth dose) for individuals >12 years (extended primary three-dose vaccination series plus a booster dose). **Timing**: Additional dose given at least 28 days after second dose followed by a booster dose (fourth dose) at least three months after the third dose.	**Recommendation**: One booster dose for individuals aged ≥18 years (primary two-dose vaccination series plus a booster dose). **Timing**: Booster given at least four months after primary vaccination with mRNA-based vaccines; four months after primary vaccination with Vaxzevria; two months after single dose of COVID-19 Vaccine Janssen.	Belgium Superior Health Council. Available at: https://www.health.belgium.be/en/superior-health-council
Bulgaria	**Recommendation**: Additional dose for individuals (extended primary three-dose vaccination series). **Timing**: Additional dose given at least 28 days after second dose.	**Recommendation**: One booster dose for individuals age ≥12 years (primary two-dose vaccination series plus a booster dose). **Timing**: Booster dose given at least three months after primary vaccination for those aged ≥18 years. For those aged 12-17 years, at least six months after primary vaccination.	Unified Information Portal Bulgaria. Guidelines for administering an additional or booster dose of COVID-19 vaccine are provided by the Expert Advisory Board on Immunoprophylaxis Surveillance. 2021. Available at: https://coronavirus.bg/bg/news/2513#
Croatia	**Recommendation**: Additional dose plus one booster dose (four doses) for individuals aged ≥5 years (extended primary three-dose vaccination series plus a booster dose).	**Recommendation**:	Croatian Institute for Public Health. Preporuke za primjenu treće doze u imunokompromitiranih osoba i docjepljivanje protiv bolesti COVID-19. 2021. Available at: https://www.hzjz.hr/wp-

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
	Timing: Additional dose given at least eight weeks after second dose, followed by a booster dose at least three months after the additional dose.	One booster dose for individuals ≥18 years (primary two-dose vaccination series plus a booster dose). Also recommended for children aged 12 years and over with underlying risk factors and at increased risk of severe disease. Two booster doses for individuals ≥80 years and residents and staff in LTCF who are over 65 years and health professionals. Also recommended for those at increased risk of developing severe disease and those vaccinated with Janssen. **Timing**: First booster dose given at least three months after primary vaccination; two months after single dose of COVID-19 Vaccine Janssen. Second booster dose given at least four months after the first booster dose.	content/uploads/2020/03/Preporuke-za-primjenu-tre%C4%87e-doze-u-imunokompromitiranih-osoba-i-docjepljivanje-protiv-bolesti-COVID-19.pdf https://cijepise.zdravlje.hr/
Cyprus	**Recommendation**: Additional dose plus one booster dose (four doses) for individuals irrespective of age (extended primary three-dose vaccination series plus a booster). **Timing:** Additional dose given at least four weeks after second dose followed by a booster dose at least five months after the third dose.	**Recommendation**: One booster dose for individuals aged ≥12 years (two dose primary vaccination series with mRNA-based vaccines plus booster dose with Comirnaty). Two booster doses given to those aged >60 years, residents and staff at LTCF, vulnerable groups (i.e. individuals with diabetes mellitus, and severe obesity), healthcare professionals (two dose primary vaccination series plus two booster doses (second booster dose with mRNA-based vaccines)). **Timing**: First booster dose given at least five months and two weeks after primary vaccination, second booster dose at least five months after the first booster dose.	Republic of Cyprus Ministry of Health. COVID-19 Vaccines and Treatment Protocols. 2022. Available at: https://www.pio.gov.cy/coronavirus/eng/categories/vaccines-en
Czechia	**Recommendation**: Additional dose for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least one month after second dose.	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). **Timing**: Booster dose given at least three months after primary vaccination for those aged >60 years, LTCF residents and staff, healthcare workers and people with chronic conditions. For the rest of the population five months after primary vaccination. Two months after single dose of COVID-19 Vaccine Janssen.	The Ministry of Health of the Czech Republic. Booster and additional dose. 2021. Available at: https://covid.gov.cz/en/situations/register-vaccination/booster-and-additional-dose
Denmark	**Recommendation**: Additional dose plus one booster dose for individuals (extended primary three-dose vaccination series plus a booster). **Timing:** Additional dose given at least one month after second dose and a maximum of eight months afterwards or at earliest convenience (different timings depending on the risk group) followed by a booster dose at least three months after the third dose.	**Recommendation** Three doses for individuals aged ≥18 years (2 dose primary vaccination series plus booster dose). 4th dose as a second booster is recommended to specific target groups. **Timing**: Booster given at least 140 days after primary vaccination.	Danish Health Authority. Booster vaccination against COVID-19. 2021. Available at: https://www.sst.dk/en/English/Corona-eng/Vaccination-against-COVID-19/Booster-vaccination
Estonia	**Recommendation**: Additional dose for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least one month after second dose.	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). **Timing**: Booster given at least three months after primary vaccination with mRNA-based vaccines; and Vaxzevria; two months after single dose vaccination with COVID-19 Vaccine Janssen. Recovered individuals – five months after recovery. Two booster doses 60+ individuals and individuals 12+ with certain diagnosis; elderly care/nursing houses (residents and care providers who	Terviseamet. https://vaktsineeri.ee/covid-19/lahen-vaktsineerima/

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
		are in direct contact with patients); health care providers who are in direct contact with patients	
Finland	**Recommendation** Additional dose plus a booster dose for individuals aged >12 years (extended primary three-dose vaccination series plus a booster dose). **Timing**: Additional dose given at least two months after second dose followed by a booster dose at least 3-4 months after the third dose.	**Recommendation**: One booster dose for individuals aged ≥18 years and persons aged 12-17 years in risk groups (two dose primary vaccination series plus booster dose). Two booster doses for individuals aged ≥80 years, residents of LTCFs, older people receiving home care or informal care (two dose primary vaccination series plus two booster doses). **Timing**: One booster dose given to those over 60 years of age and at-risk groups aged over 18 years is recommended 3-4 months after primary course. For persons between 18 and 60 years of age, a booster dose is recommended 4-6 months after primary course. In 12–17-year-olds six months after primary course. For those vaccinated with Janssen vaccine, a booster dose is recommended two months after the primary course. Second booster dose given at least three months after the first booster dose.	Terveyden ja hyvinvoinnin laitos. Kolmas koronarokoteannos. 2022. Available at: https://thl.fi/fi/web/infektiotaudit-ja-rokotukset/rokotteet-a-o/koronavirusrokotteet-eli-covid-19-rokotteet-ohjeita-ammattilaisille/kolmas-koronarokoteannos
France	**Recommendation** Additional dose plus a booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least one month after second dose, followed by a booster dose as least three months after the third dose.	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series, plus booster dose). Two booster doses for individuals aged ≥80 years, residents of LTCFs aged ≥65 years who are at risk of severe disease (two dose primary vaccination series plus two booster doses after 3 months). Two booster doses for individuals aged ≥60 years and < 80 years (with or without comorbidities) 6 months after the first booster or infection. **General population**: Booster dose given at least three months after primary vaccination and a second booster dose given at least six months after the first booster dose.	Haute Autorité de santé. Covid-19 : un second rappel réservé aux personnes les plus à risques. 2022. Available at: https://www.has-sante.fr/jcms/p_3325021/fr/covid-19-un-second-rappel-reserve-aux-personnes-les-plus-a-risques Conseil d'orientation de la stratégie vaccinale. Available at : cosv_-_addendum_du_18_fevrier_2022_a_l_avis_du_19_janvier_2022_-_deuxieme_dose_de_rappel_vaccinal-2.pdf (solidarites-sante.gouv.fr) Ministery of Health. Available at: https://solidarites-sante.gouv.fr/IMG/pdf/dgs-urgent_no_2022_47_2eme_rappel_60_-2.pdf
Germany	**Recommendation** Additional dose plus two booster doses for individuals aged ≥5 years (extended primary three-dose vaccination series plus two booster doses). **Immunocompromised individuals:** Additional dose is given at least one month after the second dose followed by a booster dose given at least three months after the third dose.	**Recommendation**: One booster dose for all individuals aged ≥12 years and for 5- to 11-year-olds at increased risk of severe illness (two dose primary vaccination series plus booster dose). Two booster doses for individuals aged >70 years, residents of LTCFs and people at risk of developing severe illness in support facilities, workers in medical and nursing facilities (especially those in direct contact with patients and residents) (two dose primary vaccination series plus two booster doses). **Timing**: Booster dose given at least three months after primary vaccination for those ≥12 years. For 5–11-year-olds, booster dose given at least six months after primary vaccination. Second booster dose at least three months after first booster dose for those at risk. For personnel in medical and nursing facilities, second booster dose given at least six months after the first booster dose. For those vaccinated with COVID-19 Vaccine Janssen, a second dose with an mRNA vaccine is recommended one month after primary course to optimise immunisation. A booster of mRNA should follow after at least three months.	Epidemiologisches Bulletin 21/2022, STIKO: 20. Aktualisierung der COVID-19-Impfempfehlung. Tab. 5 | Empfehlungen zu Indikationsgruppen, Impfstoffen und Impfabständen zur 2. Auffrischimpfung gegen COVID-19 (Stand: 24.05.2022). Available at: https://www.rki.de/DE/Content/Infekt/EpidBull/Archiv/2022/Ausgaben/21_22.pdf?__blob=publicationFile

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
Greece	**Recommendation** Additional dose plus one booster dose for individuals aged ≥12 years (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least four weeks after second dose, followed by a booster dose at least three months after the third dose.	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). Two booster doses for those aged ≥60 years. **Timing**: One booster dose given at least three months after primary vaccination. Two months after primary vaccination with COVID-19 Vaccine Janssen. Second booster dose at least four months after first booster dose.	Briefing by the President of the National Vaccination Committee Maria Theodoridou and the Secretary General Primary Health Care Mario Themistocleous. 2022. Available at: https://www.moh.gov.gr/articles/ministry/grafeio-typoy/press-releases/10335-enhmerwsh-diapisteymenwn-syntaktwn-gia-to-ethniko-sxedio-emboliastikhs-kalypshs-kata-ths-covid-19-apo-thn-proedro-ths-ethnikhs-epitrophs-emboliasmwn-maria-theodwridoy-kai-ton-g-g-prwtobathmias-frontidas-ygeias-mario-themistokleoys
Hungary	**Recommendation:** Additional dose plus one booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least 28−56 days after second dose, followed by a booster dose at least four months after third dose.	**Recommendation**: One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). Two booster doses for the elderly, and those with chronic disease and also available to anyone who asks for it (two dose primary vaccination series plus two booster doses). **Timing**: One booster dose given at least four months after primary vaccination followed by a second booster dose at least four months after first booster dose.	Hungary Ministry of Interior. https://koronavirus.gov.hu/sites/default/files/sites/default/files/imce/nnk_eljarasrend_2022.01.14._negyedik_oltas.pdf
Iceland	**Recommendation:** Additional doses for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least three months after second dose.	**Recommendation:** One booster dose for individuals ≥16 years (two dose primary vaccination series plus booster dose). A fourth dose has been recommended for those persons 65 and over with an mRNA vaccine. **Timing:** Booster dose given at least five months after second dose.	Iceland Directorate of Health. Early booster vaccination for COVID-19. 2022. Available at: https://www.landlaeknir.is/um-embaettid/greinar/grein/item48474/early-booster-vaccination-for-covid-19
Ireland	**Recommendation:** Additional doses for individuals aged 5-11 years (extended primary three-dose vaccination series). Additional dose plus one booster dose for individuals aged ≥12 years (extended primary three-dose vaccination series plus one booster dose). **Timing:** Additional dose given at least two months after second dose for those aged ≥12 years and 28 days after second dose for those aged 5-11 years. Booster dose given to those aged ≥12 years at least three months after the third dose.	**Recommendation:** One Booster dose doses for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). Two booster doses for those aged ≥65 years (two dose primary vaccination series plus two booster doses). **Timing:** One booster dose is given to those aged >16 years at least three months after the primary vaccination and for 12–15-year-olds the booster dose is given at least six months after the primary vaccination dose. Second booster dose given at least four months after first booster dose.	Ireland Department of Health. COVID-19 vaccine booster dose. 2022. Available at: https://www2.hse.ie/screening-and-vaccinations/covid-19-vaccine/get-the-vaccine/covid-19-vaccine-booster-dose/
Italy	**Recommendation:** Additional dose plus a booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least 28 days after second dose, followed by a booster dose fourth months after third dose. A second booster: 120 days from the first booster dose	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). Two booster doses for people aged 80 and over, LTCF residents, people with high fragility motivated by pathologies concomitant / pre-existing aged 60 years and over **Timing:** One booster dose given at least four months after primary vaccination. A second booster: 120 days from the first booster dose	Ministry of Health, Italy. COVID-19 vaccine plan. 2022. Available at: https://www.salute.gov.it/portale/nuovocoronavirus/dettaglioContenutiNuovoCoronavirus.jsp?lingua=italiano&id=5452&area=nuovoCoronavirus&menu=vuoto Ministry of Health, Italy. Directorate-General for Health Prevention. Indications on the administration of the second booster dose (second booster) as part of the anti SARS-CoV-2 / COVID-19 vaccination campaign. 2022. Available at: https://www.trovanorme.salute.gov.it/norme/renderNormsanPdf?anno=2022&codLeg=86755&parte=1%20&serie=null

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
Latvia	**Recommendation:** Additional dose plus a one booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least one month after second dose.	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). A second booster is under consideration. **Timing**: Booster dose given at least three months after primary vaccination with mRNA vaccines. Two months after single dose of COVID-19 Vaccine Janssen. Three months after primary vaccination with Vaxzevria.	Latvia National Council for Immunization. 2022. Available at: https://www.vmnvd.gov.lv/lv/media/15326/download
Liechtenstein	**Recommendation:** Additional dose for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least 28 days after second dose.	**Recommendation:** One booster dose for individuals ≥12 years (two dose primary vaccination series plus booster dose). **Timing**: Booster dose given at least four months after primary vaccination.	Swiss Federal Office of Public Health FOPH. Coronavirus: Vaccination. Available at: https://www.bag.admin.ch/bag/en/home/krankheiten/ausbrueche-epidemien-pandemien/aktuelle-ausbrueche-epidemien/novel-cov/impfen.html#-1386562885
Lithuania	**Recommendation:** Additional dose for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least 28 days after second dose.	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). **Timing:** Booster dose given at least 90 days months after primary vaccination; 60 days after single dose of COVID-19 Vaccine Janssen.	Minister of Health of the Republic of Lithuania. Regarding the approval of the description of the procedure for the organization of COVID-19 disease (coronavirus infection) vaccine purchased from the state budget at the expense of vaccination of the population. 2022. Available at: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/f735b430469711ebb394e1efb98d3e67/asr
Luxembourg	**Recommendation:** Additional dose plus a one booster dose for individuals aged ≥18 years (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least 12 weeks after second dose followed by a booster dose at least three months after the third dose.	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). Two booster doses for people aged 80 and over **Timing:** Booster dose given at least three months after primary vaccination with mRNA-based vaccines; four months after primary vaccination with Vaxzevria; one month after single dose of COVID-19 Vaccine Janssen followed by an optional third dose at least three months after the second dose. Second booster dose at least four months after the first booster dose.	The Luxembourg Government. Coronavirus vaccination. 2022. Available at: https://covid19.public.lu/en/vaccination.html Conseil supérieur des maladies infectieuses. 3 March 2022. Available at : CONSEIL SUPERIEUR D'HYGIENE (public.lu) Coneil supérieur des maladies infectieuses. 12 April 20222. Available at : recommandation-4e dose (public.lu)
Malta	**Recommendation:** Additional dose plus a one booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least 28 days after second dose.	**Recommendation**: One booster dose for individuals ≥18 years (2 dose primary vaccination series plus booster dose). Second booster dose to the elderly over the age 65, residence of nursing homes. **Timing:** Booster dose given at least three months after primary vaccination.	Malta Ministry of health. Vaccines. 2022. Available at: https://deputyprimeminister.gov.mt/en/health-promotion/covid-19/Pages/vaccines.aspx
the Netherlands	**Recommendation:** Additional dose plus a booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). For the immunocompromised population 12+: a third dose is recommended as part of the primary series, as well as a fourth dose as a first booster. For the immunocompromised population 18+: a fourth dose is recommended as a first booster, a fifth dose is recommended as a second booster. **Timing:** An additional/third dose at least four weeks after second dose;followed by a booster dose at least three months after third dose;followed by a second booster dose at least three months after the fourth dose.	**Recommendation**: One booster dose for individuals 18-59 years (two dose primary vaccination series plus booster dose). Two booster doses for individuals aged ≥60 years, residents in LTCFs, adults with Down syndrome (two dose primary vaccination series plus two booster doses). **Timing**: One booster dose at least three months after primary vaccination, followed by a second booster dose at least three months after the first booster dose.	The Netherlands - National Institute for Public Health and the Environment. Who can get a booster vaccination and when? 2022. Available at: https://www.government.nl/topics/coronavirus-covid-19/dutch-vaccination-programme/booster-vaccination Netherlands. National Institute for Public Health and the Environment. Repeat shot against corona (2nd booster). 2022. Available at: https://www.rijksoverheid.nl/onderwerpen/coronavirus-vaccinatie/aanpak-coronavaccinatie/herhaalprik

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
Norway	**Recommendation:** Additional dose plus a booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). Third booster dose (dose 5): recommended for people with severely weakened immune systems **Timing:** Additional dose given at least four weeks after second dose, followed by a booster dose at least three months after the third dose. Interval of minimum three months	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). No general recommendation for second booster doses but people aged 80 and older who have received 3 doses and have not had COVID-19 since then, can receive a new booster dose if they wish. **Timing:** Booster dose given at least 20 weeks after primary vaccination with mRNA-based vaccines; COVID-19 Vaccine Janssen dose is followed by mRNA vaccine after at least 8-12 weeks, followed by a booster with mRNA vaccine at least 20 weeks after second dose. Second booster dose (dose 4): four months after the last booster dose (dose 3)	Norwegian Institute of Public Health. Booster doses. 2022. Available at: https://www.fhi.no/en/id/vaccines/coronavirus-immunisation-programme/coronavirus-vaccine/#booster-doses Norwegian Institute of Public Health. Coronavirus vaccine – inforation for the public. https://www.fhi.no/en/id/vaccines/coronavirus-immunisation-programme/coronavirus-vaccine/#booster-doses
Poland	**Recommendation:** Additional dose plus a booster dose for individuals 12 years or older (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least four weeks after second dose, followed by a booster dose at least three months after third dose.	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose). Two booster doses for people aged 80 and over (the full primary vaccination schedule and the first booster dose with COVID-19 mRNA) **Timing:** Booster dose given at least five months after primary vaccination; two months after single dose of COVID-19 Vaccine Janssen. Second booter: 150 days after an mRNA booster	Polish Ministry of Health. Booster dose. 2022. Available at: https://www.gov.pl/web/szczepimysie/trzecia-dawka Polish Ministry of Health. Second booster dose for people 80+. 2022. Available at: https://www.gov.pl/web/zdrowie/druga-dawka-przypominajaca-dla-osob-80
Portugal	**Recommendation:** Additional dose for individuals 12 years and over (extended primary three-dose vaccination series). For 18 years and over and additional dose plus a booster (extended primary three-dose vaccination series). **Timing:** Additional dose of mRNA vaccine given at least three months after second dose (minimum 28 days).	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). Two booster doses for people aged 80 and over, residents of nursing homes. **Timing:** Booster dose of mRNA vaccine given six months (minimum four months) after the last dose.Three months after primary vaccination with COVID-19 Vaccine Janssen.	Portugal - Servico Nacional De Saude. Campanha de Vacinação Contra a COVID-19. 2022. Available at: https://www.dgs.pt/normas-orientacoes-e-informacoes/normas-e-circulares-normativas/norma-n-0022021-de-30012021-pdf.aspx Portugal. National Health Service. Directorate-General for Health. People over 80 and living in nursing homes will receive a second booster dose. 2022. Available at: https://www.dgs.pt/em-destaque/pessoas-com-mais-de-80-anos-e-residentes-em-lares-vao-receber-segunda-dose-de-reforco.aspx and https://covid19.min-saude.pt/wp-content/uploads/2022/06/Parecer-CTVC-Estrategia-reforco-vacinal-antecipacao-2a-dose-ERPI-11.05.2022_pdf-1281kb.pdf
Romania	**Recommendation:** Additional dose for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given 28-120 days after second dose.	**Recommendation:** One booster dose for individuals aged ≥12 years (two dose primary vaccination series plus booster dose) especially for people at high risk of exposure, vulnerable people and on request for those who have completed the full vaccination course more than four months ago. Two booster doses for people over 18 years of age upon request, according to the National Comittee on Vaccination against COVID-19. People over 18 years of age who have been vaccinated with 3 doses of mRNA vaccine or heterologous regimen that includes Vaxzevria and mRNA vaccines, may receive, upon request a fourth dose of Comirnaty at least 4 months after the third dose. For those vaccinated with Jannsen and an additional dose of mRNA vaccine, the second booster is currently not recommended. Two booster doses for people over age of 18 who have been vaccinated against COVID-19 with 3 doses of mRNA vaccine	Romanian Government website. Platform programming for the third dose has begun. 2021. Available at: https://vaccinare-covid.gov.ro/a-inceput-programarea-in-platforma-pentru-doza-a-iii-a/ The Government of Romania. National Coordination Committee for COVID-19 vaccination activities. Administration of the 4th dose of Comirnaty vaccine – Pfizer BioNTech. 2022. Available at: https://vaccinare-covid.gov.ro/wp-content/uploads/2022/05/20220511__vaccinare_doza_4.pdf The Government of Romania. Doza de rapel – booster. 2022. Available at: https://vaccinare-covid.gov.ro/doza-de-rapel-booster/

Country	Recommendation and timing of additional doses and booster doses of COVID-19 vaccination for individuals with weakened immune systems (i.e. immunocompromised and immunosuppressed)	Recommendation for booster doses of COVID-19 vaccination and timing for the general population	References
		Recommended for people over 60 years of age **Timing:** Booster dose given at least four months after primary vaccination. 4th dose: at least four months after the 3rd dose	
Slovakia	**Recommendation:** Additional dose doses for individuals (extended primary three-dose vaccination series). **Timing:** Additional dose given at least four weeks after second dose.	**Recommendation:** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). **Timing:** Booster dose given at least three months after primary vaccination.	Ministry of Health Slovak Republic. Usmernenie Ministerstva zdravotníctva Slovenskej republiky k aplikácii dodatočnej tretej dávky mRNA vakcíny pre imunokompromitované osoby a tretej posilňovacej dávky mRNA vakcíny pre ostatné osoby proti ochoreniu COVID-19. 2021. Available at: https://www.health.gov.sk/Zdroje?/Sources/Covid-19/Ockovanie/3-davka/MU-tretia-davka.pdf
Slovenia	**Recommendation:** Additional dose plus one booster dose for individuals (extended primary three-dose vaccination series plus a booster dose) Second booster dose for all particularly vulnerable chronic patients who have already received three doses (two primary doses and a booster dose). **Timing:** Additional dose given at least four weeks after second dose followed by a fourth dose at least three months after the third dose. Second booster dose at least 3 months after the 3rd dose.	**Recommendation**: One booster dose for individuals ≥18 years and 12-17 years with chronic diseases. Healthy individuals 12-17 years can choose to get a booster (2 dose primary vaccination series plus booster dose). Second booster dose (third dose) for people who have been vaccinated with the Janssen vaccine is also possible, but only when signing consent for off label use. **Timing:** Booster dose given at least three months after primary vaccination with mRNA vaccines or mixed schedule; at least two months after primary vaccination with Vaxzevria or COVID-19 Vaccine Janssen.	Slovenia - Nacionalni institut za javno zdravje (National Institute for Public Health). Priporočila za cepljenje proti COVID-19 2022. Available at: https://www.nijz.si/sites/www.nijz.si/files/uploaded/priporocila_za_cepljenje_proti_covid_uskl_psc_apr_2021.pdf
Spain	**Recommendation:** Additional dose plus one booster dose for individuals (extended primary three-dose vaccination series plus a booster dose). **Timing:** Additional dose given at least 28 days after second dose, followed by a booster dose at least five months after the third dose.	**Recommendation:** One booster dose for individuals ≥18 years prioritised from oldest to youngest age groups (two dose primary vaccination series plus booster dose). 2 doses of primary series + 1 additional dose+ 1 booster dose recommended in high-risk population groups **Timing:** Booster dose given at least five months after primary vaccination with mRNA vaccines; at least three months after primary vaccination with Vaxzevria or COVID-19 Vaccine Janssen.	Gobierno De España. Estrategia de vacunación COVID19 en España. 2022. Available at: https://www.sanidad.gob.es/profesionales/saludPublica/prevPromocion/vacunaciones/covid19/vacunasCOVID19_Profesionales.htm Government of Spain. Strategy COVID-19 vaccination. Proposal of administration of a second booster dose. Available at: https://www.sanidad.gob.es/profesionales/saludPublica/prevPromocion/vacunaciones/covid19/docs/COVID-19_Administracion_segunda_dosis_de_recuerdo.pdf
Sweden	**Recommendation:** Additional dose plus two booster doses for individuals ≥18 years (extended primary three-dose vaccination series, plus two booster doses). **Timing:** Additional dose given at least two months after second dose, followed by a first booster dose at least three months after third dose and a second booster dose at least three months after the first booster dose.	**Recommendation** One booster dose for individuals aged ≥18 years (two dose primary vaccination series plus booster dose). Two booster doses for individuals aged ≥65 years, LTCF residents, people who have home care (hemtjänst) or home healthcare (hemsjukvård) , people ≥18 with Down syndrome (two dose primary vaccination series plus two booster doses). **Timing:** First booster dose given at least three months after primary vaccination and the second booster dose given four months after the first booster dose.	Public Health Agency of Sweden/Folkhälsomyndigheten. Påfyllnadsdoser rekommenderas till alla över 18 år. 2022. Available at: https://www.folkhalsomyndigheten.se/smittskydd-beredskap/utbrott/aktuella-utbrott/covid-19/vaccination-mot-covid-19/information-for-dig-om-vaccinationen/pafyllnadsdos/