RAPID RISK ASSESSMENT

Increase of pertussis cases in the EU/EEA

8 May 2024

Summary

Epidemiological situation

Pertussis is an endemic disease in the EU/EEA and worldwide. Every three to five years, larger epidemics are expected even with high vaccination coverge.

After a few years of limited circulation in the EU/EEA, particularly during the COVID-19 pandemic, more than 25 000 cases of pertussis were reported in 2023, and more than 32 000 between January and March 2024. Similar numbers were observed in 2016 (41 026) and 2019 (34 468).

During 2023-24, in 17 EU/EEA countries, infants (those under the age of one year) represented the group with the highest reported incidence, whereas in six countries, the highest incidence is reported in adolescents 10-19 years. The majority of deaths occurred in infants. These surveillance data need to be interpreted with caution due to known differences in Member State surveillance systems, availability of laboratory methods, testing practices, as well as vaccination schedules. Furthermore, case ascertainment can vary by age group. In many countries, maternal vaccination programmes are used to protect infants in the first months of life. However coverage data, where available for such programmes, appears to be sub-optimal.

The observed epidemiological picture can be ascribed to a number of factors, which include: expected epidemic peaks, presence of unvaccinated or not up to date vaccinated individuals, waning immunity, decreased contribution of natural boosting in the overall population during the COVID-19 pandemic period.

Risk assessment

The risk from pertussis was assessed for four different population groups as a product of the probability of infection and its impact. The overall risk is assessed as **high** for unimmunised or partially immunised **infants <6 months of age**, as they represent the group with the highest morbidity and mortality from pertussis.

Infants >6 months and children up to 15 years of age have a **moderate** risk if they are unimmunised or partially immunised and have a low risk if they are fully vaccinated according to national immunisation schedules.

Older adolescents >16 years and adults up to 64 years of age have a **moderate** risk which is reduced to low if they have recently received a booster dose.

Finally, **older adults (≥65 years of age) and persons of any age with underlying conditions** such as asthma, chronic obstructive pulmonary disease (COPD) or immunosuppression, have an overall **moderate** risk from pertussis, having a moderate probability of infection and moderate impact (i.e. a higher probability of experiencing severe illness than individuals in the younger age/group).

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Recommendations

The primary objective of national pertussis immunisation programmes in EU/EEA countries should be to curb morbidity and mortality in newborn infants. To this end, and in view of the ongoing pertussis outbreaks, ECDC encourages EU/EEA public health authorities to focus on the following areas:

- Achieve and sustain **high vaccination coverage through timely and full completion of pertussis** primary immunisation series and subsequent boosters recommended nationally.
- In addition to the routine programme, **maternal immunisation (vaccination in pregnancy)** is a highly effective approach to prevent disease and death in young infants. There is a need to bolster interventions to improve access and implementation of childhood and maternal immunisation policies. Review and, if needed, upgrade of immunisation information systems will enable a follow-up of vaccination status across different providers and life stages to strategically inform vaccination programmes.
- **Increase the awareness of health professionals** about the epidemiological situation of pertussis in their geographical area, the clinical presentation of pertussis, and prevention through vaccination: if needed, develop protocols for the management of cases with protracted cough and laboratory confirmed pertussis. Pertussis can occur in persons of all ages with varying clinical picture, and clinical suspicion is often low. If needed, testing options should be outlined for the confirmation of the disease.
- **Continue surveillance of pertussis and ensure public health capacity for early detection, diagnosis, response to and control of outbreaks**, including appropriate contact tracing around the cases to protect close contacts at risk of severe disease. Monitoring and reporting of *B. pertussis* resistance to macrolides is important.
- **Employ risk communication on the disease and the importance of vaccination**, and strategies to promote vaccine acceptance and uptake. **Information on pertussis should stress that this is a highly transmissible disease, and there is a need to protect infants**. Healthcare providers' recommendations are very important for uptake of maternal vaccination, in countries that have such programmes, and for timely completion of the primary immunisation series and boosters. Factors that affect acceptance of the pertussis vaccine should be explored.

Epidemiological situation

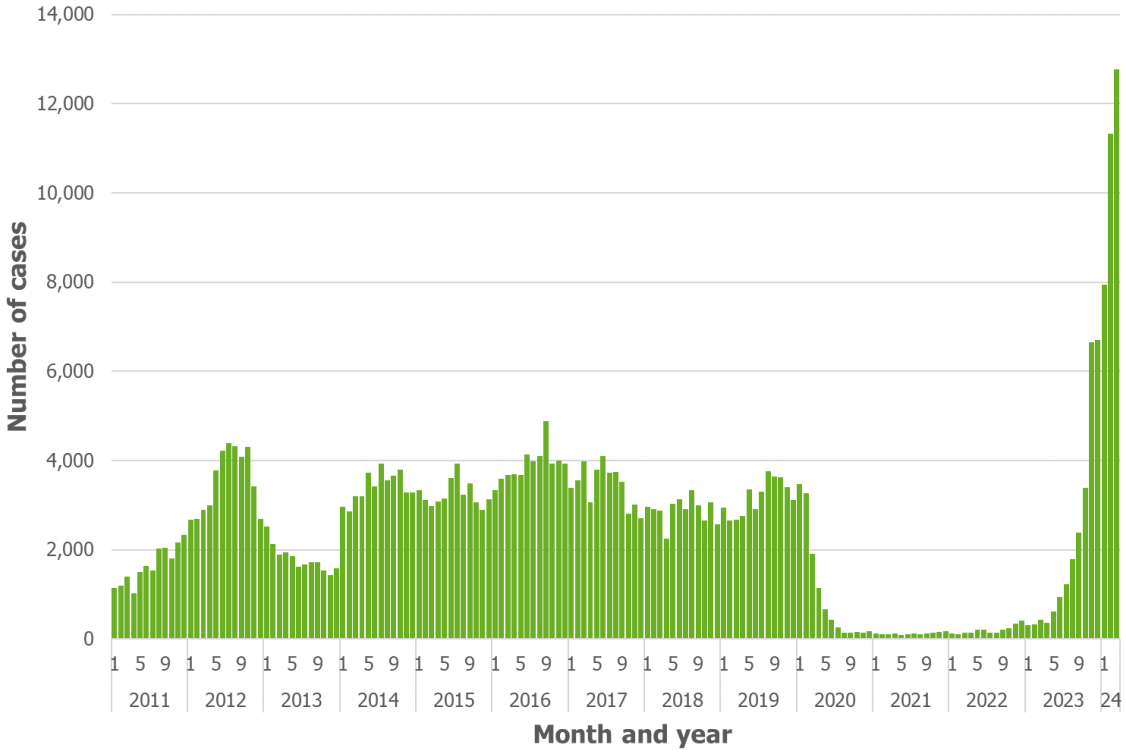
Due to increases in pertussis cases reported through epidemic intelligence sources [1,2], ECDC requested EU/EEA countries to provide pertussis surveillance data for all 2023 and January–April 2024[1] in order to quantify and assess the increase across the EU/EEA. There were 25 130 cases of pertussis reported between 1 January 2023 and 31 December 2023, and an additional 32 037 cases reported between 1 January and 31 March 2024 (Figure 1). This increase in cases occurred after a period of very low pertussis activity during the COVID-19 pandemic, between mid-2020 to the end of 2022 [3,4]. In the years between 2012–2019, inclusive, an average of 38 145 cases of pertussis were reported each year by EU/EEA countries, with a high numbers of cases observed in 2016 (41 026) and 2019 (34 468). While the number of cases reported in 2023 is below the 2012–2019 average, a steep increase was only observed in the second half of the year (Figure 1). In only the first three months of 2024, the number of reported cases is similar to what had been reported in previous years over a 12-month period.

According to information from open sources, as of 20 March 2024, an increase in pertussis cases has also been reported in many countries around the world, including Australia [5], Brazil [6,7], Bolivia [8], Canada [9], China [10], Israel [11], Montenegro [12], Serbia [13], the United States [14-16], and the United Kingdom [17,18].

[1] The additional data call was made on 11 April 2024 through the Epipulse platform, with a deadline of 18 April 2024. Countries were requested to provide aggregated data without further specification on the case definition or classification of cases. A total of 27 countries responded to this request with data of varying completeness for the period 1 January 2023 up until 11-18 April 2024. Some countries have reported data for part but not all of this time period (e.g. 1 January to 31 December 2023 only) and more recent data may be incomplete. Due to inconsitant reporting end dates, data reported for April 2024 were excluded and only data to 31 March 2024 were used for total case numbers and Figure 1. Analysis of age groups and deaths may include some cases reported in early April 2024. All 2023-2024 data are preliminary and subject to change.

The 2023-2024 data were pooled and analysed together with data available in The European Surveillance System (TESSy) for the period 1 January 2011 to 31 December 2022. Data available in TESSy were reported according to the EU case definition for the majority of countries. Information on how pertussis surveillance data are routinely collected can be found in the Surveillance Atlas of Infectious Diseases information sheet for pertussis and in the Surveillance Systems overview for 2022.

Figure 1. Number of pertussis cases reported to ECDC, by month and year, 1 January 2011 to 31 March 2024[2], EU/EEA[3]



Distribution by country

The increase in pertussis cases has not occurred uniformly across all EU/EEA countries (Annex 1). Some countries began seeing an increase from mid-2023 (such as Austria, Denmark and Norway), while most countries observed an increase from the end of 2023 and/or the beginning of 2024. The incidence per million population by country for 2023–24 is provided as a supplementary table in Annex 1.

Age distribution

Historically, infants (aged <1 year of age) have had the highest incidence of pertussis reported in EU/EEA countries (Figure 2). In 2023–24, an increase among infants has been observed along with large increases in 10–14 and 15–19 year olds, and to a lesser extent with increases in 5–9 and 1–4 year olds. Incidence among adults (>20 years old) has remained relatively low. There are some variations in the age distribution by country, which may be related to different pertussis vaccination schedules, to the timing of booster doses (described in Technical Annex 1), to the level of implementation of laboratory confirmation in different age groups, and to the age-groups targeted for surveillance.

In 2023–24, infants represented the group with the highest incidence in 17 countries[4] (Austria, Belgium, Bulgaria, Cyprus, Estonia, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Malta, the Netherlands, Portugal, Romania,

[2] Data for period 2011–2022 extracted from The European Surveillance System (TESSy) and data for 2023–2024 obtained from an additional data call to countries through EpiPulse in April 2024. The cases reported between 2011 to 2022 were reported and classified according to the EU case definition for pertussis for the majority of countries. In April 2024, countries were requested to report all pertussis cases in 2023–2024, irrespective of the classification or definition used. Some countries have reported data for part but not all of this time period (e.g. 1 January to 31 December 2023 only) and more recent data may be incomplete. All 2023-2024 data are preliminary and subject to change.

[3] Between 2011 and 2022, there were 27–29 countries reporting to TESSy each year: in 2011 (n=27), Croatia and Germany did not report; in 2012 and 2013 (n=28), Germany did not report; in 2014 (n=28), Iceland did not report; and between 2015–2022 (n=29), all countries reported. For all years, France reports data from a sentinel hospital surveillance network and only in infants <1 year of age. Despite UK historically being part of the EU, UK data have been excluded to allow comparison between all years.

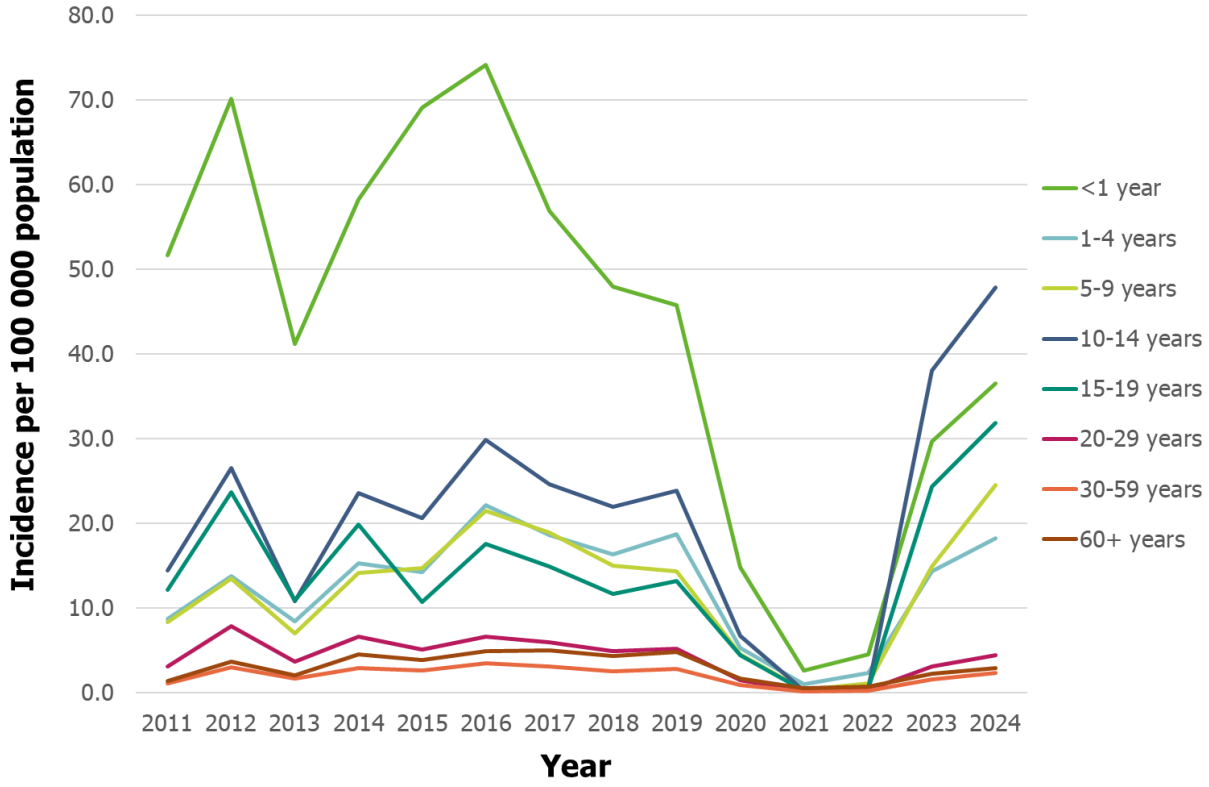
Data for 1 Jan 2023 to 31 Mar 2024: reported by 27 countries. No data were reported by Finland, Latvia or Poland. France reports data from a sentinel hospital surveillance network and only in infants <1 year of age.

[4] Incidence in France was also highest among infants however France reports data from a sentinel hospital surveillance network and only for infants <1 year of age, therefore they are not included in the list of countries.

Sweden, Slovakia). Among these countries, the age groups with the second and third highest incidence varied considerably between children aged 1–4 years, 5–9 years, 10–14 years and adolescents (15–19 years).

Three countries observed the highest incidence in children 10–14 years followed by adolescents aged 15–19 years (Croatia, Denmark, Luxembourg), and two countries had the highest incidence in adolescents 15–19 years followed by children 10–14 years (Czechia, Slovenia). In Spain, infants had the highest incidence in 2023, however, in early 2024, children aged 10–4 years had the highest incidence. In Norway, adolescents aged 15–19 years had the highest incidence in 2023, while in 2024, incidence was highest among children aged 10–14 years.

Figure 2. Incidence of pertussis cases reported to ECDC per 100 000 population[5], by age group and year, 2011–2024[6], EU/EEA[7]



Deaths

Between 2011–2022, a total of 103 deaths were reported, of which 69 (67%) were in infants and 25 (24%) were in adults 60 years of age and older. In the period between January2023 and April 2024, a total of 19 deaths have been reported: 11 (58%) in infants and eight (42%) in older adults (60+ years). The number of deaths by age group has varied between 2011 and 2024 (Figure 3).

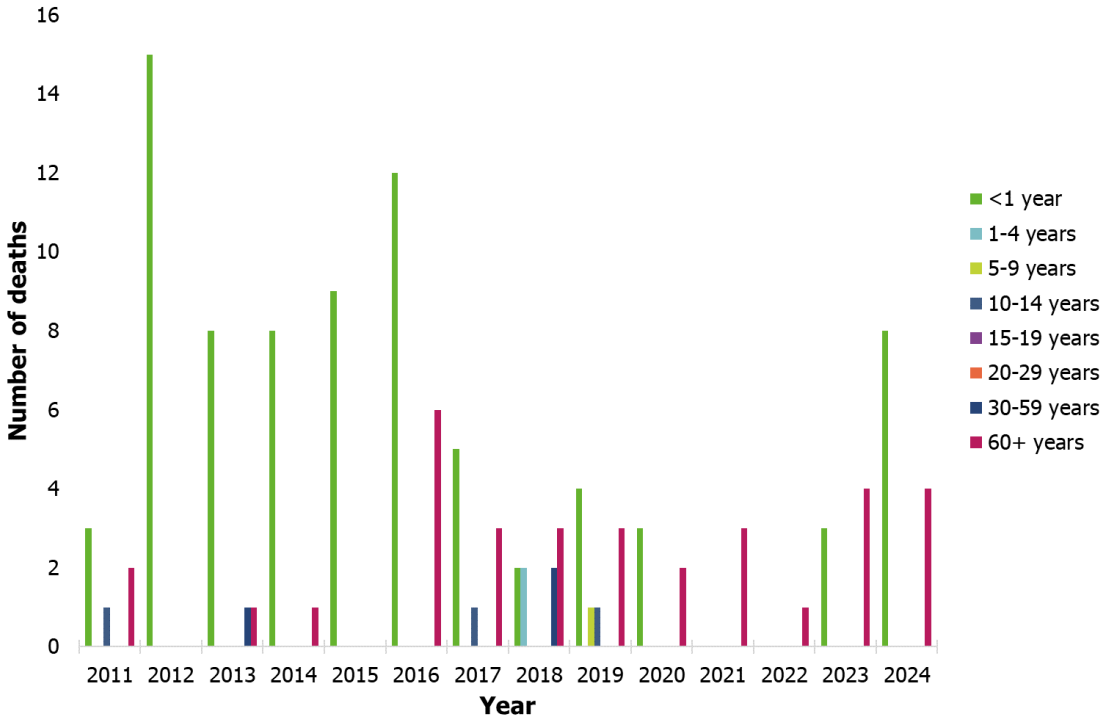
[5] Since 2024, population data are not yet available, the 2023 population estimates were used to calculate 2024 incidence. For each year and each age group, the total number of reported cases was divided by the total population for countries reporting in that year. Incidence in 2024 was calculated in the same way, despite only having cases for the first quarter. The French population used to calculate the incidence was only for infants aged <1 year, due to the nature of their surveillance system.

[6] Data for period 2011–2022 extracted from The European Surveillance System (TESSy) and data for 2023–2024 obtained from an additional data call to countries through EpiPulse in April 2024. The cases reported between 2011 to 2022 were reported and classified according to the EU case definition for pertussis for most countries. In April 2024, countries were requested to report all pertussis cases in 2023-2024, irrespective of the classification or definition used. Some countries have reported data for part but not all of this time period (e.g. 1 January to 31 December 2023 only) and more recent data may be incomplete. All 2023-2024 data are preliminary and subject to change.

[7] Between 2011 and 2022, there were 27–29 countries reporting to TESSy each year: in 2011 (n=27), Croatia and Germany did not report; in 2012 and 2013 (n=28), Germany did not report; in 2014 (n=28), Iceland did not report; and between 2015–2022 (n=29), all countries reported. For all years, France reports data from a sentinel hospital surveillance network and only in infants <1 year of age. Despite UK historically being part of the EU, UK data have been excluded to allow comparison between all years.

Data for 1 Jan 2023 to 31 Mar 2024: reported by 27 countries. No data were reported by Finland, Latvia or Poland. France reports data from a sentinel hospital surveillance network and only in infants <1 year of age.

Figure 3. Number of pertussis deaths reported to ECDC, by age group and year, 2011–2024[8], EU/EEA[9]



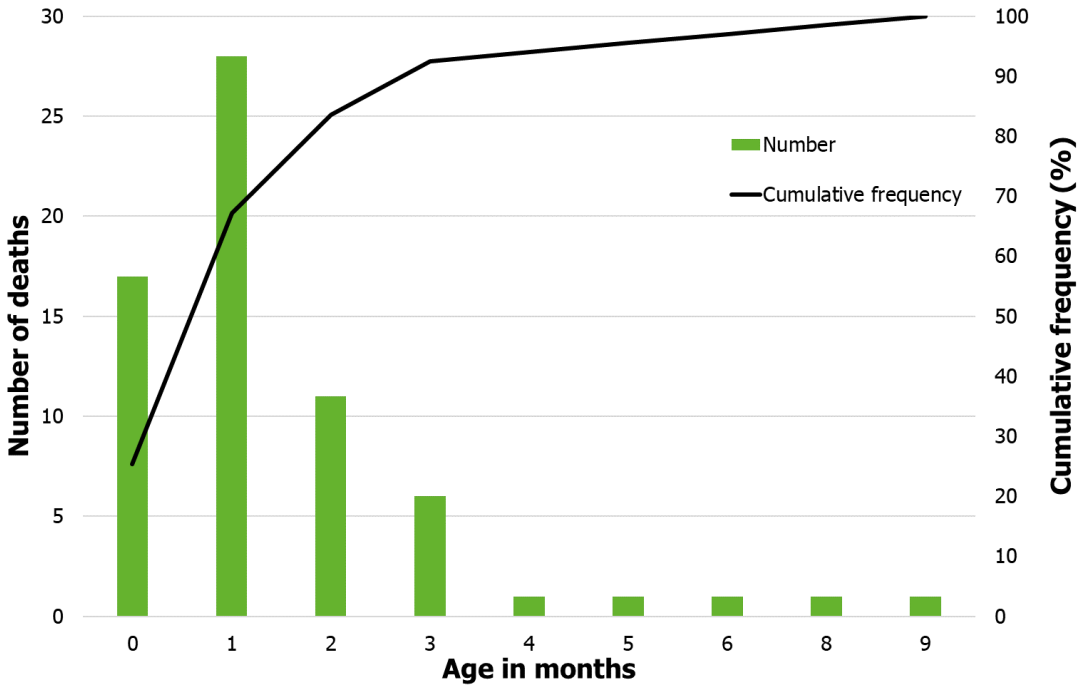
Between 2011 and 2022, 95.5% (n=64) of infant deaths occurred in infants aged <6 months, with most deaths occurring in one-month-old infants (Figure 4). Data by age in months are not available for deaths in infants occurring in 2023–24.

[8] Data for period 2011-2022 extracted from The European Surveillance System (TESSy) and data for 2023-2024 obtained from an additional data call to countries through EpiPulse in April 2024. The cases reported between 2011 to 2022 were reported and classified according to the EU case definition for pertussis for most countries. In April 2024, countries were requested to report all pertussis cases in 2023-2024, irrespective of the classification or definition used. Some countries have reported data for part but not all of this time period (e.g. 1 January to 31 December 2023 only) and more recent data may be incomplete. All 2023-2024 data are preliminary and subject to change.

[9] Between 2011 and 2022, there were 27–29 countries reporting to TESSy each year: in 2011 (n=27), Croatia and Germany did not report; in 2012 and 2013 (n=28), Germany did not report; in 2014 (n=28), Iceland did not report; and between 2015-2022 (n=29), all countries reported. For all years, France reports data from a sentinel hospital surveillance network and only in infants <1 year of age. Despite UK historically being part of the EU, UK data have been excluded to allow comparison between all years.

Data for 1 Jan 2023 to 31 Mar 2024: reported by 27 countries. No data were reported by Finland, Latvia or Poland. France reports data from a sentinel hospital surveillance network and only in infants <1 year of age.

Figure 4. Number and cumulative frequency of pertussis deaths in infants aged <1 year reported to ECDC, by age in months, 2011–2022[10], EU/EEA[11]



Vaccination programmes

All EU/EEA countries have a fully funded primary vaccination programme in place against pertussis in infants and young children [19]. While schedules and ages in the target infant/children population groups vary across countries, current pertussis schedules in use can be grouped as follows:

- Two primary doses administered between two to five months with a first booster administered between 10–12 months (2p+1 schedule) in Austria, Czechia, Denmark, Finland, France, Germany, Iceland, Italy, Liechtenstein, Luxembourg, the Netherlands[12], Norway, Romania, Slovakia, Slovenia[13] Spain, Sweden.
- Three primary doses (3p) administered between two to six months plus one booster commonly administered at 18–24 months (3p+1 schedule) in Belgium, Bulgaria, Croatia[14], Cyprus, Estonia, Greece, Hungary, Latvia (booster at 12–15 months), Lithuania, Malta, the Netherlands, Poland, Portugal. Notably the booster is administered earlier in Latvia (booster at 12–15 months).
- Three primary doses administered between two to six months and no booster by the age of 24 months in Ireland (3p+0 schedule).

In addition to the routine childhood programme, all EU/EEA countries, apart from Bulgaria, Estonia, Finland, Malta and Slovakia have a recommendation in place for a booster dose of acellular pertussis containing vaccine with reduced antigen (acp) in pregnant women [19]. Maternal vaccination with acellular pertussis containing vaccine can protect newborns before they are old enough to receive their own vaccines through the transfer of antibodies from their mothers. The recommendation was introduced on a temporary basis in Croatia and Hungary, respectively, during periods and in areas of high incidence. The recommendation is government funded in all countries. Depending on the countries, the maternal booster is usually recommended from the second semester of the pregnancy with a common window of administration recommended between 16 to 36 weeks of amenorrhea.

[12] In the Netherlands, two primary doses (at 3 and 5 months) are provided for infants born from mothers who were vaccinated during pregnancy (at 22 weeks gestation). An additional vaccination is given at 2 months if the mother is not vaccinated during pregnancy.

[13] In Slovenia, the first booster is recommended at 11-18 months.

[14] In Croatia, the first booster is recommended at 15-18 months.

The recommendations for a booster dose to adolescents and adults vary between countries. While Croatia[15], Denmark, Malta, the Netherlands, Portugal and Spain have no recommendation for a booster in adolescents, all the remaining countries recommend it for adolescents (10–16 years of age), with an interval since the last dose of the primary course of 3 to 11 years. In addition, Austria, Belgium, Finland, Cyprus, France, Finland, Germany, Greece, Italy, Liechtenstein, Luxembourg, Norway, Slovenia and Poland also recommend a booster dose to adults. The adult booster is recommended every 10 years in Austria, Belgium, Cyprus, , Greece, Italy, Luxembourg, Norway, Poland. In France, one dose is recommended for individuals 25 to 39 years old, followed by a booster dose every 10 years afterwards; in Liechtenstein and in Finland, the adult booster is recommended at the age of 25 years. In Czechia and in Germany[16] one booster dose in adulthood is recommended.

Vaccination coverage

In the EU/EEA, monitoring of pertussis vaccination coverage is done by WHO through the electronic WHO/UNICEF Joint Reporting Form (e-JRF). Data are collected annually for the third and fourth dose of pertussis-containing vaccines. According to the latest data available (2022), the vaccination coverage of the third dose of diphtheria tetanus toxoid and pertussis containing vaccine (DTP3) remains high in EU/EEA countries. This, reflects a good level of protection of infants at the age of six months in countries that adopted the 3p primary vaccine schedule, or in infants at the age of 11-12 months in countries that adopted the 2p+1 primary vaccine schedule [20]. At the EU/EEA level, the calculated median value currently reaches 94% coverage, with an observed decreasing trend from 97% in 2012 to 94% in 2022.

There are very scarce data on the vaccination coverage for the fourth dose of diphtheria tetanus toxoid and pertussis containing vaccine (DTP4) [20]. This indicator reflects the vaccination coverage for the primary booster administered at the age of 24 months or during preschool/primary school, depending on whether the primary schedule adopted is a 3p or a 2p+1.

In spite of the recommendation being in place in 24 EU/EEA countries[17], the reported maternal immunisation coverage collected through the ad-hoc data call through EpiPulse in preparation of this risk assessment was only reported by nine countries, for different years of estimates, and ranging between 1.6% and 88.5%, for the year 2023.

No data are available on uptake levels in either the adolescents or in adult age groups.

Further detailed analyses of pertussis vaccination schedules and data available on reported coverage are provided in Technical Annex 1.

Interpretation of data

Pertussis is endemic in the EU/EEA and worldwide, with resurgences observed every 3-5 years with increases often observed in the summer months in the EU/EEA.

The epidemiological data presented in this report need to be interpreted with caution taking into account the differences in Member States surveillance systems (e.g. covering various age groups, sentinel versus comprehensive), availability of laboratory methods, testing practices, as well as vaccination schedules. Furthermore, case ascertainment can vary by age group (e.g. lack of clinical suspicion in adults can lead to underdiagnosis).

The low level of pertussis activity between 2020–2022 [3,4] in the EU/EEA may have increased the proportion of the population susceptible to pertussis, and may be partly responsible for the increase currently observed. Indeed, low-level endemic, interseasonal transmission acting as a natural booster may contribute to the immunity in populations, thereby minimising the risk of large-scale outbreaks. Vaccination coverage rates of the childhood programmes are very high but have been affected by a small overall decline for the third dose of pertussis containing vaccines. Sub-national variation may exist and variations also exist in the implementation of a life course approach for pertussis vaccination. Preliminary data indicate that maternal vaccination coverage is moderate-low.

Worldwide, recent increased levels of pertussis have also been observed following the lower disease circulation during the COVID-19 pandemic, combined with sub-optimal vaccination uptake during the same timeframe, and coupled with waning immunity.

[15] Temporary recommendation of a cocooning strategy.
[16] Booster doses every 10 years are recommended for healthcare workers and those with close contact to newborns.
[17] In some countries, no monitoring systems are yet in place for maternal vaccination.

Pertussis incidence needs to be interpreted alongside vaccination schedules (primary series and boosters) and vaccination coverage (see Technical Annex 1). Past changes in schedules and uptake over time may result in changes in the age distribution of cases. There is strong evidence showing that vaccine and naturally-derived immunity against pertussis wane over time [21], (see Technical Annex 2). This means that cases can occur among individuals who were previously vaccinated.

Changes in the availability or use of PCR testing, particularly multiplex PCR panels (with *B. pertussis* included alongside other respiratory pathogens such as SARS-CoV-2 and influenza) may have led to increased case detection and reporting [22]. Similarly, increased clinician awareness as well as active case finding during outbreaks can lead to increased testing and case detection [23]. For these reasons, caution needs to be exercised when comparing current (2023–2024) data with historical pertussis data.

ECDC risk assessment for the EU/EEA

This risk assessment has been developed based on the currently available data at the time of publication and follows the ECDC rapid risk assessment methodology, where the overall risk is determined by a combination of the probability of infection and its impact [24]. The probability of infection and the impact of the disease are assessed at the time of an emerging health threat, taking into consideration characteristics of place (country (-ies) occurring) and person (prevalence of risk groups in EU/EEA population).

What is the risk associated with the observed increase of pertussis in the EU/EEA?

Table 1. Assessment of the risk associated with pertussis infection in the EU/EEA, by population

	Infants < 6 months	Infants > 6 months - children 15 years	Adolescents >16 years and persons up to 64 years of age	Persons ≥65 years, and/or younger persons with chronic respiratory conditions, or immunosuppression*
Probability	High	Moderate	Moderate	Moderate
Impact	High	Low	Low	Moderate
Overall risk	**High**	**Moderate**	**Moderate**	**Moderate**

**underlying conditions with increased risk for complications include asthma, chronic pulmonary disease or immunocompromised persons; e.g. persons living with HIV, cancer, etc.*

The probability of exposure to pertussis and potential subsequent infection depends on multiple factors including the vaccination status of the person (number of doses and time passed since last dose) and the vaccination status of close contacts, as well as the circulation of *B. pertussis* in the particular community, setting or age-group. Pertussis epidemics occur in cycles every three to five years, even in the post-vaccine era, and the disease is currently considered endemic in the adult population. Pertussis is very infectious, with a basic reproduction number (R0) of 12–17 and secondary attack rate in the household setting estimated at 70–100% [25]. The probability of exposure to pertussis in the EU/EEA is expected to rise in the coming months as the incidence of pertussis usually increases in late summer, although the COVID-19 pandemic may have affected this pattern.

The overall risk **for infants under the age of six months**, unimmunised or partially immunised, is assessed as **high**, with high probability of exposure and high impact. The source of infection for infants is often a parent, older sibling, or other caregiver with an unrecognised infection [26]. Nosocomial outbreaks in neonatal ICUs may also occur. Almost 80% of hospitalisations are reported among infants aged six months or younger. Furthermore, this age group experiences the highest reported mortality due to complications such as pneumonia, apnoea, seizures and encephalopathy. Neonates and infants up to two months of age have a pertussis case fatality rate of 2% [27]. Of the deaths reported to ECDC between 2011–22, 95.5% were in infants younger than six months of age. Therefore we assess that pertussis infection in this age group has a high impact. Maternal vaccination during the second and third trimester of pregnancy, currently recommended in most EU/EEA countries, has high effectiveness in preventing pertussis in the first two months of life [28-31]. Cocooning strategies, where immunisation of the caretakers of a newborn is recommended, have a lot of logistical issues and are often not effective [32,33].

For **infants >six months and children up to 15 years of age,** the overall risk is assessed as **moderate if they are unimmunised or partially vaccinated.** ECDC data show that 43% of the currently reported pertussis cases, both in 2023 and the first months of 2024, are in this age group, reflecting most likely the partial vaccination status and some waning immunity after the primary schedule. However, this group is likely to also include children who have recently completed the recommended vaccination doses with a pertussis containing vaccine (usually DTaP), thus having a high degree of protection from infection. The overall risk for these children will be low. The impact of pertussis in this age group is generally low.

Adolescents **over 16 years of age and adults** are at a **moderate risk** from pertussis**.** There is a moderate probability of infection due to the ongoing outbreaks and low impact of the disease. This population may include unvaccinated, partially vaccinated or fully vaccinated individuals in their childhood or even persons previously exposed or diagnosed with pertussis, including health professionals who may transmit pertussis in healthcare settings. Due to the waning of both natural and vaccine induced immunity, infections are common. This population may also have complications, but with overall good prognosis. Persons in this population group who have recently (<5 years) received a booster dose of a pertussis-containing vaccine (usually Tdap) are better protected from infection, and therefore at low risk.

Finally, **older adults (≥65 years of age) and persons of any age with underlying conditions** such as asthma or chronic obstructive pulmonary disease (COPD) or immunosuppression may experience increased severity of pertussis with higher rates of hospitalisation, usually due to pneumonia. Of the deaths reported to ECDC in 2023 and so far in 2024, 42% (8/19) occurred in older adults (60+ years). As the probability and impact in this category are moderate, their **overall risk** is assessed as **moderate** [34,35].

ECDC recommendations

Considerations for immunisation policy

Pertussis remains a challenging vaccine-preventable disease to control on a global scale. Recurring outbreaks and epidemics of pertussis are not unexpected according to the epidemiological cycle of the disease, and for the multifactorial reasons outlined earlier in this Rapid Risk Assessment.

Despite such challenges, the benefits of current immunisation programmes (see Technical Annex 1) should not be underestimated. Pertussis vaccines currently in use in EU/EEA immunisation programmes are highly effective and safe, and their use continues to significantly reduce morbidity and mortality. Without relentless efforts to sustain high pertussis vaccination coverage in line with existing national recommendations, the epidemiological picture would look more burdensome than it already does.

The **primary objective of national vaccination programmes in EU/EEA countries** is to curb morbidity and mortality in newborn babies and young infants, especially among those at higher risk, in their early stages of life.

To this end, and in view of the ongoing pertussis outbreaks, ECDC stresses that EU/EEA public health authorities should focus on the following areas:

- The **timely and full completion of primary immunisation series and subsequent booster doses** recommended nationally remains paramount, regardless of the specific design of the vaccination schedule in use. In line with WHO recommendations, every country should strive to achieve early and timely vaccination and maintain high coverage (≥90%) with at least three doses of pertussis vaccine at all levels (national and subnational). A decline in coverage can lead to a further increase in cases of pertussis. Timely and complete implementation of routine childhood vaccination programmes should take priority over potential schedule changes, as any such changes to current programmes may offset the fundamental benefits accrued in terms of coverage by current schedules, which are based on healthcare system capacity to reach and sustain high uptake in the target populations. Therefore, any programmatic changes, including temporary adaptations, should be duly justified by the national or local epidemiological situation, taking into account costs and avoiding jeopardising effects on other vaccines co-administered at the same time as pertussis vaccines.
- **Maternal immunisation is a highly effective approach to prevent disease and death in infants** in addition to the routine pertussis immunisation programme, among complementary vaccination strategies aimed to protect young infants that are still too young to be vaccinated. EU/EEA countries adopting maternal immunisation strategies are encouraged to strengthen efforts for an effective delivery of immunisation services to pregnant women. From a programmatic perspective, out of all complementary strategies considered over time to reduce the burden in very young individuals, maternal immunisation remains a more feasible strategy for the healthcare system to deliver, with documented evidence on its cost-effectiveness [36]. The current picture shown for the EU/EEA denotes that a significant number of countries (24 countries) are now recommending maternal immunisation in addition to the routine childhood programme. Nonetheless, data on implementation remain scarce (with vaccine coverage data available for only nine countries in 2023) and, where available, it reveals a somewhat suboptimal implementation of this programme in spite of its benefits (with reported vaccination coverage between 1.6% to 88.5%).

- Furthermore, considering the general epidemiological shift observed in recentyears towards adolescents and/or adults (and the observed waning immunity in this population) as well as the documented extensive circulation of *B. pertussis* in adults [37], some countries offer or may consider offering **booster doses in adolescents/adults as well as across the life-course**. The direct though waning protection that such vaccination may confer, especially for individuals with co-morbidities and at higher risk from pertussis, remains relevant for individual protection. While this approach may help reduce the burden in the adolescent or adult population, to date, there is no substantial evidence that this would effectively and/or cost-effectively help preventing severe pertussis in infants too young to be vaccinated, whose protection remains the main objective of pertussis vaccination programmes [38-40]. Such an approach should therefore be considered based on the national and local epidemiological situation, including from the perspective of the potential direct clinical benefit to the individuals. Boosting in adults in later years of life may also provide an opportunity for ensuring up-to-date vaccination of individuals with commonly co-administered vaccines against tetanus and diphtheria, for which, in particular, the lack of vaccine-induced seroprotection against diphtheria in adults is of concern and deserves further action [41]. Such an approach should be regarded as complementary in terms of objectives at the immunisation programme level, and should not divert resources from efforts to protect younger age groups.

A number of programmatic actions and healthcare system-related policy interventions considered advantageous to strengthen current pertussis immunisation programmes are provided in Technical Annex 3.

Actions to strengthen disease surveillance, early detection and control

Countries should continue surveillance of pertussis and strengthen their capacity for early detection and control of outbreaks at the local, regional, and national level.

Capacity for case investigation and contact tracing are needed.

- Contact identification and follow-up should focus on household members as well as close contacts at high risk of severe disease (e.g. infants, pregnant women, persons with asthma or other chronic lung disease or immunosuppression) and close contacts who work in high risk settings (e.g. healthcare workers in maternity, neonatal or paediatric settings, and childcare workers). Contact tracing should follow national guidance. Antibiotic post-exposure prophylaxis (PEP) may be considered for household members and close contacts at high risk of severe disease along the lines of national reccomendations. Vaccination can also be offered to household/close contacts who are unvaccinated or partially vaccinated, according to national recommendations.
- Antibiotic treatment is most useful if given early in the course of the disease; however, this is usually not possible due to delays in diagnosis. Treatment with a macrolide (erythromycin, clarithromycin, azithromycin) can be given within 21 days from the onset of cough of the index case to help reduce transmission. If appropriate, antibiotic treatment is commenced within 21 days of disease onset and patients are no longer considered infectious after five days of treatment [26,43].
- Children with pertussis (cases) should be excluded from childcare/school for 21 days from onset of symptoms, or five days if on appropriate antibiotic treatment, and in line with national guidelines. The same exclusion period should apply to cases who work in high-risk settings (e.g. healthcare workers in maternity, neonatal or paediatric settings, childcare workers or other settings with regular interaction with individuals at high risk of severe disease), and in line with national guidelines. All cases of pertussis should avoid contact with individuals at high risk of severe disease and should not attend any high-risk settings (e.g. maternity or paediatric wards) while infectious.
- Appropriate hand washing, respiratory etiquette and good ventilation of closed spaces should be advised.

Countries should strengthen laboratory diagnostic capacity for pertussis to manage increased needs. See Technical Annex 2 for details on laboratory diagnosis of pertussis.

Monitoring and reporting of *B. pertussis* resistance to macrolides is also important, as it may affect treatment options (see also Technical Annex 2).

Risk communication

There is a need to employ risk communication on the disease and importance of vaccination, and strategies to promote vaccine acceptance and uptake.

- Information on pertussis for parents, caregivers and others in close contact with a newborn and young infant should stress that this is a highly transmissible disease, and that there is a need to protect infants, as they are at highest risk of severe outcomes.
- The public should be made aware of disease symptoms, that these can vary by age, in particular in young infants, and of the importance of early treatment across all age groups.
- Communication activities addressing parents, caregivers and pregnant people should highlight the importance of vaccination during pregnancy to protect the newborn, in countries that have such a programme, and of the

timely administration of the first dose and completion of the child's primary vaccination schedule as per national recommendations in all countries.

- Strategies to increase uptake of pertussis vaccination should consider the importance of recommendations from healthcare providers, as a trusted source of information, and provision of information that addresses potential concerns around vaccination, for example during pregnancy. Factors that affect uptake of vaccines, during pregnancy (in countries which recommend pregnancy vaccination), in the national context should be explored, in order to develop tailored strategies. For example, studies have identified lack of knowledge about recommendations, perceptions that the pertussis vaccine is not needed and concerns around vaccine safety as important factors that contribute to lower vaccine uptake, in particular during pregnancy (details on study findings and specific references are provided in the Technical Annex 4).
- People should be made aware of the fact that neither previous infection, nor the vaccination, offer lifelong immunity. Misinformation around the disease and the vaccine should be addressed.
- More information from research on drivers and barriers of vaccine uptake, in particular during pregnancy, and suggested strategies to address low vaccine uptake, as well as examples of risk communication activities from countries and organisations, are provided in Technical Annex 4.

Limitations

Differences exist among national pertussis surveillance systems across the EU/EEA (case definition, laboratory testing etc), therefore data should be interpreted with caution, especially when comparing over time or between different countries.

Surveillance data for 2023 and 2024 should be considered as preliminary and are subject to change.

There are limitations in the available vaccination coverage data due to the differences among the national immunisation schedules for the primary series of pertussis containing vaccines. In addition, there is no global monitoring of vaccination coverage data for adolescents and adults, or for maternal immunisation. Finally, no subnational data were available.

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Technical Annex 1. Pertussis vaccination programmes and uptake in EU/EEA countries

Data source

The information on vaccination programmes was retrieved from the ECDC vaccination scheduler and completed with a desk review of specific national recommendation when required (e.g. insufficient information available in the ECDC vaccination scheduler) [19].

Vaccination programmes with pertussis containing vaccines are in place in all EU/EEA countries, with some variation across countries and target groups.

In pregnant women

Apart from Bulgaria, Estonia, Finland, Malta and Slovakia, all EU/EEA countries have recommendations for a booster dose of acellular pertussis-containing vaccine with reduced antigen (acp) in pregnant women. The recommendation had been taken on a temporary basis in Croatia and Hungary respectively during a period and in areas of high incidence. The recommendation is government funded in all countries. Depending on the countries, the booster is usually recommended during the second semester of the pregnancy with a common window of administration recommended between 16 to 36 weeks of amenorrhea.

In infant/young children

All EU/EEA countries have a primary vaccination programme in place against pertussis in infants and young children with the acellular vaccine component (acP) apart from Poland where the whole cell pertussis vaccine (wP) is recommended. The primary doses are administered following three vaccination schedules:

- Two primary doses administered between two to five months with a first booster administered at the age of 10–12 months (2p+1 schedule) in Austria, Czechia, Denmark, Finland, France, Germany, Iceland, Italy, Liechtenstein, Luxembourg, the Netherlands[18], Norway, Romania, Slovakia, Slovenia[19], Spain and Sweden
- Three primary doses (3p) administered between two to six months plus one booster commonly administered at 18–24 months (3p+1 schedule) in Belgium, Bulgaria, Croatia[20], Cyprus, Estonia, Greece, Hungary, Lithuania, Malta, Poland and Portugal. Notably the booster is administered earlier in Latvia[21] and in the Netherlands (booster at 12 months).
- Three primary doses administered between two to six months and no booster by the age of 24 months in Ireland (3p+0 schedule).

The primary vaccine doses and the first booster dose administered as part of the primary schedule are funded in all EU/EEA countries. The recommendation for primary vaccination, including the first booster either as part of 2p+1 or 3p+1 is mandatory in Bulgaria, Croatia, Czechia, France, Hungary, Italy, Latvia, Poland, Slovakia, Slovenia.

Depending on the countries, pertussis immunisation is initiated between two and three months of age regardless of the primary schedule adopted (2p or 3p). Some countries may choose to shorten the interval between the first two or first three primary doses to one month, while others may choose to have extended intervals (two months) between primary doses.

In children

Apart from Malta ('3p+1' primary schedule), all countries adopted a booster dose in children of late preschool or primary school ages (4–7 years). Depending on whether the primary doses was administered as a 2p+1 schedule or 3p+1 schedule, the children booster is either a fourth or a fifth dose of acP. The booster for children is funded in all countries and is mandatory in Bulgaria, Croatia, Czechia, Hungary, Italy, Latvia, Poland, Slovakia and Slovenia.

The time interval between the last dose of primary schedule ('2p+1' or '3p+1') and booster ranges between 2.5 years and six years across countries.

[18] In the Netherlands, two primary doses (at 3 and 5 months) are provided for infants born from mothers who were vaccinated during pregnancy (at 22 weeks gestation). An additional vaccination is given at 2 months if the mother is not vaccinated during pregnancy.
[19] In Slovenia, the first booster is recommended at 11-18 months.
[20] In Croatia , the first booster is recommended at 15-18 months.
[21] In Latvia, the first booster is recommended at 12–15 months.

In adolescents

Croatia, Denmark, Malta, the Netherlands, Portugal, Slovenia and Spain have no recommendations for a booster dose of pertussis antigen-containing vaccine in adolescents. Remaining countries have a recommendation for a booster dose of acellular pertussis containing vaccine in adolescent which is the fifth or sixth dose depending on countries adopted a '2+1' or '3+1' primary schedule. Depending on the countries, the adolescent booster is scheduled between 10- and 16-year-old.

When recommended the time interval between last dose of childhood booster and adolescent booster ranged between 3 years and 11 years (maximum range) across countries.

In adults

As of 2024, a total of 12 countries have a pertussis-containing vaccine programme in place for adults, albeit with different schedules adopted in terms of age of the recommendation and number of booster doses recommended during the adult life course [19]. Austria, Belgium, Czechia, Finland, France, Germany, Greece, Italy, Liechtenstein, Luxembourg, Norway and Poland, Slovenia have recommendations for a booster dose of pertussis-containing vaccine in adults. The adult booster is recommended every 10 years in Austria, Belgium, Greece, Italy, Luxembourg, Norway and Poland. In Czechia, one booster is recommended in adulthood 10–15 years after last dose, in Germany one booster during adulthood. In France, one dose is recommended between 25- and 39-year-old followed by a booster dose every 10 years afterwards; in Liechtenstein and in Finland, the adult booster is recommended at 25 years of age.

Some countries have a single dose recommendation, usually in early adulthood (25 years), while others recommend that a pertussis antigen is added to the diphtheria tetanus booster every 10 years.

Table A1. Summary table of pertussis vaccination programmes in the EU/EEA countries as of April 2024

Country	Infant programme		Children/adolescent programmes			Adult programme
	Type of primary schedule including first booster	Age third dose*	Booster 1	Booster 2	Booster 3	
Austria	2p+1	11–12m	6–7y	16		Every 10y
Belgium	3p+1	4m	15m	5–6y	14–16y	Every 10y
Bulgaria	3p+1	4m	16m	6y	12y	
Croatia	3p+1	6m	15–18m	5y		
Cyprus	3p+1	6–8m	18–20m	4–6y	11–12y	
Czechia	2p+1	11–13m	5–6y	10–11y		One booster dose in adulthood
Denmark	2p+1	12m	5y			
Estonia	3p+1	6m	24m	6–7y	15–16y	
Finland	2p+1	12m	4y	14–15y		At age 25y
France	2p+1	12m	6y	11–13y		At age 25y
Germany	2p+1	11m	5–6y	9–16y		One booster dose in adulthood[22]
Greece	3p+1	6m	15–18m	4–6y	11–12y	Every 10Y
Hungary	3p+1	4m	18m	6y	11–12y	
Iceland	2p+1	12m	4y	14y		
Ireland	3p+0	6m	4–5y	12–13y		
Italy	2p+1	10m	5y	12y		At age 19y and then every 10y
Latvia	3p+1	6m	12–15m	7y	14y	
Liechtenstein	2p+1	12m	4–7y	11–15y		At age 25Y
Lithuania	3p+1	6m	18m	6–7y	15–16y	
Luxembourg	2p+1	11m	5–6y	15–16y		Every 10y
Malta	3p+1	4m	18m			
Netherlands[23]	2p+1	5m	12m	4y		
Norway	2p+1	12m	7y	15y		Every 10y
Poland	3p+1	5–6m	16–18m	6y	14y	Every 10y
Portugal	3p+1	6m	18m	5y		
Romania	2p+1	11m	6y	14y		
Slovakia	2p+1	10m	5y	12y		
Slovenia	2p+1	11–18m	7y	16y		One booster dose in adulthood (not funded)
Spain	2p+1	11m	6y			
Sweden	2p+1	12m	5y	14–16y		

"p" primary, "m" months, "y" years.
**The third dose is either the third primary dose in case of "3p" schedule or the first booster administered after the second primary dose in case of "2p+1" schedule.*

[22] Booster doses every 10 years are recommended for healthcare workers and those with close contact to newborns.
[23] In the Netherlands, two primary doses (at 3 and 5 months) are provided for infants born from mothers who were vaccinated during pregnancy (at 22 weeks gestation). An additional vaccination is given at 2 months if the mother is not vaccinated during pregnancy.

Vaccination coverage

Data source

Vaccination coverage data of the third and fourth doses of diphtheria-tetanus-pertussis containing vaccines (respectively DTP3 and DTP4) were retrieved from the WHO immunisation data portal websites. As WHO WUENIC data estimations are not yet available for 2023, vaccination coverage data for 2023 was collected from the countries as defined as 'official national coverage' through the Epipulse data call and should be considered preliminary. For the remaining years and to allow comparisons, the other vaccination coverage data in this review is based on the so defined 'official national vaccination coverage' value reported as available in the WHO Immunisation data portal WHO [20]. The vaccination coverage data available in the WHO Immunisation data portal does not include vaccination coverage documenting the maternal pertussis vaccination programme. The vaccination coverage of the DTP3 reflects the level of protection obtained with the last dose of the primary pertussis vaccination schedule at six months with a 3p primary vaccination schedules or at 11 or 12 months with a 2p+1 primary vaccination schedule. The vaccination coverage of the DTP4 reflects the level of protection observed at time of first booster dose administered at 18–24 months of age in countries that adopted the '3p' primary dose schedule or at time of booster dose administered at 4–7 years of age in countries that adopted the '2+1' primary vaccination schedule.

DTP3

In 2022, the vaccination coverage for DTP3 ranged between 84% in Austria to 99% in Greece, Hungary and Portugal with the calculated median value reaching 94% for the EU/EEA countries (no data available for Liechtenstein). In 2022, the level of vaccination coverage was below 90% in Austria, Estonia, Poland, Romania and Slovenia and 90% in Lithuania. At the EU/EEA level, a slightly decreasing trend was observed with the median vaccination coverage declining from 97% in 2012 to 94% in 2022.

A total of 18 countries reported vaccine coverage for 2023 data through Epipulse. The median vaccination coverage remained stable to 94%. Out of 18 countries, three countries reported vaccine coverage data below 90%.

DTP4

In 2022, the vaccination coverage for DTP4 ranged between 16% and 100% (with no data reported for Austria, Czechia, Finland, France, Greece, Ireland, Slovenia). Although there is no specific objective set up for the coverage of this specific vaccine dose, the vaccination coverage was below 90% in Bulgaria, Croatia, Cyprus, Estonia, Iceland, Italy, Lithuania, the Netherlands, Poland and Spain. In 2022, at the EU/EEA level, the median vaccination coverage reached 89.7% and declined compared to 2018 (91.1%).

A total of 16 countries reported vaccine coverage for 2023 data through Epipulse. The median vaccination coverage was slightly higher compared to 2022 and reached 92.5%.

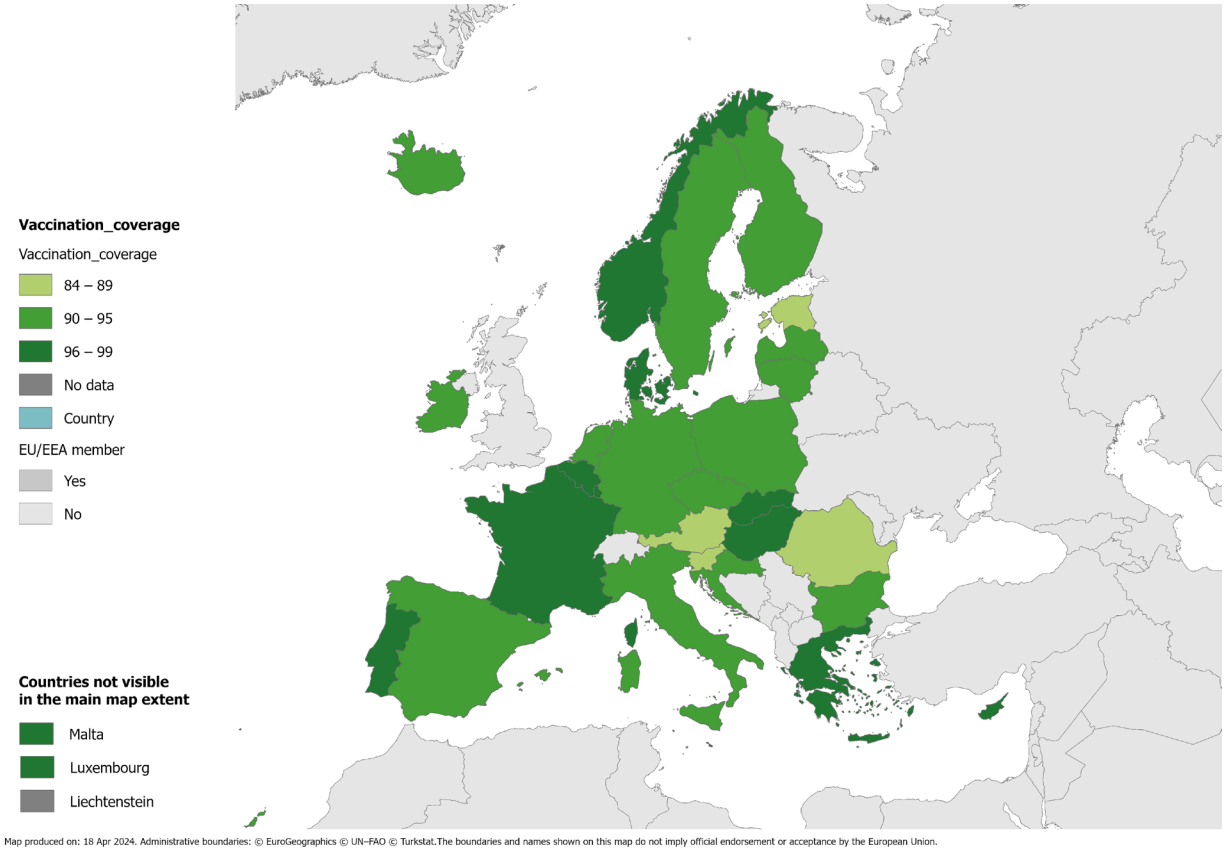
In pregnant women

Few countries reported vaccination coverage data through the ad-hoc data call in Epipulse in pregnant women, albeit for different years. It ranged between 1.6% and 88.5%. Data are reported in the table below.

Table A2. Reported vaccination coverage of pertussis containing vaccine in pregnant women in selected European countries

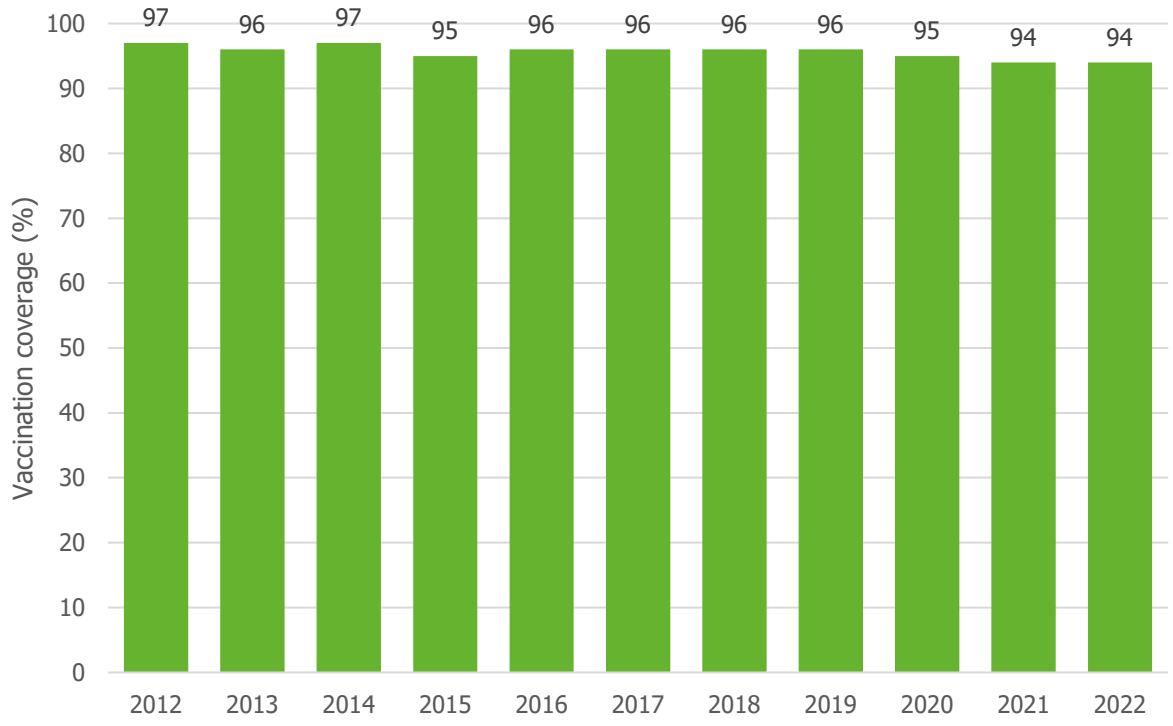
Country	Year of estimates	Vaccination coverage (%)
Belgium	2023	64.3 (Flanders 85%; Wallonia 38.9%; Brussels 31.1%)
Czechia	2023	1.6
Denmark	2023	69
Germany	2021	39.7
Ireland	2019	49.9
Portugal	2023	84
Romania	2023	8.8
Slovenia	2023	6.5
Spain	2023	88.5

Figure A1. Vaccination coverage (%) of third dose of diphtheria-tetanus-pertussis (DTP3) (- containing) vaccines, EU/EEA, 2022



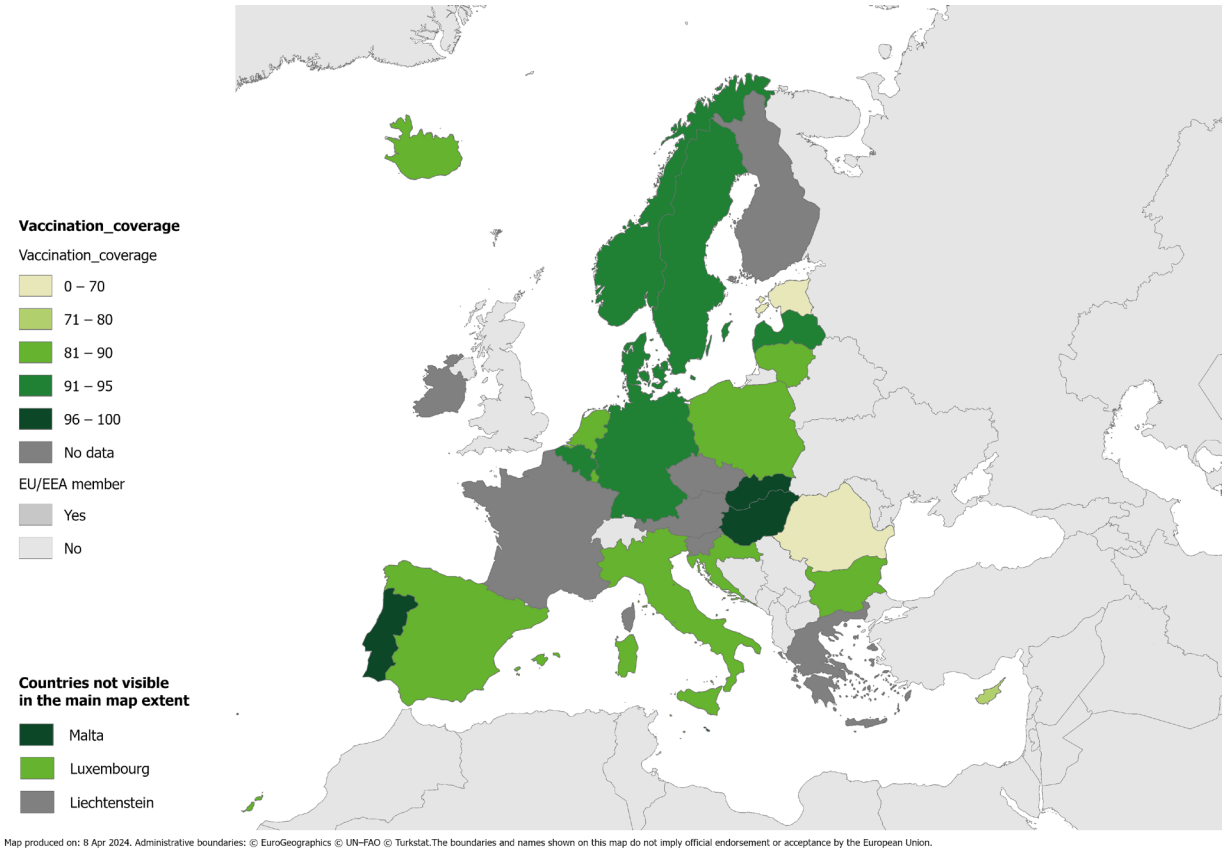
Source: WHO Immunisation data portal.

Figure A2. Median vaccination coverage (%) of third dose of diphtheria-tetanus-pertussis (DTP3) (- containing) vaccines, EU/EEA, 2012–2022



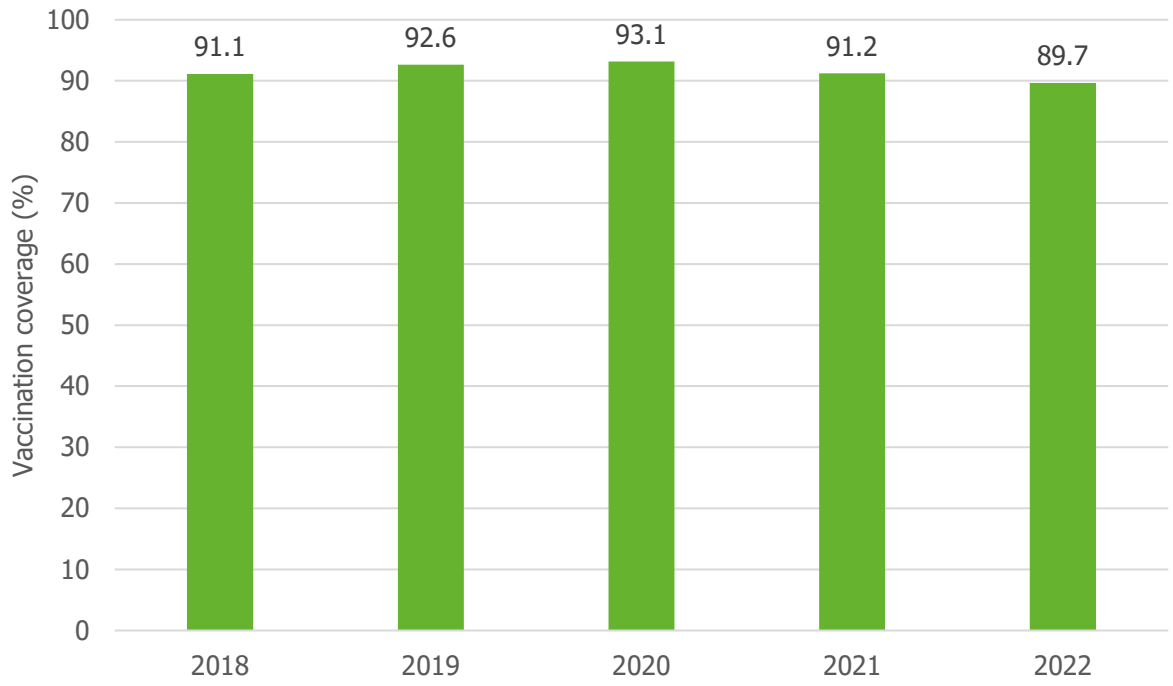
Source: Immunisation data portal.

Figure A3. Vaccination coverage (%) of fourth dose of diphtheria-tetanus-pertussis (DTP4) (- containing) vaccines, EU/EEA, 2022



Source: WHO Immunisation data portal.

Figure A4. Median vaccination coverage (%) of fourth dose of diphtheria-tetanus-pertussis (DTP4) (- containing) vaccines, EU/EEA, 2018–2022.



Source: WHO Immunisation Data Portal; data not available before 2018.

Technical Annex 2. Characteristics of pertussis disease, pertussis vaccines and pertussis laboratory confirmation

Despite long-running vaccination programmes, control of pertussis transmission remains challenging. This is due to a combination of factors, including the scheduling of pertussis-containing vaccine doses and coverage (already described in Technical Annex 1), the non-specific clinical presentation of cases, laboratory diagnosis methods, waning of both vaccine and infection-derived immunity, and other factors. A more detailed description of some of these factors is provided below. As a result of these barriers, increases in pertussis transmission, including large outbreaks, are often observed every three to five years.

Clinical presentation of pertussis

The clinical presentation of pertussis varies by age and immunity status, making early diagnosis and prevention of transmission challenging [43]. Among all cases, in the first one to two weeks following onset of pertussis infection (catarrhal stage), the symptoms are non-specific and can include coryza, low-grade fever, and a mild cough (that gradually becomes more severe) [26,43]. In young infants, the cough may be mild, or apnoea may be the only symptom [26]. In the subsequent weeks (paroxysmal stage), the cough becomes more severe, with bouts (paroxysms) of coughing, sometimes followed by post-tussive vomiting [26,43]. More commonly among immunologically naïve children and adolescents, the characteristic 'whoop' may be audible associated with paroxysms. In children, adolescents and adults whose immunity has waned, the catarrhal stage may be mild, followed by a persistent cough (with or without paroxysms) lasting from two weeks to several months [26,43]. Studies have shown that up to 13% of protracted cough is due to pertussis [25]. Cases are highly infectious from onset until the early paroxysmal stage (approximately first one to two weeks), with infectiousness gradually decreasing over the subsequent three weeks [26]. If appropriate antibiotic treatment is commenced within 21 days of disease onset, patients are no longer considered infectious after five days of treatment [26,43]. Due to the non-specific presentation of pertussis in the early (but highly infectious) stage, there can be a delay in presentation to healthcare, testing and diagnosis. Transmission may already occur, especially to close contacts, during this time [26].

Laboratory diagnosis of pertussis

Several laboratory methods are available for diagnosis of pertussis (including PCR, serology and culture), however the interval between onset of illness and presentation to healthcare services influences the use of these methods [44].

In 2022, ECDC published a guidance document (*Laboratory diagnosis and molecular surveillance of Bordetella pertussis*) in which these methods are described in more detail.

Where the incorrect diagnostic method is selected, based on the timing of presentation, a false negative result may be obtained. During the early stages of infection (within 21 days of onset), PCR or culture can be used as *B. pertussis* organisms are present in high numbers in the upper airway. Diagnosis using PCR is often performed, as *B. pertussis* is difficult to culture even under ideal circumstances, however even though the use of culture has been decreasing from year to year, it is still highly recommended as the isolates can be used for molecular surveillance of emerging antigenic variants and of antimicrobial resistance. Where presentation and testing occur two weeks or more after onset, serology to detect *B. pertussis* specific antibodies should be used.

Furthermore, commercial real-time quantitative PCR kits (qPCR) and multiplex respiratory panels are now widely used in diagnostics, allowing many respiratory pathogens to be tested simultaneously (for example influenza, RSV, parainfluenza, *B. pertussis* etc). However, this may lead to false negative results for pertussis as the sensitivities of these kits for individual pathogens are likely to be compromised due to multiplexing and/or choice of target [45,46]. Despite the lower sensitivity, multiplex panels may assist in diagnosing some pertussis cases where a stand-alone pertussis test was not considered due to presentation with non-specific symptoms.

A study carried out in the EU/EEA found that there is high heterogeneity in methods used for the laboratory confirmation of pertussis among national pertussis reference laboratories [47]. To evaluate the effects of different pertussis immunisation programmes in the EU/EEA, standardisation and harmonisation of laboratory methods are needed. Further understanding of changes in use of different diagnostic methods over time are key to describe the picture in the EU/EEA and need to be further detailed.

Waning of pertussis vaccines and duration of immunity

Pertussis immunity, whether vaccine-derived or following infection, is not life-long. Pertussis vaccines provide high levels of protection against symptomatic infection (especially severe) for the first few years following vaccination [48]. However, the protective immunity derived from vaccination wanes as time since vaccination increases [48,49]. This waning immunity effect is also seen after pertussis infection [49]. Vaccine-derived immunity wanes in the 2–12 years after vaccination [49-51], while infection-derived immunity wanes in the 4–20 years after infection [49]. The rate of waning may be more rapid for individuals who had only received acellular vaccines, than for those who had whole-cell vaccines (or priming with a whole-cell vaccine followed by acellular vaccine doses) [48].

High vaccination coverage is important to provide protection to the age cohort being vaccinated, however it is important to note that as the immunity in this cohort wanes, they become susceptible to infection. The optimal timing of vaccination booster doses needs to consider waning immunity of children/adolescents in order to have effective pertussis control [49].

Other emerging issues

Bordetella parapertussis

Bordetella parapertussis is closely related to *B. pertussis*, and both have similar common virulence factors, such as pertactin (PRN), filamentous hemagglutinin (FHA), adenylate cyclase toxin, and heat-labile toxin, with the notable exception of pertussis toxin, which is specific to *B. pertussis* [52]. *B. parapertussis* causes a similar but often milder illness that cannot be clinically distinguished from *B. pertussis* [53]. Pertussis vaccines usually do not provide protection against *B. parapertussis* [26,54].

Laboratory-confirmation of *B. parapertussis* is possible using PCR-based methods [44]. However, as a number of genetic targets are present in the genome of more than one species of *Bordetella*, the choice of targets and interpretation of the results are crucial [44]. Mis-interpretation of these targets can lead to incorrectly identifying *B. pertussis* isolates as *B. parapertussis*, or vice versa [44]. In 2018, an External Quality Assessment (EQA) was conducted to assess the use of PCR by national pertussis reference laboratories to differentiate between *B. pertussis* and other *Bordetella* species, including *B. parapertussis* [22]. Overall, this EQA found that the interpretation and reporting of results for *Bordetella* species was problematic with certain PCR targets and/or assays [22].

In most EU/EEA countries, identification of a *B. pertussis* infection requires mandatory reporting to national public health authorities [55], with cases classified according to a standard case definition [56]. However, as *B. parapertussis* infection does not require mandatory reporting, the prevalence and potential contribution to the overall pertussis burden is largely unknown. A study in Finland between 1994–1997 showed that 32% of patients with paroxysmal cough had *B. parapertussis*, and that co-infections with both *B. pertussis* and *B. parapertussis* can occur [57]. A study of clinical samples collected between 2008–2010 across nine US States identified that overall, 14% were positive for *B. parapertussis*, but also that positivity for *B. parapertussis* varied by year and age group (with higher *B. parapertussis* positivity in children aged <5 years) [58].

Vaccine evading strains

Acellular *B. pertussis* vaccines (ACV) are most commonly used in the EU/EEA. Unlike whole-cell vaccines (WCV), which were developed from suspensions of killed whole *B. pertussis* organisms, the acellular vaccines contain only purified components from the *B. pertussis* organism. There is some variation in the production of these vaccines, however acellular vaccines typically contain a combination of pertussis toxin (PT), pertactin (PRN), filamentous hemagglutinin (FHA), and fimbriae 2 and 3 (FIM2,3).

The antigenic variation between *B. Pertussis* vaccines (both WCV and ACV) and circulating strains has been described in detail [59]. Following the introduction of ACVs, *B. pertussis* isolates not expressing the vaccine antigen PRN have been widely reported, but these *B. pertussis* PRN-deficient isolates can still cause typical symptoms of pertussis [22]. In addition, *B. pertussis* strains not expressing PT or FHA have been reported in countries including Australia, France, Slovenia, Sweden and the US [60-66].

While the non-expression of vaccine antigen targets is a cause for concern, as these isolates may evade vaccine-derived immunity, the clinical implications remain unclear. One study did not find an impact in the vaccine effectiveness of acellular vaccines in a setting with high prevalence of PRN-deficient strains [67]. The isolation of vaccine antigen deficient isolates of *B. pertussis* from clinical cases of pertussis clearly means that they are still capable of causing infection. Antigen expression testing of *B. pertussis* isolates is not routinely performed by all Member State reference laboratories. A combination of laboratory, epidemiological and clinical data will allow better assessment of their significance.

In 2021, an EQA was conducted to assess the ability of national pertussis reference laboratories to determine expression/non-expression of *B. pertussis* antigens [22]. Overall, the results were encouraging, however the need for additional training in this area was recommended [22].

Macrolide resistance

Macrolide antibiotics (erythromycin and azithromycin) are the recommended drugs to treat *B. pertussis* infection in many countries [68]. An increase in the spread of macrolide resistant *B. pertussis* isolates could impact pertussis treatment and control efforts. However, to date, macrolide resistant *B. pertussis* isolates have mainly been found in China, and such isolates have only been found sporadically in Europe, the Middle East and in North and South America [69].

In 2022, an EQA was conducted to assess the ability of national pertussis reference laboratories to characterise the antimicrobial susceptibility of *B. pertussis* isolates [22]. Overall, the ability of the participating laboratories to correctly identify the antimicrobial susceptibility was encouraging, however the need for guidelines and additional training in this area were also identified [22].

Technical Annex 3. Programmatic actions and healthcare system-related policy interventions

In view of strengthening vaccination efforts, the following key public health actions are identified and can be considered by the different actors involved in the design, implementation and/or evaluation of pertussis immunisation programmes:

For **stakeholders responsible for the management of immunisation programmes**:

There is an important need to strengthen or upgrade, if needed, the use of effective immunisation information systems so as to:

- Follow-up on the status of those eligible for vaccination across the entire journey of complete pertussis immunisation; as the full vaccination course requires the delivery of several doses, including a booster dose where recommended, with often large time intervals in between doses as well as different parts of the healthcare system responsible for the delivery of each dose (e.g. primary series vs. booster in school-age children), **immunisation information systems must effectively enable the follow-up of vaccination and care across different health providers and stages of life**;
- More accurately generate population-based estimates of vaccination coverage, while at the same time, **enabling the identification of children and individuals who may be partially/insufficiently vaccinated**; this should help inform the design of **more targeted catch-up vaccination efforts** helping both providers and vaccine recipients to complete the primary immunisation series and/or subsequent booster doses in line with national recommendations. Such intervention would, in principle, benefit not only the effective monitoring and management of pertussis vaccination programmes, but also all immunisations, especially those co-administered with pertussis vaccines through combined vaccine products;
- For **maternal immunisation coverage, the implementation of robust systems to monitor the deployment of the vaccine in an open cohort of pregnant women is critical** to further study the acceptability, the effectiveness and the impact of the maternal recommendations. The implementation of a vaccination coverage monitoring system in pregnant women is challenging, the denominator is an open cohort of women, and there might be no system in place for the recording of information about vaccine administered during pregnancy. Different sets of indicators could be considered based on those used for the monitoring of influenza vaccination coverage in pregnant women including 1) the percentage of pregnant women vaccinated with a pertussis-containing vaccine during pregnancy; 2) percentage of newborns or young infants of mothers vaccinated with a pertussis-containing vaccine during pregnancy. Further work is needed to implement a routine monitoring system and to harmonise the indicators across countries.

From a **healthcare system perspective, efforts to specifically strengthen the delivery of maternal immunisation programmes, where they exist,** can take into account the following considerations and actions drawn from international experience [70-72]:

- The design and use of opt-in/opt-out orders, and especially opt-out orders, which convey a preference for vaccination by setting maternal vaccination as the 'default' and requiring an 'active' decline of the immunisation service by provider and/or vaccine recipient (also defined as 'standing' orders);
- The provision of 'on-site' vaccination as an integrated part of routine antenatal care versus 'off-site' vaccination options, in view of a more convenient access to the service for busy pregnant mothers. This requires clear roles and responsibilities as well as effective communication between different healthcare providers/services (e.g. antenatal care specialists/nurses, gynaecologists, obstetricians, general practitioner) responsible for the follow-up on pregnancy to ensure adequate responsibility and training for the delivery of the immunisation service;
- The implementation of integrated clinical decision support tools as part of Electronic Health Records (EHRs) which can effectively support healthcare personnel with prescribing/access privileges to the record, with evidence-based recommendations on immunisation needs.

Regarding **healthcare providers**, public health authorities should increase, where needed, awareness about pertussis and assist in developing appropriate case management protocols. In particular, the following could be considered:

- Raise pertussis clinical suspicion in individuals of all ages, including awareness of the different clinical picture pertussis presents as of different ages, and/or in regards to on vaccination status, and awareness that pertussis can occur in the same individual as immunity wanes;
- Raise awareness of appropriate methods of testing for laboratory confirmation of pertussis, which vary in relation to time since onset of clinical symptoms, identification of cases, clinical suspicion, testing, etc.;
- Healthcare workers need to be updated on the local epidemiological situation and provided with guidance for heightened suspicion and prompt diagnosis of pertussis.

- Protocols for the management of cases with protracted cough (>14 days) should be developed, including for healthcare settings:
  - Pertussis is transmitted via droplets and fomites; therefore, cases should be in respiratory isolation and excluded from school, daycare or other public setting. Young children with primary infection shed more *B. pertussis* than older children and adults. Disinfection plays little role in controlling transmission, but respiratory hygiene should be implemented. Cases are not considered infectious after receiving five days of macrolide treatment, or 21 days after the onset of cough, if not treated. [25].
  - Healthcare workers themselves can contract pertussis and transmit the disease in healthcare settings. If diagnosed, they should be removed from clinical duties and preferably self-isolate. Healthcare workers can return to work after receiving at least five days of treatment with a macrolide antibiotic.
  - Treatment with a macrolide (erythromycin, clarithromycin, azithromycin) given as early as possible before the paroxysmal stage can reduce symptoms and the severity of the disease; otherwise, it assists in reducing transmission [26].

Technical Annex 4. Further information on strategies to increase vaccine acceptance, and risk communication activities

Studies on barriers and facilitators for vaccine acceptance and uptake, and strategies to promote vaccination

A variety of factors can influence uptake of recommended vaccinations, be it for vaccination during pregnancy, for parents to follow the recommended routine childhood immunisations schedule, or for uptake of recommended vaccines and booster doses in adolescents and adults. Vaccine acceptance is complex and context-specific, and varies across time, place and type of vaccine [73]. ECDC has highlighted the importance of identifying the factors leading to lower vaccine acceptance and uptake for designing targeted strategies, and a framework such as the 5Cs model (looking at Confidence, Constraints, Complacency, Calculation, and Collective responsibility) can serve to understand these [74].

Studies done on vaccine acceptance of pertussis vaccination (and other vaccines) during pregnancy and among mothers of infants, indicate that main barriers to vaccine uptake include lack of knowledge of recommendations among those pregnant, as well as risk perceptions around the disease and vaccine safety concerns. Studies continuously highlight the important role of healthcare providers' recommendations in increasing vaccine uptake. Examples of studies are provided below:

- An Italian study [75] among women and gynaecologists identified lack of knowledge on recommendations and perceptions that the vaccine is not needed as key factors leading to low uptake (of diphtheria-tetanus-pertussis containing vaccines and of flu vaccine) in pregnant women. Notably, some of the women believed that they were protected by previous vaccination as a reason for not taking the pertussis vaccine.
- Similarly, a study from Czechia [76] found low awareness among pregnant women about the possibility of being vaccinated against pertussis during pregnancy. The study stresses the importance of increasing awareness about recommendations among the public and HCWs, emphasising the benefits of the vaccine, and incorporating vaccination into routine prenatal care.
- Findings from a systematic review of interventions to increase vaccination during pregnancy (including also against pertussis) [77] suggest the following strategies at the patient level to improve maternal vaccination rates:
  - addressing misconceptions and promoting the benefits of vaccination amongst pregnant women and their families;
  - tailored approaches, including written material, can enhance understanding and confidence in vaccination;
  - community outreach programmes can educate pregnant women and their families about the importance of vaccination.
  - sharing success stories and personal testimonials from pregnant women who have received vaccines was also mentioned as a strategy that can increase confidence and motivation.

Acknowledging that adolescents and adults can be an important source of disease transmission to vulnerable infants, a Canadian study looked into factors that determine uptake among adults of tetanus, diphtheria and pertussis vaccination [78]. Perceived severity of pertussis was significantly linked to willingness to receive the vaccination, but overall participants characterised pertussis as a less severe disease. Even the elderly were less inclined to take the pertussis vaccine. However, this study also found that adults were particularly inclined to accept the vaccine in order to protect vulnerable infants. Based on findings, the study highlighted the importance of addressing perceived disease risk in the efforts to promote uptake, and that campaigns should include personally relevant messages that emphasise on: disease severity in older persons, perceived interference with regular activities in young adults, and on the protection of infants among new parents or infant caretakers.

Examples of risk communication activities

Examples from available communication materials, awareness raising strategies on pertussis and information on the importance of vaccination, from countries and organisations, are provided below:

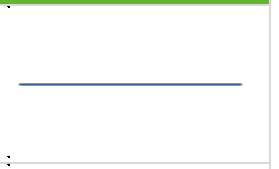
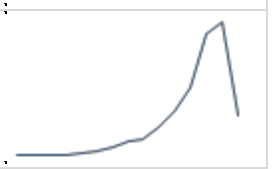
- A factsheet for the general public, with key information on pertussis, is available in the European Vaccination Information Portal, in all EU/EEA languages [79].
- In the context of the current pertussis outbreaks, Spain's Paediatric Association-Advisory Committee on Vaccination is raising awareness about the situation [80]. It encourages healthcare professionals involved in children's and women's health to inform about the risks of pertussis and other infectious diseases and to promote and facilitate access to vaccination. It also calls on families to ensure that children are up to date with vaccinations and appeals especially to pregnant women to take the recommended vaccines, including against pertussis. An infographic (in Spanish) provides information about the disease, the importance of maternal vaccination, the vaccination schedule for infants, and also mentions that close family members should be vaccinated as another measure to protect the baby [81].
- Belgium includes recommendations on communication in a risk assessment on the pertussis situation, such as awareness raising activities among GPs and paediatricians, including via professional networks, and highlighting the importance of maternal vaccination to protect the newborn [82].
- The health services of Ireland published a leaflet (from 2020) for pregnant women on pertussis, with answers to several potential questions, e.g. about the disease, vaccination, vaccine safety, contraindications [83].
- In the context of the introduction of free of charge vaccination of pregnant women in Norway from May 2024, the Norwegian Institute of Public Health has published information and a leaflet (in several languages) on pertussis vaccination in pregnancy [84,85]. The leaflet can be handed-out for example during antenatal checks.
- Among a variety of communication materials, Immunize Canada also developed messages for social media addressing some of the common myths around pertussis (e.g. that it is only a childhood disease, that symptoms are always similar) and around safety concerns on getting vaccinated during pregnancy [86].

Annex 1. Pertussis incidence by country

Supplementary Table 1. Incidence of pertussis cases reported to ECDC per 1 million population*, by country and year, 1 January 2023 to 31 March 2024†, EU/EEA‡

Country	2023												2024			TREND
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Austria	2.6	2.2	3.1	2.3	2.3	8.9	17.2	33.8	57.0	51.2	65.7	60.1	83.6	86.0	127.4	
Belgium	1.1	1.4	3.0	2.5	3.2	6.0	7.8	13.7	13.9	11.7	11.6	13.1	17.3	19.7	27.8	
Bulgaria	0.0	0.5	0.2	0.0	0.2	0.3	0.2	0.8	0.2	0.0	0.6	0.3	0.8	2.8	14.1	
Croatia	0.3	0.0	0.5	0.0	0.5	0.3	3.6	8.1	16.1	93.7	571.3	553.6	258.1	112.7	43.4	
Cyprus	0.0	0.0	1.1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	
Czechia	1.2	0.6	1.2	1.4	0.7	0.8	0.5	1.1	4.3	6.3	12.2	15.2	34.9	116.0	338.0	
Denmark	2.0	2.5	5.4	6.4	17.5	48.9	50.2	76.0	134.0	190.6	280.7	207.0	138.6	81.8	63.5	

Country	2023												2024			TREND
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Estonia	0.0	0.7	0.7	0.0	0.7	1.5	1.5	1.5	1.5	3.7	8.1	2.2	5.1	0.7	8.8	
France'	0.0	1.5	7.4	7.4	1.5	1.5	7.4	7.4	4.4	2.9	5.9	5.9	-	-	-	
Germany	1.9	2.0	2.4	1.4	1.7	1.3	1.6	1.6	2.2	3.0	4.4	4.2	7.6	8.8	11.5	
Greece	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.3	1.1	2.2	3.9	
Hungary	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.3	0.4	0.4	
Iceland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Ireland	0.0	0.0	0.2	0.2	0.4	0.0	0.0	0.4	0.0	0.9	0.6	0.8	1.5	0.9	3.6	
Italy	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.4	0.4	0.4	0.4	0.4	0.8	2.9	9.9	

Country	2023												2024			TREND
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Lichenstein	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Lithuania	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.3	0.0	0.3	0.0	1.0	2.8	2.8	3.5	
Luxembourg	0.0	0.0	0.0	1.5	1.5	6.1	3.0	1.5	0.0	1.5	6.1	6.1	43.9	99.9	402.5	
Malta	0.0	0.0	0.0	0.0	1.8	0.0	3.7	0.0	0.0	0.0	1.8	0.0	3.7	1.8	1.8	
Netherlands	0.7	0.7	0.4	0.8	2.0	3.9	6.5	12.9	13.4	23.2	37.3	56.9	100.0	110.8	32.6	
Norway	5.3	5.5	9.7	6.9	16.9	14.6	10.4	16.0	17.9	29.9	47.7	38.1	39.7	51.7	59.8	
Portugal	0.2	0.0	0.0	0.0	0.1	0.0	0.1	0.3	0.2	0.3	0.3	1.1	2.7	5.6	7.0	
Romania	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.3	0.0	0.2	0.1	0.8	1.7	1.2	

Country	2023												2024			TREND
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
Slovakia	0.7	1.7	1.5	3.1	1.5	2.2	2.0	2.2	4.1	5.2	8.3	8.7	8.3	15.8	26.5	
Slovenia	0.9	0.0	2.4	1.9	0.5	0.9	0.5	3.3	0.9	3.8	17.0	27.4	72.3	119.0	184.2	
Spain	0.8	0.7	0.6	1.3	3.1	4.1	6.5	6.1	4.3	5.6	9.7	15.1	36.2	91.2	72.8	
Sweden	0.0	0.2	0.1	0.0	0.3	0.8	0.6	1.0	1.7	4.1	2.5	2.0	2.5	2.9	4.4	

**Since 2024 population data are not yet available, the 2023 population estimates were used to calculate 2024 incidence. For each year, the total number of reported cases was divided by the total population for countries reporting in that year. Incidence in 2024 was calculated in the same way, despite only having cases for the first quarter. The French population used to calculate the incidence was only for infants aged <1 year, due to the nature of their surveillance system.*

† Data for period 1 Jan 2023 to 31 Mar 2024 obtained from an additional data call to countries through EpiPulse in April 2024. Countries were requested to report all pertussis cases in 2023–2024, irrespective of the classification or definition used. Some countries have reported data for part but not all of this time period (e.g. 1 January to 31 December 2023 only) and more recent data may be incomplete. All 2023-2024 data are preliminary and subject to change.

‡ Data for 1 Jan 2023 to 31 Mar 2024 were reported by 27 countries. No data were reported by Finland, Latvia or Poland.