Folkhälsomyndigheten
PUBLIC HEALTH AGENCY OF SWEDEN

Pertussis surveillance in Sweden

23rd annual report

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Purpose

The Public Health Agency of Sweden has conducted enhanced surveillance of pertussis since 1996, when acellular vaccines were introduced into Sweden's national immunisation programme for children. The surveillance includes the incidence of reported pertussis cases per age group and follow-up of all reported cases of pertussis in patients 0–20 years of age through structured telephone interviews. This report includes results for 2020, as well as some analyses from the past 23 years.

Pertussis is serious and sometimes life threatening for unvaccinated infants under the age of 6 months. Both pertussis infection and vaccination provide good but relatively short-lived protection against infections of pertussis disease.

The aim of the surveillance of pertussis is to provide knowledge to inform potential changes in the national immunisation programme or other interventions to protect infants. Surveillance data on pertussis epidemiology, on severe disease progression, and on the importance of laboratory testing and prophylactic antibiotic treatment of infants are disseminated regularly through scientific articles, on the Public Health Agency's website, at conferences and in courses aimed at health care professionals.

This report is primarily written for health care professionals, particularly those working in maternal and child health care, school health care, primary care, and those working in the counties' Departments of Communicable Disease Control and Prevention as well as public health officials and authorities in Sweden elsewhere.

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Abbreviations

aP Acellular pertussis (vaccine)

CHC Child health care

DTaP Diphtheria-, tetanus, and acellular pertussis vaccine

dTap Diphtheria, tetanus, pertussis vaccine (low-dose diphtheria and pertussis vaccine)

EPS Enhanced pertussis surveillance

Hib *Haemophilus influenzae* type b

NIP National immunisation programme

PCR Polymerase chain reaction

PHAS Public Health Agency of Sweden

SHC School health care

SMI *Smittskyddsinstitutet*, in English: Swedish Institute for Communicable Disease Control

SmiNet Computer-linked reporting system for reports of infections, including pertussis infections

wP whole-cell pertussis (vaccine)

Summary

During 2020, 241 laboratory-confirmed cases of pertussis in all ages were reported, of which 20 cases were among children younger than one year of age. This 23rd annual report of enhanced pertussis surveillance summarises the epidemiology of pertussis in Sweden since the introduction of acellular pertussis (aP) vaccine into the national immunisation programme in 1996. The current report will particularly focus on the most vulnerable age group with the highest risk for severe disease, namely children 0–12 months of age.

The incidence of pertussis among infants as well as among the population overall has decreased since 1996. There have been no infant deaths due to pertussis since 2015. The incidence of pertussis was low during 2009–2013, but the number of reported cases increased threefold in 2014 for all ages and stayed at an elevated level during 2015–2019. The incidence among infants in 2020 was the lowest since the reporting of pertussis cases became mandatory in 1997, which was interpreted as being due to measures to reduce the spread of COVID-19. As in previous years infants aged 3 months and younger had the highest overall incidence of pertussis and also the highest rate of hospitalisation and complications due to pertussis. This group of infants contracted pertussis before they had received the first dose of vaccine. Although the timeliness of the first dose of vaccine was 97% overall, the time between onset of disease and start of antibiotic treatment for infants was still more than 10 days. Hence, the awareness of the disease among caregivers needs to be further improved.

Compliance with the COVID-19 measures resulting in social distancing has likely been a key factor in the historically low number of pertussis cases in infants in 2020. The historically low numbers emphasises the importance of continued enhanced surveillance of pertussis. Also, continued work to maintain timely immunization and to increase the awareness of pertussis among health care workers is important. Advising a minimum of social contacts for the new-born child and its family could also be of importance in the post pandemic era to decrease the burden of pertussis disease in infants. In August 2022 recommendations for maternal vaccination was introduced.

Background

See **22nd Pertussis report** for more description of the background (1).

Vaccination registration and vaccine coverage in Sweden

For many years, Sweden has had a well-established and internationally renowned Child Health Care (CHC) system covering >99% of all children in the country from new-borns to 6 years of age, and for decades Sweden has had a 97–99% coverage of the DTaP vaccinations recommended in infancy by the national immunisation programme (NIP). Health care, including vaccinations, is provided by the School Health Care (SHC) system for children from 6 to 18 years of age. CHC and SHC nurses vaccinate children and register the vaccinations in individual medical records and report the vaccine doses given within the NIP. Vaccination coverage is then estimated at the national level by the PHAS. Since January 2013, it has been mandatory to report all vaccinations given within the NIP to the national immunisation register. A mandatory reporting directly to the national vaccination register at PHAS will in coming years replace the current reporting system from the regions.

In the pertussis vaccine studies (Trial I and II) performed in the 1990s, a large proportion of Swedish children were enrolled. The largest study, Trial II, comprised 46.9% of the infants born in 1993 and 42.0% of those born in 1994. Infants born during the latter part of 1995 were vaccinated against pertussis in most parts of the country, with the start of vaccination taking place in January 1996 when aP vaccines were introduced into the NIP. At the age of 2 years, the overall three-dose coverage for the 1995 cohort was 59.3% (Table 1).

With the introduction of a DTaP vaccine in 1996, the three-dose coverage for pertussis vaccination at 3, 5, and 12 months of age rapidly reached 98.7%. The national vaccination coverage has remained at a high and stable level over subsequent years during which a switch was also made to combination vaccines of aP vaccines (2) (Table 1). Free catch-up vaccinations to more than 65,000 children born in the 1990s were offered in the Gothenburg study area from 1996 to 1999 (3). Likewise, children in the rest of the country were also offered catch-up vaccination to some degree. The vaccination coverage for the fourth dose of aP-containing vaccine (DTaP-Polio) among 5-year-old children is estimated to be above 90%according to the vaccination register . Vaccination of 14–16-year-old teenagers with the fifth booster dose (dTap) started in August 2016, and so far the coverage is about 90% according to the vaccination register. The lower coverage compared to infant vaccination may partly be due to underreporting.

Table 1: Vaccination coverage with the three-dose vaccination with aP-containing vaccines for children born from 1993 to 2018. The children should have had their second birthday before the evaluation of coverage in January each year.

Year of birth	aP coverage with 3 doses (percent)
1993	46.9
1994	42.0
1995	59.3
1996	98.7
1997	98.6
1998	98.7
1999	98.5
2000	98.3
2001	98.4
2002	98.6
2003	98.7
2004	98.6
2005	98.3
2006	98.4
2007	98.0
2008	98.3
2009	98.3
2010	98.4
2011	98.4
2012	98.2
2013	98.1
2014	97.5
2015	97.3
2016	97.4
2017	97.5
2018	97.3

The enhanced pertussis surveillance study in Sweden

See **22nd Pertussis report** for a description of the enhanced pertussis surveillance study (1).

Method

Data sources and Methods

See **22nd Pertussis report** for a description of the data sources and methods (1).

Diagnostics

Diagnostic methods

The diagnostic methods used have changed over time. Until 2003, confirmation of Bordetella pertussis by culture was the dominant laboratory method in all age groups. In 1997 the proportion of PCR-confirmed cases was less than 5%, but in 2003 around 20% of all laboratory reports were based on PCR. In children, PCR is now the most common method for diagnosing pertussis. Since 2006, serology and PCR have been the most common methods used for diagnosing pertussis also in patients older than 10 years of age. Nowadays fewer than 5% of the pertussis reports are based on culture (Figures 1 and 2).

Table 2 shows the diagnostic methods for cases 0–20 years of age included in the enhanced pertussis surveillance (EPS). PCR was the most common diagnostic method used in 2020 (Table 2).

Figure 1: Laboratory methods used for verification of cases in children aged 0–10 years between 1997 and 2020. Data are based on laboratory-confirmed cases reported to SmiNet.

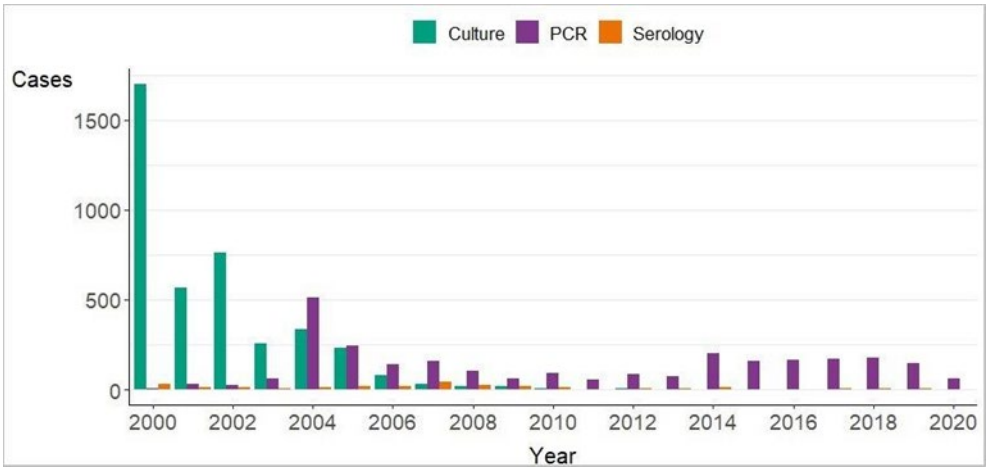


Figure 2: Laboratory methods used for verification of cases in children aged 11 years or older and adults between 1997 and 2020. Data are based on laboratory-confirmed cases reported to SmiNet.

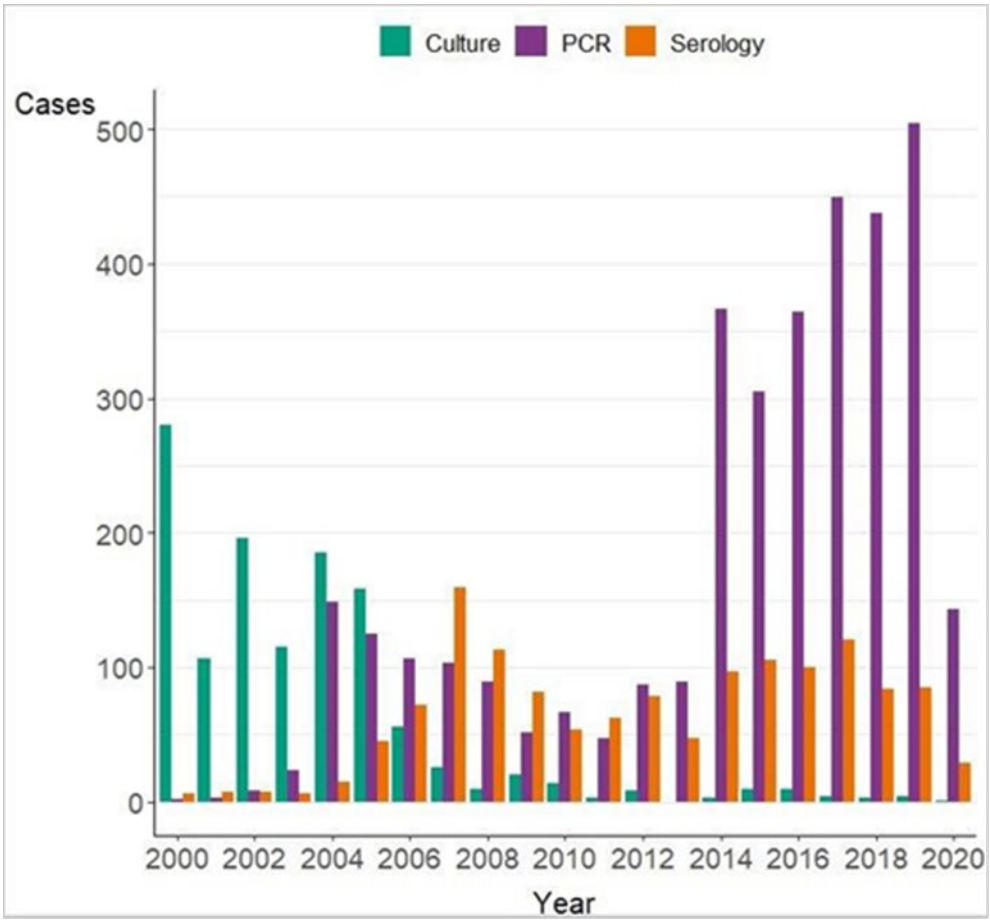


Table 2: Laboratory methods used for verification of cases in children 0-20 years of age (number of tests by method)

Age (years)	Method	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0–1	Culture	263	121	229	94	112	82	33	14	12	12	4
0–1	PCR	1	7	2	24	186	69	56	68	45	39	46
0–1	Serology	1	1	0	0	0	1	4	12	6	2	1
2–6	Culture	653	210	224	61	69	43	23	10	5	6	1
2–6	PCR	3	8	10	16	181	63	35	41	14	11	26
2–6	Serology	5	1	3	0	3	7	2	8	9	6	2
7–12	Culture	873	282	383	144	236	163	38	10	4	1	1
7–12	PCR	2	18	18	35	182	149	67	65	45	11	22
7–12	Serology	22	10	16	9	13	17	24	30	15	11	13
13–16	Culture	56	25	44	38	64	46	19	8	4	5	4
13–16	PCR	1	0	2	4	38	38	28	40	33	22	10
13–16	Serology	2	0	0	1	4	16	12	29	21	22	6
16–20	Culture	24	3	10	5	4	9	2	3	1	5	2
16–20	PCR	0	0	0	0	10	8	11	7	11	9	12
16–20	Serology	1	1	1	1	0	2	6	13	8	11	6

Age (years)	Method	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0–1	Culture	2	1	2	1	0	1	1	1	0	2
0–1	PCR	36	53	42	135	94	93	89	77	70	22
0–1	Serology	1	2	0	4	0	0	2	1	0	0
2–6	Culture	0	2	1	0	1	1	1	0	0	0
2–6	PCR	12	22	24	44	42	44	43	65	46	25
2–6	Serology	1	2	6	4	0	2	2	3	4	3
7–12	Culture	2	3	0	0	1	0	1	0	1	0
7–12	PCR	5	10	15	37	41	60	68	65	61	24
7–12	Serology	1	2	2	8	5	3	5	7	3	1
13–16	Culture	0	2	0	0	3	0	0	0	0	0
13–16	PCR	10	12	11	44	29	45	57	50	48	19
13–16	Serology	7	5	3	7	6	11	15	16	8	10
16–20	Culture	0	1	0	1	2	1	0	0	0	0
16–20	PCR	11	11	13	43	34	36	34	23	59	16
16–20	Serology	11	11	5	9	9	6	7	6	9	1

Case definition in the EPS study

A case in the EPS study is defined as having a laboratory-confirmed or clinically reported pertussis diagnosis. Only positive samples that are taken more than 6 months after a previous positive sample are considered to be a new episode of pertussis.

Sample size considerations and the calculation of incidences

Formal a priori sample size calculations are not meaningful in a post-marketing follow-up of the NIP or in the observational studies included in this report. Age-specific incidence rates of pertussis cases per 100,000 person years are based on the number of laboratory-confirmed reported pertussis cases during the study period from Oct. 1, 1997, to December 31, 2020, reported to SmiNet. In addition, annual overall incidences and age-specific incidences of pertussis in Sweden are based on the number of notified culture-confirmed or PCR-confirmed cases of pertussis, and from 2008 also serology-confirmed cases in the whole population and in all age groups. Furthermore, annual incidences are based on age at the notification of cases and on the corresponding mid-year populations derived from the mean of population numbers in two consecutive years divided by two (Länk till SCBs webbsida To simplify the calculations of person time of follow-up, we assumed an equal number of new-born infants each month of a calendar year, i.e. 7,212 children per month during 1996 and 6,842 children per month during 1997. In addition, it was assumed that all children were born in the middle of the month and that vaccination took place according to the recommended schedule, i.e. at 3, 5, and 12 months of age. Only person time since Oct. 1, 1997, was included because the collection of laboratory-confirmed cases of pertussis started from that date.

With these simplifications, we calculated the number of person months for each monthly cohort of new-borns in the following age/vaccination intervals:

- Person-months from birth to 3 months of age (before dose 1).
- Person-months between 3 and 5 months of age (between dose 1 and 2).
- Person-months between 5 and 12 months of age (between dose 2 and 3).
- Person-months after 12 months of age (after dose 3) until December 31, 2020.

Results

Number and incidence of reported pertussis cases in all ages

A total of 269 cases were reported to SmiNet during 2020, including both laboratory-confirmed and clinically suspected cases (reported by physicians) (4).

In the present report the data referred to as SmiNet data presented in Tables 3 and 4 are laboratory-confirmed cases reported during each year. According to this definition, 241 laboratory-confirmed cases of pertussis were reported to SmiNet during 2020 with a corresponding incidence 2.3/100,000 person years (Table 3). After five years (2009–2013) with low incidence of reported cases of pertussis (2.5/100,000 person years on average), a significant three-fold increase in incidence was observed in the general population (7.1/100,000 person years) in 2014 as compared to 2013 (2.3/100,000 person years). This increase was partly sustained during both 2015 (5.9/100,000 person years) and 2016 (6.5/100,000 person years) and with a slight but stable increase in incidence for 2017 (7.5/100,000 person years), 2018 (7.0/100,000 person years), and 2019 (7.3/100,000 person years) (Table 4, Figure 3).

Twenty laboratory-confirmed cases were reported in infants, which corresponds to an incidence of 17.5/100,000 person years, which is considerably higher than in older age groups (Tables 3 and 4). In infants, incidences have varied between 104 and 284/100,000 person years during the years 1997–2006. In 2006, the age-specific incidence in infancy was below 100/100,000 person years for the first time since 1997. In 2007, the incidence in infants was 85/100,000 person years, and from 2008 to 2013 the incidence in infants was stable at below 50/100,000 person years. In 2014, the incidence in infants increased by three-fold (105.3/100,000 person years) compared to 2013 (34.3/100,000 person years), and the higher incidence in infants remained, although at a slightly lower level, during 2015 (73.4/100,000 person years), 2016 (74.1/100,000), 2017 (69.6/100,000 person years), 2018 (58.3/100,000 person years), and 2019 (51.7/100,000 person years). There was a significant difference regarding infant incidences between 2020 and 2019 ($p < 0.001$). When comparing 2015, 2016, 2017, 2018, 2019, and 2020 to 2014, respectively, the decrease in incidence was significant (2014 vs. 2015, $p = 0.004$; 2014 vs. 2016, $p = 0.002$; 2014 vs. 2017 $p = 0.003$; 2014 vs. 2018, $p < 0.001$; 2014 vs. 2019, $p < 0.001$; 2014 vs. 2020, $p < 0.001$).

Table 3: Number of laboratory-reported cases of pertussis in defined age-groups reported to SmiNet between 2000 and December 31, 2020

Age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	219	115	217	112	285	154	98	91	47	43	49
1	76	33	42	19	53	27	15	18	17	10	2
2	36	37	53	19	50	14	13	9	7	1	6
3	52	29	37	8	31	23	8	7	4	7	8
4	155	28	46	20	50	20	10	10	7	3	5
5	281	47	51	14	67	26	21	10	2	8	6
6	254	122	86	25	77	51	22	25	8	4	5
7	345	98	147	31	83	55	26	27	10	3	7
8	289	105	92	45	105	50	30	19	12	6	6
9	208	79	99	34	87	74	24	28	24	5	9
10	131	43	74	45	86	103	23	13	12	5	7
11	62	32	58	43	78	73	28	10	1	3	3
12	41	24	36	28	64	64	28	15	5	1	4
13	30	14	24	23	51	46	32	22	13	5	1
14	21	9	17	13	44	28	21	25	19	11	2
15	11	6	13	9	12	25	14	19	13	23	10
16	11	2	10	10	16	20	14	14	16	16	8
17	14	1	6	3	9	9	4	13	12	12	10
18	7	0	6	1	9	6	9	7	6	9	4
19	5	2	1	3	2	9	7	4	2	4	3
20–24	14	3	13	8	13	12	10	12	13	12	11
25–29	14	7	8	11	19	16	16	14	14	6	11
30–34	28	11	12	6	24	21	11	8	13	9	11
35–39	29	6	20	10	33	30	25	18	19	12	15
40–44	14	8	11	8	18	33	15	29	19	7	16
45–49	7	1	10	2	7	20	12	18	12	5	8
50–54	4	4	9	3	8	12	13	11	8	6	5
55–59	8	5	7	7	7	5	17	14	6	7	1
60–64	9	2	7	2	4	16	17	14	10	6	8
65+	14	2	10	14	15	26	24	38	22	11	11
Total	2389	875	1222	576	1407	1068	607	562	373	260	252

Age	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0	37	51	39	121	85	87	82	68	60	20
1	2	5	5	19	9	7	10	11	10	4
2	3	4	9	13	8	9	11	12	9	1
3	2	4	7	12	11	11	8	13	15	4
4	4	5	5	5	9	9	14	22	9	12
5	1	7	5	10	9	10	4	14	8	5
6	3	6	5	8	6	8	9	7	9	6
7	0	6	3	3	6	8	9	4	5	2
8	0	2	3	7	8	8	9	10	9	4
9	3	5	2	8	7	10	7	18	6	3
10	2	1	4	7	3	5	18	9	11	6
11	2	1	3	13	13	18	17	12	15	7
12	1	0	2	7	10	14	14	20	19	4
13	0	2	1	12	5	17	42	28	24	9
14	2	1	0	7	11	15	13	21	16	5
15	6	7	7	11	11	10	9	10	11	9
16	9	9	6	21	11	14	9	7	5	6
17	13	7	3	17	15	15	19	8	8	4
18	6	7	7	10	14	7	6	8	14	6
19	1	5	5	13	9	12	9	6	29	2
20–24	15	18	13	50	34	42	36	39	59	12
25–29	5	11	12	40	38	40	45	43	42	7
30–34	6	21	11	36	33	37	43	45	40	11
35–39	5	10	16	47	40	40	47	39	36	14
40–44	5	16	12	45	40	48	63	50	57	17
45–49	4	9	7	23	39	36	56	67	74	21
50–54	6	9	5	26	23	24	37	32	42	9
55–59	9	7	4	21	14	17	25	21	36	7
60–64	5	7	5	16	14	14	13	17	18	5
65+	12	26	17	60	47	55	71	54	53	19
Total	169	269	223	688	582	647	755	715	749	241

Table 4: Incidence of laboratory-reported cases of pertussis in defined age-groups reported to SmiNet between 2000 and December 31, 2020.

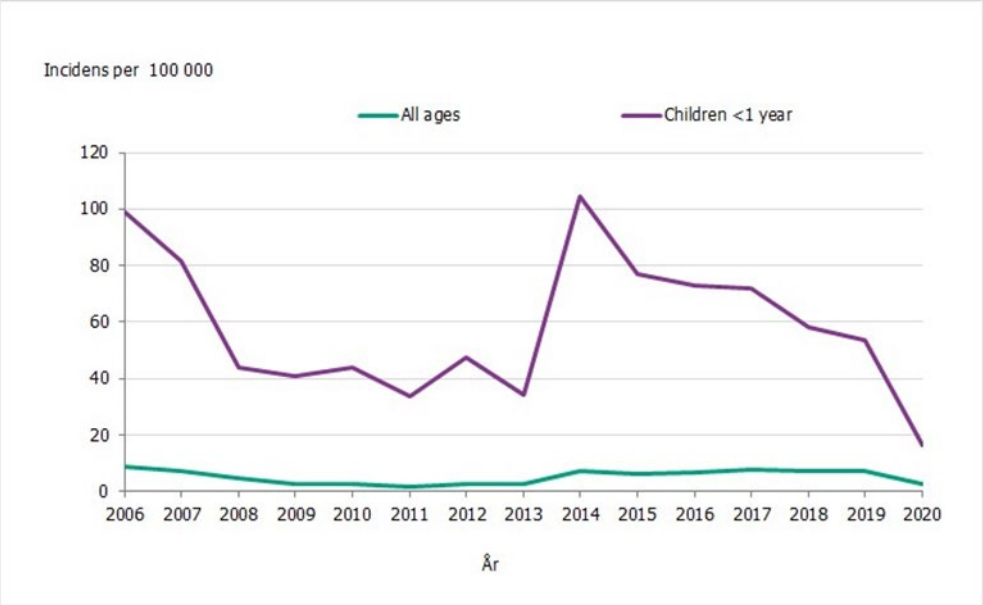
Age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0	244.6	126.1	231.2	114.7	284.5	152	94.3	85	43.2	38.8	43
1	84.9	36.5	45.6	20	53.7	26.7	14.6	17.1	15.7	9.1	1.8
2	39.7	41.1	58.3	20.5	52.4	14.1	12.8	8.7	6.6	0.9	5.4
3	55.5	31.8	40.9	8.7	33.3	24	8	6.8	3.8	6.5	7.3
4	155.1	29.8	50.2	22	54.4	21.4	10.4	9.9	6.8	2.9	4.6
5	259.3	46.8	54	15.2	73.3	28.2	22.4	10.3	2	7.7	5.7
6	220.3	112.2	85.3	26.3	83.3	55.6	23.7	26.4	8.2	3.9	4.8

7	285.3	84.7	134.7	30.6	87.1	59.3	28.2	28.9	10.5	3	6.8
8	230.8	86.6	79.2	41.1	103.4	52.3	32.2	20.4	12.7	6.2	6.1
9	163.6	62.9	81.3	29.2	79.1	72.6	25	29.8	25.6	5.3	9.3
10	105.4	33.7	58.7	36.8	73.5	93.4	22.5	13.4	12.7	5.3	7.3
11	52	25.7	45.3	34	63.7	62.2	25.2	9.7	1	3.1	3.2
12	35.9	20	28.8	21.8	50.4	52.1	23.8	13.4	4.8	1	4.2
13	27.3	12.2	20	18.3	39.6	36.2	25.9	18.6	11.6	4.8	1
14	19.6	8.2	14.7	10.8	34.9	21.7	16.4	20.1	15.9	9.7	1.9
15	10.6	5.6	11.7	7.8	9.9	19.8	10.8	14.8	10.4	19.1	8.8
16	11	1.9	9.2	9	13.8	16.5	11	10.7	12.4	12.7	6.6
17	14	1	5.7	2.8	8.1	7.7	3.3	10.2	9.1	9.2	7.9
18	7	0	5.9	1	8.2	5.3	7.7	5.7	4.6	6.8	3
19	4.9	2	1	2.9	1.9	8.2	6.2	3.4	1.6	3.1	2.2
20–24	2.7	0.6	2.5	1.5	2.5	2.3	1.9	2.2	2.3	2	1.8
25–29	2.4	1.2	1.4	2	3.4	2.9	2.9	2.5	2.5	1.1	1.9
30–34	4.4	1.8	2	1	3.9	3.4	1.8	1.3	2.2	1.5	1.9
35–39	4.7	0.9	3	1.5	5	4.7	3.9	2.9	3	1.9	2.4
40–44	2.4	1.4	1.9	1.4	3	5.3	2.3	4.4	2.8	1	2.4
45–49	1.2	0.2	1.7	0.3	1.2	3.4	2.1	3.1	2	0.8	1.3
50–54	0.6	0.6	1.5	0.5	1.4	2.1	2.2	1.9	1.4	1	0.9
55–59	1.4	0.8	1.1	1.1	1.1	0.8	2.7	2.3	1	1.2	0.2
60–64	2.1	0.4	1.5	0.4	0.8	2.9	2.9	2.3	1.6	1	1.3
65+	0.9	0.1	0.7	0.9	1	1.7	1.5	2.4	1.4	0.7	0.6
Total	26.9	9.8	13.7	6.4	15.6	11.8	6.7	6.1	4	2.8	2.7

Age	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
0	32.5	45.2	34.3	105.3	73.4	74.1	69.6	58.3	51.7	17.5
1	1.7	4.3	4.4	16.5	7.7	5.9	8.3	9.1	8.4	3.4
2	2.7	3.4	7.7	11.3	6.9	7.6	9.1	9.8	7.4	0.8
3	1.8	3.5	6	10.2	9.4	9.3	6.6	10.7	12.2	3.3
4	3.6	4.5	4.4	4.2	7.6	7.6	11.6	18	7.3	9.7
5	0.9	6.3	4.4	8.6	7.5	8.3	3.3	11.5	6.5	4
6	2.8	5.5	4.5	7	5.1	6.6	7.3	5.7	7.3	4.8
7	0	5.6	2.7	2.6	5.2	6.7	7.3	3.2	4	1.6
8	0	1.9	2.8	6.3	7	6.8	7.5	8	7.2	3.2
9	3	4.8	1.9	7.3	6.2	8.6	5.9	14.7	4.8	2.4
10	2	1	3.8	6.5	2.7	4.4	15.2	7.4	8.9	4.7
11	2.1	1	3	12.2	11.8	16	14.7	10	12.3	5.6
12	1	0	2	6.8	9.3	12.6	12.3	17	15.7	3.3
13	0	2.1	1	11.9	4.8	15.6	37.2	24.3	20.2	7.4
14	2	1	0	7	10.8	14.2	11.7	18.3	13.7	4.2

15	5.6	6.9	7.1	11.1	10.9	9.6	8.4	8.9	9.5	7.7
16	7.8	8.3	5.8	20.8	10.9	13.5	8.4	6.4	4.4	5.1
17	10.6	6	2.7	16.3	14.5	14.4	17.8	7.3	7.2	3.5
18	4.7	5.7	5.9	9	13.1	6.6	5.6	7.3	12.6	5.3
19	0.8	3.9	4	10.9	8	11.1	8.3	5.4	25.7	1.8
20–24	2.3	2.7	1.9	7.4	5.1	6.5	5.7	6.4	10	2.1
25–29	0.8	1.8	1.9	6.2	5.7	5.7	6.2	5.8	5.7	1
30–34	1	3.6	1.8	6	5.4	5.9	6.6	6.7	5.7	1.5
35–39	0.8	1.6	2.6	7.7	6.6	6.5	7.5	6.1	5.6	2.1
40–44	0.8	2.5	1.9	7	6.1	7.4	9.8	7.8	9	2.7
45–49	0.6	1.3	1	3.4	5.9	5.4	8.5	10.2	11.2	3.1
50–54	1	1.5	0.8	4.3	3.6	3.7	5.5	4.7	6.2	1.3
55–59	1.6	1.2	0.7	3.6	2.4	2.9	4.3	3.5	5.9	1.1
60–64	0.8	1.2	0.9	2.8	2.5	2.5	2.3	3	3.2	0.9
65+	0.7	1.4	0.9	3.2	2.4	2.8	3.6	2.7	2.6	0.9
Total	1.8	2.8	2.3	7.1	5.9	6.5	7.5	7	7.3	2.3

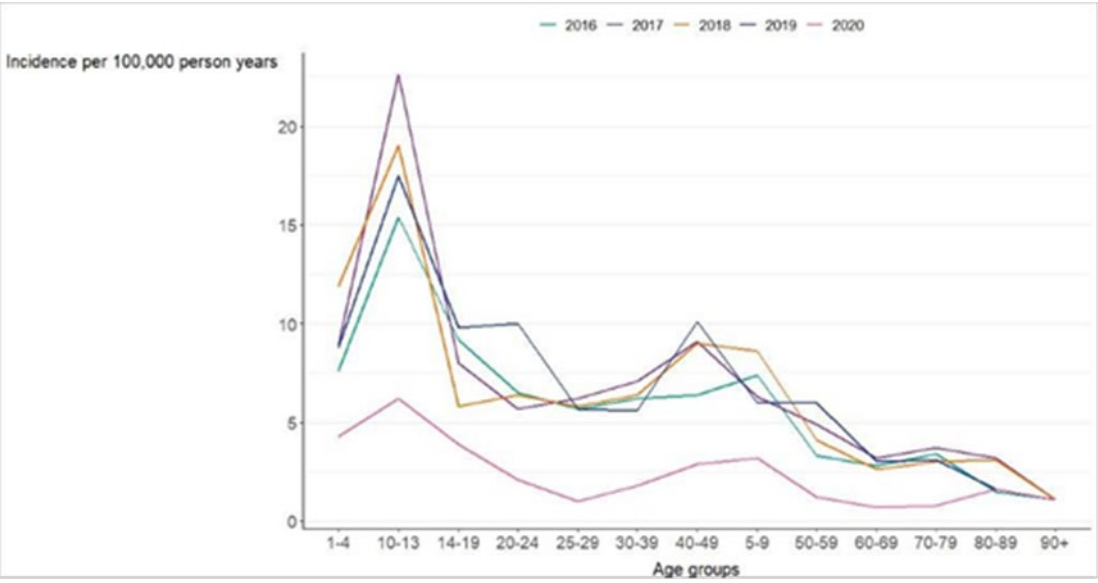
Figure 3: Incidence of pertussis in infants <12 months of age (purple line) and all ages (including infants) (green line) between 2006 and 2020. Data are based on laboratory-confirmed cases reported to SmiNet.



Incidence and number of cases of pertussis distributed by age and year, 2016–2020

In figure 4 the incidences in age groups 1 year and older are illustrated. As in previous years the incidence in 2020 was high in 10–14 year olds and in 40–49 year olds (Figure 4).

Figure 4: Incidence of pertussis in age groups above 12 months of age, years 2016-2020. Data are based on laboratory-confirmed cases.

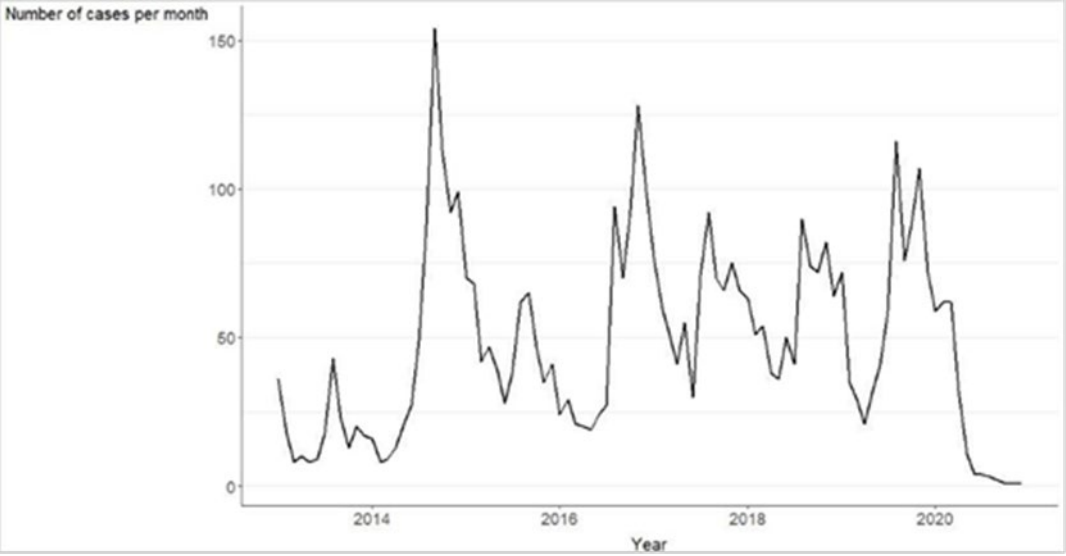


Incidence and cases on a monthly basis

The peaks in recent years 2014–2019 during the last 5 months of each year might indicate a tendency for a seasonal pattern from August to December. The pattern is easier to observe during years with high numbers of pertussis cases (Figure 5).

In the first 3 months of 2020 the number of reported cases in all ages varied between 62 and 77. A decline in the number of reported cases was seen in April (37 cases) and in May (13 cases). During June until December very few cases were reported, varying between 0 and 5 cases per month.

Figure 5: Number of laboratory-confirmed cases (all ages) on monthly records during 2013–2020



Geographic and age group differences in Sweden for laboratory-confirmed pertussis cases

The highest number of cases (n = 41) was reported from Blekinge region followed by Scania region (Skåne) (n = 35) and Västra Götaland region (n = 34). Due to a local and prolonged outbreak, Blekinge region had the highest incidence of pertussis with 26/100,000 person years in 2020.

See the **22nd Pertussis report** for a description of the incidence of reported pertussis cases (laboratory reports) in different Swedish counties from 1997 to 2019 (1). The 22nd report also includes a description of different age groups before and after the introduction of DTaP vaccines (1).

Pertussis in children

Pertussis in infants

In 2020 the number of laboratory-confirmed cases (n = 20) and the incidence (17.5/100,000) was low in infants. However, infants had the highest incidence of all age groups. The data analysis and presentation in this report focuses on reported

cases of pertussis among infants, markers of severity in relation to age at onset of disease, and individual vaccination histories.

The EPS study included a total of 16 infants with laboratory-confirmed pertussis with onset of pertussis disease during 2020.

Previous years, the incidences were higher in the youngest age groups, 0–3 and 3–5 months of age, compared to the older age group of 6–12 months of age (Figure 6).

In 2020 both the number of laboratory-confirmed infant cases and the incidence were low and the differences in incidences in these age groups were small (Figure 6 and Table 5).

While zero or one dose of vaccine still left children apparently susceptible to some risk of disease, as seen by the 2014–2015 peak and subsequently higher incidence, as soon as two doses are reached the epidemiologic patterns seem to be significantly decreased.

Figure 6: Incidence of pertussis in laboratory-confirmed pertussis cases in infants 0–2 months, 3–4 months, and 5–12 months of age. Data collection was performed in the EPS study in infants with onset of pertussis disease between January 1, 2003, and December 31, 2020.

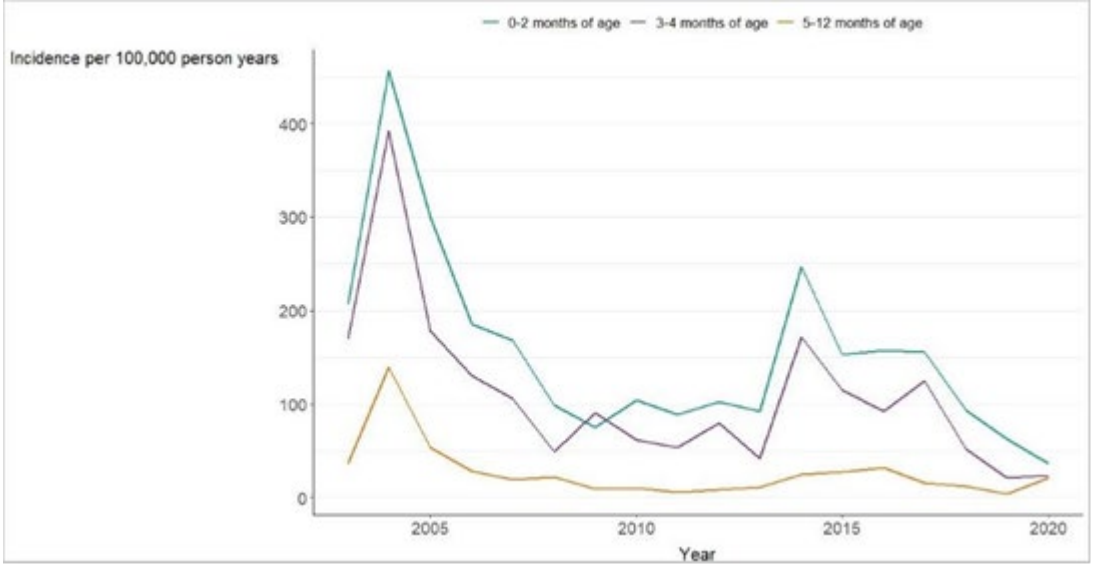


Table 5: Incidence of pertussis in laboratory-confirmed pertussis cases in infants 0–<3, 3–<5, and 5–<12 months of age. Data collection was performed in the EPS study in infants with onset of pertussis disease between January 1, 2003, and December 31, 2020.

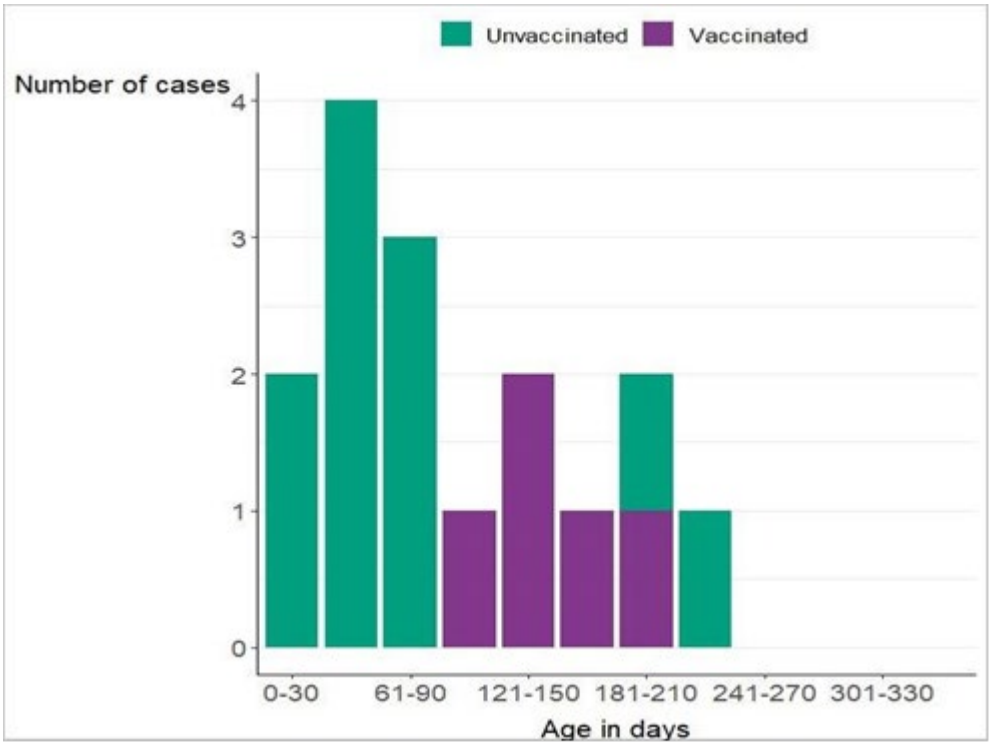
Age groups (months)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0–<3	226	476	328	196	175	102	75	104	89	102	92	247	153	157	156	128	140	36
3–<5	175	422	207	153	112	60	91	62	54	80	42	172	115	92	125	88	63	24
5–<12	36	148	54	29	21	24	9	10	6	8	11	25	27	32	16	18	13	21

Cases of pertussis in infants, distributed by age and vaccination status

A substantial proportion of pertussis cases reported in the EPS study were among the unvaccinated children who were too young to be fully vaccinated with three doses of aP vaccine at 3, 5, and 12 months of age (90, 120, and 365 days of age) according to the NIP.

The number of cases reported in 2020 in unvaccinated and vaccinated infants (one dose or more) for different ages (in days) is shown in Figure 7. Out of all 16 laboratory-confirmed infant cases with vaccination status in 2020, 9 (67%) infants had their first symptoms of pertussis during the first 90 days of life, and all of these cases were unvaccinated infants. See the **22nd Pertussis report** for a more extensive description of pertussis based on vaccination status in pertussis cases (1).

Figure 7: Number of reported pertussis cases in infancy in 2020 by vaccination status (not vaccinated or vaccinated with at least one dose of aP vaccine) and age (days). SmiNet data for reported pertussis infant cases and vaccination status from the EPS database.



Incidence of pertussis in infancy by year and after changes to the NIP

The age-specific incidence of laboratory-confirmed pertussis cases among infants was around 700–800/100,000 person years during the 10-year period prior to 1996. The incidence decreased rapidly after the introduction of pertussis vaccination and oscillated around 200/100,000 person years from 1996 to 2005, after which time the incidence decreased further (Figure 8, Table 4). This decrease could be due to the new vaccination schedule that included preschool booster vaccinations for children born in 2002 and a booster vaccination at 10 years of age leading to a higher proportion of vaccinated children in the population during 2007–2012.

In 2014 the incidence was around three times higher than the mean incidence during the time period 2008–2013 (p = 0.002) and slightly higher than the incidence in 2005, which was when the vaccine booster in 10 year olds was introduced (Table 4).

During the increase in pertussis incidence in infants in 2014, the NIP in Sweden was well established, using a 3, 5, 12-month programme with a booster dose at 5–6 years of age and with high vaccination coverage. In 2016, 2 years after this increase, the booster dose at 14–16 years of age was implemented with high coverage.

Severity of pertussis cases in infants

In the following sections, data are presented for age-specific complication and hospitalisation rates in vaccinated (one dose or more) and unvaccinated infants, with information on length of hospital stay and the duration of cough in infants. In the EPS study, the first day with symptoms was considered the age at episode start.

Clinical data were analysed according to cough definitions from the World Health Organization (5) and principally according to the definition of 21 days of paroxysmal cough as recommended by the WHO (6) for use in previous efficacy trials.

During the period from January 1, 2003, to December 31, 2020, the age-specific incidence of any complication due to pertussis was highest in children 0–<3 months of age at 60/100,000 person years (Table 6).

Table 6: Incidence of pertussis in relation to severity and age per 100,000 person years (95% confidence interval). Incidences are presented for all reported cases with pertussis, reported cases of pertussis with paroxysmal cough for 21 days or more, hospital admissions due to pertussis, and complications due to pertussis. Data collection was performed in the EPS with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases 0–20 years of age.

Age groups in months	Incidence of all pertussis cases	Incidence of pertussis with ≥21 days of spasmodic cough	Incidence of hospital admission	Incidence of hospital admissions with complications
0–<3	150	124	103	60
0–<3	(140–162)	(114–134)	(94–112)	(53–67)
3–<5	109	84	38	23
3–<5	(98–121)	(74–94)	(32–46)	(18–29)
5–<12	25	16	3	3
5–<12	(22–28)	(13–18)	(2–4)	(2–4)
≥12	9	6	0	1
≥12	(9–10)	(6–7)	(0–0)	(1–1)

The rate of complications due to pertussis by age

To analyse the association between complications during the pertussis episode and age and/or vaccination status of the child at the start of the episode, individuals were grouped into either having no complication during the pertussis episode or having at least one noted complication. Data collection was performed in the EPS study with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases 0–20 years of age.

Table 7: Numbers and proportions of children with at least one complication due to pertussis, by age at onset of disease. Data collection was performed in the EPS with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases 0–20 years of age.

Age at episode start (days)	Number of children with at least one complication / total number of cases reported	Proportions of children with at least one complication (percent)
0–90	311/796	39
91–150	79/377	21
151–365	30/303	10
>365	191/2676	7
Total	611/4152	15

Severity of pertussis in infant cases less than 6 months of age at the start of the pertussis episode

The greatest burden of morbidity and mortality related to pertussis is among the youngest infants prior to their primary immunisation series. The number of hospitalisations, complications, and spasmodic cough for 21 days or more in infant pertussis cases younger than 6 months of age with episodes starting between January 1, 2012, and December 31, 2020, are presented in Table 8, with the aim to evaluate the severity of pertussis in the youngest infants during the last 9-year period. In 2020 the number of infants younger than 6 months of age at onset of pertussis was low (n = 13).

During the time period 2012–2020, the rate of infants with any complication in this age group was 20%–63%. The hospitalisation rate was 54%–66%, and the median duration of hospital stay was 5.5–7 days.

Almost all infants had spasmodic cough for 21 days or more. There was no significant difference in the proportion of hospitalised infants younger than 6 months of age during 2012–2020. The proportion of infants with respiratory complications with apnoea varied during this studied time period (6%–41%) but with no significant trend over the years.

Table 8: Number of infants aged 6 months or less with and without complications, spasmodic cough and median days of hospitalisation. Data collection was performed in the EPS with episodes starting between January 1, 2012, and December 31, 2020.

Complications	2012 N = 48	2013 N = 35	2014 N = 109	2015 N = 71	2016 N = 70	2017 N = 64	2018 N = 52	2019 N = 46	2020 N = 13
No complication	36	27	79	43	26	41	39	37	11
Any complication	12	8	30	28	44	23	13	9	2
Respiratory, with apnoea	4	7	21	21	29	8	3	6	2
Respiratory, without apnoea	7	1	6	4	12	15	8	3	0
Dehydration	1	0	3	2	0	0	1	0	0
Other severe events	0	0	0	1	3	0	1	0	0
Spasmodic cough for 21 days or more	37	34	93	66	62	56	48	43	13
Hospitalised	29	21	66	43	42	42	33	27	7
Median days of hospitalisation	7	7	7	7	6	5.5	7	6	6

Hospital admission due to pertussis

In 2020, 7 infants aged 6 months or less (54%) with pertussis were hospitalised, and the corresponding number in 2019 was 27 (59%).

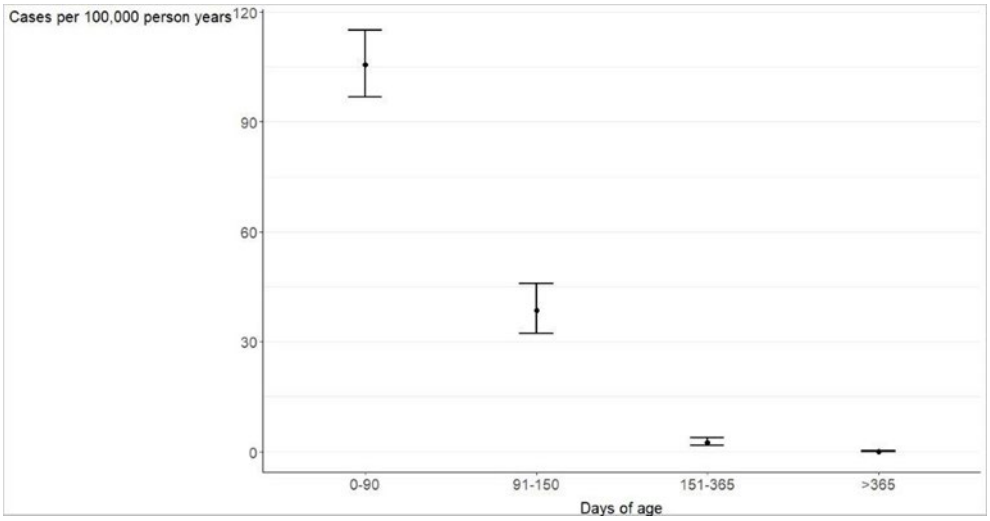
In the EPS study (January 1, 2003, to December 31, 2020), 758 of the children (17%) were admitted to hospital during the pertussis episode (Table 9). A total of 549 of 809 infants (68%) who were younger than 90 days of age at the start of the pertussis episode were admitted to hospital. The corresponding admission rates, regardless of vaccination status at the start of the episode, for the 385 children in the age group 91–150 days of age, for the 308 children in the age group 151–365 days of age, and for the 2,924 children older than 365 days of age at episode start were 36%, 10%, and 1%, respectively (Table 9).

Table 9: Hospital admissions by age at episode start (number and percent). Data collection was performed in the EPS with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases 0–20 years of age with data on hospital admission.

Age at episode start (days)	Number of children with hospital admission / total number of cases reported	Proportions of children with hospital admission (percent)
0–90	549/809	68
91–150	137/385	36
151–365	31/308	10
>365	41/2924	1
Total	758/4426	17

The age-specific incidence rate of hospitalisation due to pertussis was highest for children 0–90 days of age (105.5/100,000 person years). The incidence decreased with increasing age to less than 1/100,000 person years for children older than 1 year of age at the start of the pertussis episode (Figure 8).

Figure 8: Incidence of hospital admission per 100,000 person years due to pertussis stratified by age at episode start. Data collection was performed in the EPS study, with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases among those 0–20 years of age.



Complications due to pertussis in all infant cases by hospitalisation

For the time period 2003–2020, respiratory complications (with apnoea, n = 266, or without apnoea, n = 230) were reported in 496 (12%) of the children, and dehydration was reported in 96 (2.3%) of the children. Uncommon complications, e.g. neurological and other serious complications, were reported in 14 (0.3%) children (Table 10).

Altogether, most of the children with respiratory complications with apnoea were admitted to the hospital (86%). The majority of the children with dehydration were also hospitalised (Table 10).

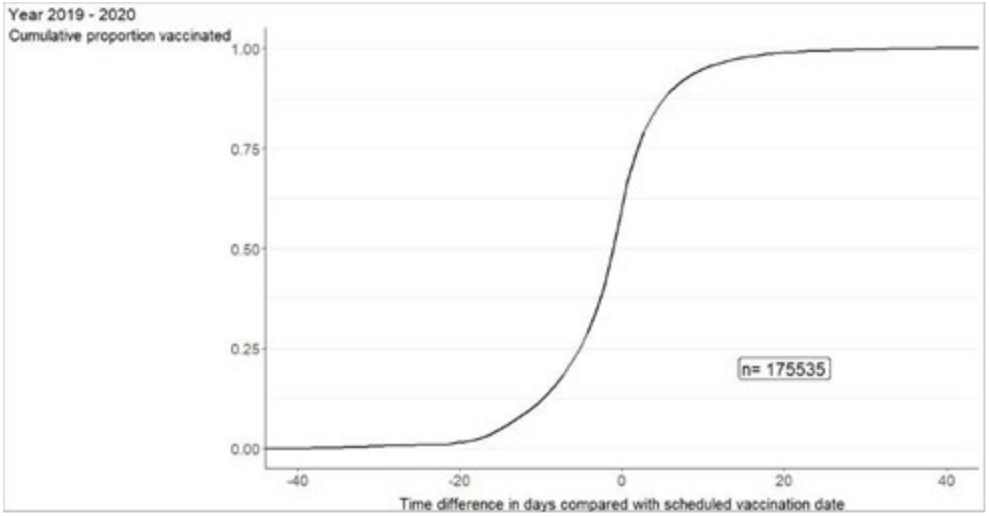
Table 10: Number of children with pertussis by complication type and rate of hospitalisation. Data collection was performed in the EPS study with episodes starting between January 1, 2003 and December 31, 2020. Data are presented for pertussis cases 0–20 years of age with data on hospital admission and complications.

Complication type	Hospitalised (percent)	Not hospitalised (percent)	Total
Respiratory, with apnoea	229 (86)	37 (14)	266
Respiratory, without apnoea	99 (43)	131 (57)	230
Dehydration	59 (61)	37 (39)	96
Other severe events	10 (71)	4 (29)	14
No complications	359 (10)	3183 (90)	3542
Total	756 (18)	3392 (82)	4148

Timing of vaccinations

The cumulative proportion of infants (n = 175,535) that received their first dose within 40 days from the planned vaccination day was 97% (January 1, 2019, to December 31, 2020 (Figure 9).

Figure 9: Cumulative proportion of vaccinated children with the first dose of aP vaccine with differences in actual vaccination dates from the planned date according to the NIP (2019–2020). The horizontal line indicates the percentage of infants vaccinated within 40 days after the planned vaccination. Data are from the Swedish vaccination register.

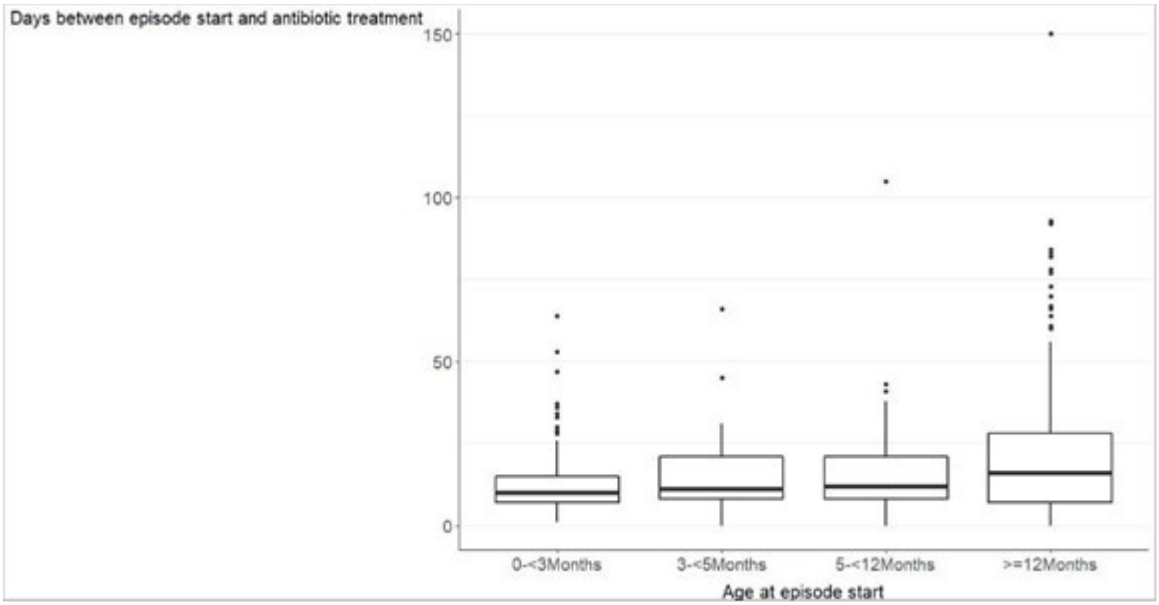


Treatment of pertussis in infants and in children above 1 year of age

The time between the onset of the pertussis disease and the start of antibiotic treatment is shown in Figure 10. The treatment period tends to start rather late, and there is no clear difference between the youngest infants (0–3 months of age) and the older infants based on the median values (10–12 days between the onset of pertussis and the start of antibiotic treatment). However, there are some extreme values. Furthermore, in the youngest age group and in the age groups 5–<12 months and older than 12 months of age, one child in each group had received prophylactic treatment before the episode start.

Please see the previous 22nd Pertussis report for information on the number of times parents have sought medical care for their sick child before a pertussis diagnosis was established.

Figure 10: Number of days between episode start and start of antibiotic treatment. Data collection was performed in the EPS with episodes starting between January 1, 2003, and December 31, 2020. Data are presented for pertussis cases among those 0–20 years of age.



Number of samples analysed for pertussis

Starting in 2014, the PHAS began to collect data from all laboratories in Sweden on the total number of samples analysed for *B. pertussis* (PCR, culture, and/or serology). A total of 13,194 samples were tested for pertussis in 2014, 12,935 were tested in 2015, 14,508 were tested in 2016, and 18,791 were tested in 2017. Due to the COVID-19 pandemic these data were not collected in 2019 or 2020.

Comments

This report is the last report that contains more detailed information based on the EPS study from all age groups, and this report will not be continued in the present format.

Due to the pandemic in 2020, it is clear that the interventions to prevent the spread of COVID-19 have diminished the spread of pertussis in the population of Sweden. In 2020 the overall incidence decreased by at least three-fold compared to 2019. The incidence decreased in all age groups except for a slight increase in the 4 year olds. In addition to improved hygiene and social distancing, one explanation for this overall decrease could be that people who were infected with pertussis did not visit health care services for diagnosis and treatment due to fear of being infected with COVID-19 or due to general advice not to visit health care facilities unless having severe health problems. However, the much lower incidence in infants does not support this explanation because medical care is often sought for infants with pertussis.

Compliance with measures to decrease the spread of infectious diseases to infants, including social distancing within family members during the infant's first months of life, might be an important factor explaining the low numbers of infant cases during 2020. The EPS study gives important data on the changes in epidemiology of pertussis during a global pandemic.

Preparedness, awareness, continued focus on timely immunization, prophylactic treatment, testing, and continued surveillance for pertussis in infants are substantial actions for reducing infection rates. Potentially, advising of a minimum of social contacts for the new-borns and its family could maintain low numbers of infant pertussis cases and protect infants from severe disease also in the post-pandemic era, but this needs to be studied further.

Future surveillance and reporting

As of January 1st 2021, the funding for the EPS will be discontinued and therefore this is the last report in the series of "Pertussis surveillance in Sweden". Data collection, however, continued according to the primary protocol described in the **22nd Pertussis** report all throughout the year. Data for pertussis 2021 and onwards is presented in the annual and coming reports for the childhood immunization programme (7). Published reports are available on the PHAS website, (Folkhälsomyndighetens webbsida).

Scientific publications planned based on EPS data

Papers planned:

1. Publication of data from the analysis of aP vaccine effectiveness. By using data on pertussis cases in fully vaccinated children reported within the framework of the EPS and data from the Swedish vaccination registry, it will be possible to evaluate vaccine effectiveness in different age groups, to describe the cyclic patterns of pertussis cases in Sweden from 1997 and onwards , and to describe the proportion of fully vaccinated cases observed among 12–60-month-old and 6–15-year-old children and adolescents in contrast with expected proportions, taking into account the cyclic patterns and changes in vaccination schedule.. Data were presented at ESPID 2020 as an oral presentation.
2. Publication of data from the analysis of the probable source of pertussis infection for the youngest infants. Work in progress.

Limitations

While it is likely that the mandatory reporting system is reasonably reliable in reporting diagnosed cases, there is substantial risk that infected individuals are not diagnosed in the first place. One reason for not being diagnosed is because infected persons can have no, mild, or atypical symptoms. While mild symptoms reduce the probability that the disease will be diagnosed, these cases might still be relevant in the circulation of the disease. Also, there appears to be a conception among both medical professionals and the public that pertussis disease does not affect vaccinated individuals. It is therefore likely that even patients with typical symptoms are not tested for pertussis if they have already been vaccinated. Because there are no data on the true incidence of pertussis, we cannot quantify the magnitude of such under-diagnosis, but it is likely that failure to obtain a diagnosis is more common in adults than in children and that it might be increasing with time as the awareness of pertussis has decreased because a large proportion of the population has been vaccinated. Possible consequences of under-diagnosis include overly optimistic conclusions about pertussis incidence, vaccine effectiveness, and the duration of vaccine immunity.

Adverse events in vaccinated children are reported directly to the Medical Product Agency in Sweden by the child's nurse or doctor. These reported data are confidential, and the surveillance team at PHAS has no access to these data. The study on pertussis in fully vaccinated children can be reported on a group level (by age), but not on an individual level. If a parent reports an adverse event (any symptoms), the team at PHAS will contact the reporting doctor or nurse for proper action.

Administration

The EPS study in Sweden started on Oct 1, 1997, and was ongoing with annual reconsideration of continuation. Financial support has been obtained from the vaccine manufacturers Sanofi of France and GlaxoSmithKline, Belgium. Contracts for the EPS study in Sweden have been agreed upon for the continued follow-up of clinical epidemiology since 1997 by the manufacturers named above. Major policy decisions relating to the conduct of the study were made by the team at PHAS, including the Internal Steering Committee at PHAS, and are discussed with representatives from the supporting manufacturers at annual review meetings. The General Director and the management team at the PHAS have decided to end the support from manufacturers described above on January 1, 2021. Study staff on the PHAS team: Bernice Aronsson (principal investigator, project leader), Jann Storsaeter (investigator), Kerstin Drakes Jämtberg (study nurse), Emma Appelqvist (research assistant), Henrik Källberg (statistician), and Bo Östlund (administrative coordinator). This is the last EPS report to be published in the series of "Pertussis in Sweden".

Published scientific articles and reports based on the enhanced surveillance data

1. The five-component aP vaccine is recommended for general use: Gustafsson L, Hallander HO, Olin P, Reizenstein E, Storsaeter J. A controlled trial of a two-component acellular, a five-component acellular and a whole cell pertussis vaccine. N Engl J Med 1996; 334:349-55
2. Similar efficacy of the UK whole-cell vaccine and the five-component and three-component vaccines: Olin P, Rasmussen F, Gustafsson L, Hallander HO, Heijbel H. Randomised controlled trial of two-component, three-component, and five-component acellular pertussis vaccines compared with whole-cell pertussis vaccine. Ad Hoc Group for the Study of Pertussis Vaccines. Lancet. 1997 350:1569-77.
3. First signs of waning immunity at 6-7 years of age: Olin P, Gustafsson L,Barreto L, Hessel L, Mast C, Van Rie A, et al. Declining pertussis incidence in Sweden following the introduction of acellular pertussis vaccine. Vaccine 2003;21:2015-21
4. A booster dose of acellular pertussis vaccine is warranted from 5 to 7 years of age: Gustafsson L, Hessel L, Storsaeter J, Olin P. Long term follow-up of Swedish children vaccinated with acellular pertussis vaccines at 3, 5, and 12 months of age indicates the need for a booster dose at 5 to 7 years of age. Pediatrics September 2006; 118:3 978-984
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Årsrapporten för övervakningen av kikhosta (pertussis) beskriver utfallet av antal rapporterade fall av kikhosta för alla åldersgrupper med förstärkt övervakning av kikhosta hos barn och ungdomar som pågått i Sverige under tjugotre års tid. Rapporten beskriver i detalj förekomst av kikhosta utifrån ålder, vaccinationsstatus och sjukdomsbörda med särskilt fokus på barn yngre än ett år. Rapporten ar avsedd som kunskapsstöd för forskare och vårdgivare. Målgruppen för årsrapporten är hälso- och sjukvårdspersonal, och då särskilt personal inom mödravård, barnhälsovård och barnsjukvård samt primarvård och smittskyddsenheter.

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