

## Supplementary material

### Descriptive overview of pertussis epidemiology among older adults in Europe during 2010–2020

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**Supplementary table S1.** Data sources

<b>Country</b>	<b>Type of data</b>	<b>Source</b>	<b>Reference</b>
<b>Denmark</b>	Contextual epidemiological information	Statens Serum Institut (SSI), literature, and personal communication	[1-7]
	Number of cases and incidence rate	2010 & 2011: Literature	2010 & 2011: [1]
		2012–2019: Statens Serum Institut (SSI)	2012–2015: [8]
			2016–2019: [9]
Outbreaks		Statens Serum Institut (SSI)	2012: [10]
			2016 & 2019: [9]
<b>England</b>	Contextual epidemiological information	Public Health England (PHE), UK Government, World Health Organization (WHO), literature, and personal communication	[2, 11-23]
	Number of cases and incidence rate	Public Health England (PHE)	Written communication
	Outbreaks	Literature	2012: [24]

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<b>Finland<sup>a</sup></b>	Contextual epidemiological information	Finnish Institute for Health and Welfare (THL), Ministry of Social Affairs and Health, and literature	[2, 25-28]
	Number of cases	Finnish Institute for Health and Welfare (THL)	[29]
	Population	Statistics Finland's PxWeb databases	[30]
	Incidence rate	OA non-stratified: Calculated by authors	OA non-stratified: NA
		Children and stratified OA: Finnish Institute for Health and Welfare (THL)	Children and stratified OA: [29]
<b>Germany</b>	Contextual epidemiological information	Robert Koch Institute (RKI), literature, and personal communication	[2, 12, 31-38]
	Number of cases	Robert Koch Institute (RKI)	[39]
	Population	The database of the Federal Statistical Office	[40]
	Incidence rate	Stratified OA: Robert Koch Institute (RKI)	Stratified OA: [39]
		OA combined: Calculated by authors	OA combined: NA

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<b>The Netherlands<sup>b</sup></b>	Contextual epidemiological information	National Institute for Public Health and the Environment (RIVM), Dutch Government, and literature	[2, 12, 41-45]
	Number of cases	National Institute for Public Health and the Environment (RIVM)	[42, 44]
	Population	Central Bureau of Statistics Statline	[46]
	Incidence rate	Calculated by authors	NA
	Outbreaks	National Institute for Public Health and the Environment (RIVM)	[42, 47]
<b>Norway<sup>c</sup></b>	Contextual epidemiological information	Norwegian Institute of Public Health (FHI), World Health Organization (WHO), and literature	[2, 12, 48-53]
	Number of cases	Norwegian Surveillance System for Communicable Diseases (MSIS)	[54]
	Population	Norwegian Institute of Public Health – Statistics databank	[53]
	Incidence rate	Calculated by authors	NA

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<b>Scotland</b>	Contextual epidemiological information	Public Health England (PHE), UK Government, World Health Organization (WHO), literature, and personal communication	[2, 11-23]
	Number of cases and incidence rate	Public Health Scotland	Written communication
	Outbreaks	Health Protection Scotland (HPS) and Public Health Scotland	2012–2013: [55]
<b>Sweden<sup>d</sup></b>	Contextual epidemiological information	The Public Health Agency of Sweden and personal communication	[2, 56, 57]
	Number of cases	The Public Health Agency of Sweden	[56]
	Population	Statistics Sweden – The statistics database	[58]
	Incidence rate	Calculated by authors	NA
<b>Other countries</b>			
<b>Austria</b>	Number of cases and incidence rates (age-stratified only)	The Austrian Agency for Health and Food Safety (AGES)	Written communication

<b>Estonia<sup>e</sup></b>	Number of cases (OA only)	Health Board of Estonia	Written communication
	Population	Estonian population statistics database	[59]
	Incidence rate	Calculated by authors	NA

NA, not applicable; OA, older adults (≥50 years of age).

<sup>a</sup> population data were retrieved from reference [30] by selecting the period of interest (2010–2019), both sexes, and the applicable age groups in strata of 5 years – number of pertussis cases were retrieved from reference [29] by selecting the period of interest (2010–2019), both sexes, all regions, and the applicable age groups in strata of 5 years; <sup>b</sup> population data were retrieved from reference [46] by selecting the period of interest (2010–2019), all regions, and the applicable age groups in strata of 5 years; <sup>c</sup> population data were retrieved from reference [53] by selecting “population” and both genders, followed by a selecting of the period of interest (2010–2020), all regions, and the applicable age groups in strata of 5 years; <sup>d</sup> Population data were retrieved from reference [58] by selecting “population statistics” followed by “number of inhabitants” and “population by age and sex”, lastly, the period of interest was selected (2010–2018), as well as both sexes and applicable age groups in strata of 5 years; <sup>e</sup> population data were retrieved from reference [59] by selection “Population” followed by “Population figure and composition” and “RV021: POPULATION BY SEX AND AGE GROUP, 1 JANUARY”, lastly, both sexes were selected (“Males and females”) as well as the period of interest (2010–2019) and all applicable age groups in strata of 5 years.

## References

1. Dalby T, Andersen PH, Hoffmann S. Epidemiology of pertussis in Denmark, 1995 to 2013. *Euro Surveill.* 2016;21:30334.
2. He Q, Barkoff AM, Mertsola J, *et al.* High heterogeneity in methods used for the laboratory confirmation of pertussis diagnosis among European countries, 2010: integration of epidemiological and laboratory surveillance must include standardisation of methodologies and quality assurance. *Euro Surveill.* 2012;17:20239.
3. Statens Serum Institut (SSI). Diagnosis of pertussis - choice of correct method. <https://www.ssi.dk/-/media/arkiv/dk/produkter-og-ydelser/diagnostik/diagnostisk-haandbog/diagnostik-af-kighoste---valg-af-korrekt-metode.pdf?la=da>. Accessed on 12 May 2022.

*Infectious Diseases and Therapy*

4. Statens Serum Institut (SSI). Temporary substitution of child vaccine to Infanrix hexa® and 5-year booster to dTap booster and separate polio vaccine (IPV). <https://en.ssi.dk/news/epi-news/2013/no-50---2013>. Accessed on 12 May 2022.
5. Danish Ministry of Health. Pregnant women will still be able to get a free pertussis vaccination. <https://sum.dk/nyheder/2021/juni/gravide-vil-fortsat-kunne-faa-en-gratis-kighostevaccination->. Accessed on 12 May 2022.
6. Statens Serum Institut (SSI). The Danish Vaccination Program - Annual report 2016 version 2. [https://en.ssi.dk/-/media/arkiv/indhold/dk-dansk/vaccination/boernevaccination/boernevaccinationsprogram\\_2016\\_v2\\_jan18](https://en.ssi.dk/-/media/arkiv/indhold/dk-dansk/vaccination/boernevaccination/boernevaccinationsprogram_2016_v2_jan18). Accessed on 12 May 2022.
7. Statens Serum Institut (SSI). Annual reports on disease incidence. <https://en.ssi.dk/surveillance-and-preparedness/surveillance-in-denmark/annual-reports-on-disease-incidence>. Accessed on 12 May 2022.
8. Statens Serum Institut (SSI). Whooping cough 2015 - EPI-NEWS No 16 - 2016. <https://en.ssi.dk/news/epi-news/2016/no-16---2016>. Accessed on 12 May 2022.
9. Statens Serum Institut (SSI). Whooping cough - 2019 report on disease occurrence. <https://en.ssi.dk/surveillance-and-preparedness/surveillance-in-denmark/annual-reports-on-disease-incidence/whooping-cough---2019-report-on-disease-occurrence#>. Accessed on 12 May 2022.
10. Statens Serum Institut (SSI). No 41 - 2012. Current whooping cough situation and updated recommendations for prophylaxis. <https://en.ssi.dk/news/epi-news/2012/no-41---2012>. Accessed on 12 May 2022.
11. United Kingdom Government. Pertussis: guidance, data and analysis. <https://www.gov.uk/government/collections/pertussis-guidance-data-and-analysis>. Accessed on 12 May 2022.
12. World Health Organization (WHO). Vaccine-Preventable Diseases - Surveillance Standards: Pertussis. <https://www.who.int/publications/m/item/vaccine-preventable-diseases-surveillance-standards-pertussis>. Accessed on 12 May 2022.
13. Public Health England (PHE). Pertussis brief for healthcare professionals. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/762782/Pertussis\\_brief\\_for\\_health\\_care\\_professionals.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762782/Pertussis_brief_for_health_care_professionals.pdf). Accessed on 12 May 2022.
14. United Kingdom Government. Pertussis: background information on prevention and management. <https://www.gov.uk/guidance/pertussis-clinical-and-public-health-management>. Accessed on 12 May 2022.
15. Public Health England (PHE). Historical vaccine development and introduction of routine vaccine programmes in the UK. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/816174/Vaccine\\_Timeline\\_2019.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816174/Vaccine_Timeline_2019.pdf). Accessed on 12 May 2022.

*Infectious Diseases and Therapy*

16. Health Protection Agency. Health protection report - weekly report volume 5 number 50. <https://webarchive.nationalarchives.gov.uk/20140714091638/http://www.hpa.org.uk/hpr/archives/2011/hpr5011.pdf>. Accessed on 12 May 2022.
17. World Health Organization (WHO). United Kingdom of Great Britain and Northern Ireland: WHO and UNICEF estimates of immunization coverage: 2020 revision. [https://cdn.who.int/media/docs/default-source/country-profiles/immunization/immunization\\_gbr\\_2021.pdf?sfvrsn=353c63e3\\_9&download=true](https://cdn.who.int/media/docs/default-source/country-profiles/immunization/immunization_gbr_2021.pdf?sfvrsn=353c63e3_9&download=true). Accessed on 12 May 2022.
18. Public Health England (PHE). Vaccine update. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/653401/VU\\_271\\_october\\_2017.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/653401/VU_271_october_2017.pdf). Accessed on 12 May 2022.
19. Public Health England (PHE). Vaccine update. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/805502/PHE\\_vaccineupdate\\_294\\_May19.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/805502/PHE_vaccineupdate_294_May19.pdf). Accessed on 12 May 2022.
20. United Kingdom Government. Pertussis Vaccination Programme for Pregnant Women: vaccine coverage estimates in England, October 2013 to March 2014. <https://www.gov.uk/government/publications/pertussis-immunisation-in-pregnancy-vaccine-coverage-estimates-in-england-october-2013-to-march-2014/pertussis-vaccination-programme-for-pregnant-women-vaccine-coverage-estimates-in-england-october-2013-to-march-2014>. Accessed on 12 May 2022.
21. Public Health England (PHE). Pertussis vaccination programme for pregnant women update: vaccine coverage in England, April to June 2020. <https://webarchive.nationalarchives.gov.uk/ukgwa/20220201225652/https://www.gov.uk/government/publications/pertussis-immunisation-in-pregnancy-vaccine-coverage-estimates-in-england-october-2013-to-march-2014>. Accessed on 12 May 2022.
22. Public Health England (PHE). Guidelines for the public health management of pertussis in England. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/762766/Guidelines\\_for\\_the\\_Public\\_Health\\_management\\_of\\_Pertussis\\_in\\_England.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762766/Guidelines_for_the_Public_Health_management_of_Pertussis_in_England.pdf). Accessed on 12 May 2022.
23. Public Health England (PHE). Pertussis: the green book, chapter 24. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/514363/Pertussis\\_Green\\_Book\\_Chapter\\_24\\_Ap2016.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/514363/Pertussis_Green_Book_Chapter_24_Ap2016.pdf). Accessed on 12 May 2022.
24. Riolo MA, King AA, Rohani P. Can vaccine legacy explain the British pertussis resurgence? *Vaccine*. 2013;31:5903-8.
25. Finnish Institute for Health and Welfare (THL). Procedure for cases of pertussis. <https://thl.fi/fi/web/infektioaudit-ja-rokotukset/taudit-ja-torjunta/taudit-ja-taudinaiheuttajat-a-o/hinkuyska/toimenpideohje-hinkuyskatapauksiin>. Accessed on 12 May 2022.



*Infectious Diseases and Therapy*

26. Finnish Institute for Health and Welfare (THL). Notifiable diseases and microbes. <https://thl.fi/fi/web/infektiaudit-ja-rokotukset/seurantajarjestelmat-ja-rekisterit/tartuntatautirekisteri/ilmoitettavat-taudit-ja-mikrobit>. Accessed on 12 May 2022.
27. Ministry of Social Affairs and Health. Health care payments. <https://stm.fi/terveydenhuollon-maksut>. Accessed on 12 May 2021.
28. Finnish Institute for Health and Welfare (THL). Vaccination coverage. <https://www.thl.fi/roko/rokotusrekisteri/atlas/public/atlas.html?show=infantbc>. Accessed on 12 May 2022.
29. Finnish Institute for Health and Welfare (THL). Statistical database of the Communicable Diseases Register. [https://sampo.thl.fi/pivot/prod/fi/ttr/shp/fact\\_shp?row=area-12260&column=time-12059&filter=reportgroup-12175](https://sampo.thl.fi/pivot/prod/fi/ttr/shp/fact_shp?row=area-12260&column=time-12059&filter=reportgroup-12175). Accessed on 12 May 2022.
30. Statistics Finland. Statistics Finland's PxWeb databases. <https://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/>. Accessed on 19 March 2021.
31. Hellenbrand W, Beier D, Jensen E, *et al*. The epidemiology of pertussis in Germany: past and present. *BMC Infect Dis*. 2009;9:22.
32. Robert Koch Institut (RKI). Whooping cough (pertussis). [https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber\\_Pertussis.html;jsessionid=43B103E0BB8908B877D43BBF36C691E0.internet072#doc2374534bodyText9](https://www.rki.de/DE/Content/Infekt/EpidBull/Merkblaetter/Ratgeber_Pertussis.html;jsessionid=43B103E0BB8908B877D43BBF36C691E0.internet072#doc2374534bodyText9). Accessed on 5 January 2021.
33. Robert Koch Institut (RKI). Falldefinitionen für die Gesundheitsbehörden der Länder, in denen zusätzlich zum IfSG eine Meldepflicht für weitere Krankheiten besteht (Ausgabe 2009). [https://www.rki.de/DE/Content/Infekt/IfSG/Falldefinition/laenderverordnungen\\_falldefs.html](https://www.rki.de/DE/Content/Infekt/IfSG/Falldefinition/laenderverordnungen_falldefs.html). Accessed on 12 May 2022.
34. Sin MA, Zenke R, Ronckendorf R, Littmann M, Jorgensen P, Hellenbrand W. Pertussis outbreak in primary and secondary schools in Ludwigslust, Germany demonstrating the role of waning immunity. *Pediatr Infect Dis J*. 2009;28:242-4.
35. Robert Koch Institut (RKI). Archive of the STIKO recommendations. [https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Archiv/seit\\_1972/archiv\\_tab.html](https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Archiv/seit_1972/archiv_tab.html). Accessed on 12 May 2022.
36. Robert Koch Institut (RKI). Vaccination calendar (standard vaccinations). <https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Aktuelles/Impfkalender.pdf?blob=publicationFile>. Accessed on 12 May 2022.
37. World Health Organization (WHO). WHO-UNICEF estimates of national immunization coverage. <https://www.who.int/teams/immunization-vaccines-and-biologicals/immunization-analysis-and-insights/global-monitoring/immunization-coverage/who-unicef-estimates-of-national-immunization-coverage>. Accessed on 12 May 2022.

*Infectious Diseases and Therapy*

38. Rieck T, Matysiak-Klose D, Hellenbrand W, *et al.* [Compliance with adult measles and pertussis vaccination recommendations : Analysis of data from the national monitoring system KV-Impfsurveillance]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz.* 2019;62:422-32.
39. Robert Koch Institut (RKI). SURVSTAT@RKI 2.0. <https://survstat.rki.de/Content/Query/Create.aspx>. Accessed on 12 May 2022.
40. Federal Statistical Office (Destatis). The database of the Federal Statistical Office. <https://www-genesis.destatis.de/genesis/online>. Accessed on 19 March 2021.
41. National Institute for Public Health and the Environment (RIVM). Kinkhoest richtlijn. <https://lci.rivm.nl/richtlijnen/kinkhoest>. Accessed on 12 May 2022.
42. National Institute for Public Health and the Environment (RIVM). The National Immunisation Programme in the Netherlands: Surveillance and developments in 2019-2020. <https://www.rivm.nl/publicaties/national-immunisation-programme-in-netherlands-surveillance-and-developments-in-2019>. Accessed on 12 May 2022.
43. Dutch Government. Wanneer betaal ik een eigen risico voor mijn zorg? <https://www.rijksoverheid.nl/onderwerpen/zorgverzekering/vraag-en-antwoord/eigen-risico-zorgverzekering>. Accessed on 24 April 2021.
44. National Institute for Public Health and the Environment (RIVM). The National Immunisation Programme in the Netherlands: Surveillance and developments in 2018-2019. <https://www.rivm.nl/publicaties/national-immunisation-programme-in-netherlands-surveillance-and-developments-in-2018>. Accessed on 12 May 2022.
45. Heil J, Ter Waarbeek HLG, Hoebe C, *et al.* Pertussis surveillance and control: exploring variations and delays in testing, laboratory diagnostics and public health service notifications, the Netherlands, 2010 to 2013. *Euro Surveill.* 2017;22.
46. Central Bureau for Statistics (CBS) Statline. Bevolking; geslacht, leeftijd en burgerlijke staat, 1 januari. <https://opendata.cbs.nl/statline/#/CBS/nl/dataset/7461BEV/table?ts=1616172184222>. Accessed on 12 May 2022.
47. National Institute for Public Health and the Environment (RIVM). The State of infectious diseases in the Netherlands. <https://www.rivm.nl/bibliotheek/rapporten/150002002.pdf>. Accessed on 12 May 2022.
48. Norwegian Institute of Public Health (FHI). Barnevaksinasjonsprogrammet. Rapport for perioden 2001-2010. <https://www.fhi.no/publ/2012/barnevaksinasjonsprogrammet.-rappor/>. Accessed on 12 May 2022.
49. Norwegian Institute of Public Health (FHI). Notification criteria for diseases in MSIS. <https://www.fhi.no/publ/2017/meldingskriterier-for-sykdommer-i-msis/>. Accessed on 12 May 2022.

*Infectious Diseases and Therapy*

50. Norwegian Institute of Public Health (FHI). Whooping cough (pertussis) - supervisor for health professionals. <https://www.fhi.no/nettpub/smittevernveilederen/sykdommer-a-a/kikhoste-pertussis---veileder-for-h/>. Accessed on 12 May 2022.
51. Norwegian Institute of Public Health (FHI). When will your child be offered vaccines? <https://www.fhi.no/en/id/vaccines/childhood-immunisation-programme/when-will-your-child-be-offered-vaccines/>. Accessed on 12 May 2022.
52. World Health Organization (WHO). WHO vaccine-preventable diseases: monitoring system. 2020 global summary - Coverage time series for Norway. [https://apps.who.int/immunization\\_monitoring/globalsummary/coverages?c=NOR](https://apps.who.int/immunization_monitoring/globalsummary/coverages?c=NOR). Accessed on 12 May 2022.
53. Norwegian Institute of Public Health (NIPH). Norhealth. <https://www.norgeshelsa.no/norgeshelsa/>. Accessed on 12 May 2022.
54. Norwegian Surveillance System for Communicable Diseases (MSIS). <http://www.msis.no/>. Accessed on 12 May 2022.
55. Health Protection Scotland (HPS). Whooping cough. <https://www.hps.scot.nhs.uk/a-to-z-of-topics/whooping-cough/>. Accessed on 27 April 2021.
56. The Public Health Agency of Sweden. Pertussis surveillance in Sweden - 21st annual report. <https://www.folkhalsomyndigheten.se/contentassets/cd49fff196f44e6a8db234ffb9da8b80/pertussis-surveillance-sweden-twenty-first-report-19071.pdf>. Accessed on 12 May 2022.
57. The Public Health Agency of Sweden. Pertussis surveillance in Sweden - Eighteen-year report. <https://www.folkhalsomyndigheten.se/contentassets/dbd8cd9e157c47189d72dd8ad9f6c94b/pertussis-eighteen-year-report-16109.pdf>. Accessed on 12 May 2022.
58. Statistics Sweden. The statistics database. [https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START\\_BE\\_BE0101\\_BE0101A/BefolkningR1860N/](https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START_BE_BE0101_BE0101A/BefolkningR1860N/). Accessed on 12 May 2022.
59. Statistics Estonia. Statistical database. <https://andmed.stat.ee/et/stat>. Accessed on 19 March 2021.

**Supplementary table S2.** Surveillance systems, case definitions, and recommended diagnostical methods for pertussis in the countries included in the analysis from 2010 to 2020 as available at the time of analysis

Country	Surveillance system <sup>a</sup>	Case definition	Recommended diagnostical methods used for laboratory confirmation	References
Denmark	Passive, population-based surveillance with mandatory, case-based reporting	Diagnosis based on clinical symptoms (not defined); Only laboratory-confirmed cases are registered	<p>If &lt;3 weeks of symptoms with cough: block-based PCR (culture) on an inoculum from the nasopharynx (initial PCR targeting gene <i>IS481</i> and a confirmatory PCR targeting gene <i>ptxP</i>)</p> <p>If ≥2 weeks of symptoms (including cough)</p> <ul style="list-style-type: none"> <li>• Children &lt;8 YoA compliant with the vaccination schedule and children/adults who received a pertussis vaccine in the preceding 2 years: PCR (culture)</li> <li>• Children/adults who did not receive a pertussis vaccine in the preceding 2 years: Serology (coating antigen: PT; standard sera: WHO) At SSI, an in-house ELISA with</li> </ul>	[1-4]

			<p>IgG anti-PT cut-off of 75 IU/mL was introduced in 2010.</p> <p>During the analytical period, most cases in older adults were confirmed by PCR and serology (<math>\pm 50\%</math>–<math>60\%</math> PCR until 2015 and <math>\pm 70\%</math>–<math>80\%</math> PCR from 2016)</p>	
England and Scotland	Enhanced passive (for laboratory-confirmed cases), population-based surveillance with mandatory, case-based reporting	WHO criteria; Only laboratory-confirmed cases are registered	<p>All age groups with &lt;3 weeks symptom duration: real-time PCR (targeting genes <i>IS481</i> and <i>ptxA-Pr</i>) and culture (if local laboratory facilities permit) (note, culture is not in use as per reference [3])</p> <p>Patients with &gt;2 weeks of cough symptoms who were not vaccinated in the preceding year: Serology (ELISA; coating antigen: PT; cut-off anti-PT IgG &gt;70 IU/mL; standard sera: WHO)</p> <p>Patients 2–16 YoA with &gt;2 weeks of cough symptoms who were not vaccinated in the preceding year: oral fluid testing (anti-PT IgG &gt;70 IU/mL; coating antigen: PT; standard sera: WHO). Oral fluid testing is not used for older adults.</p>	[2, 5-7]

			<p>During the analytical period, most cases were confirmed using serology.</p> <p>Patients with &lt;3 weeks of cough symptoms: block-based PCR (targeting gene <i>IS481</i>) and, if possible, culture</p> <p>Patients with &gt;3 weeks of cough symptoms who were not vaccinated in the preceding year: serology (ELISA; coating antigen: whole-cell bacteria; standard sera include in-house controls or not defined).</p> <p>Based on recent information (2020), serology was the most frequently used method for case confirmation.</p>	
Finland	Passive, population-based surveillance with mandatory, case-based reporting for the laboratories	Diagnosis based on clinical symptoms (coughing); Only laboratory-confirmed cases are registered.	<p>Patients with &lt;3 weeks of cough symptoms: block-based PCR (targeting gene <i>IS481</i>) and, if possible, culture</p> <p>Patients with &gt;3 weeks of cough symptoms who were not vaccinated in the preceding year: serology (ELISA; coating antigen: whole-cell bacteria; standard sera include in-house controls or not defined).</p> <p>Based on recent information (2020), serology was the most frequently used method for case confirmation.</p>	[2, 8, 9]
Germany	Passive, population-based surveillance with mandatory, case-based reporting (since 2013) <sup>b</sup>	<p>WHO criteria; Laboratory confirmation is not necessary if clinical and/or epidemiological confirmation is available.</p> <p>Note: in this analysis, data reported are from clinically- and laboratory-confirmed cases.</p> <p>A case is to be submitted to the responsible state authority in all of the following</p>	<p>Laboratory-confirmed cases need at least one of the following:</p> <ul style="list-style-type: none"> <li>• Positive culture of smears/secretions of the nasopharynx</li> <li>• Positive PCR (targeting genes <i>IS481</i> and <i>ptxA-Pr</i>) from smears/secretions of the nasopharynx</li> </ul>	[2, 5, 10-12]

instances: (i) a clinically diagnosed disease (i.e., clinical picture of whooping cough without laboratory diagnostic evidence and without epidemiological confirmation), (ii) a clinically and epidemiologically confirmed disease (i.e., clinical picture of whooping cough without laboratory diagnostic evidence but with epidemiological confirmation), (iii) a disease confirmed by clinical laboratory diagnostics (i.e., clinical picture of whooping cough and laboratory diagnostic evidence), (iv) the infection is confirmed by laboratory diagnostics if the clinical picture is not fulfilled (i.e., laboratory diagnostic evidence if the clinical picture is known that does not meet the criteria for whooping cough), or (v) the infection is confirmed by laboratory diagnosis with an unknown clinical picture (i.e., laboratory diagnostic

- Patients who did not receive an aP vaccine in the preceding 3 years: serology (ELISA; coating antigens PT and PRN; standard sera according to WHO; positive and negative control: in-house]) with significantly increased IgG antibody levels (anti-PT IgG antibodies  $\geq 100$  IU/mL for recent contact; anti-PT IgG antibodies  $< 40$  IU/mL for no evidence of recent contact. To ensure specificity, in case of anti-PT IgG antibody levels between 40 and 100 IU/mL, a second sample is tested or a significant increase in anti-PT IgA antibodies [ $> 12$  IU/mL] is needed).
- A clear change between two samples in IgG or IgA antibody preferably measured using ELISA

No data were available on the method that was most frequently used for laboratory confirmation.

evidence in the absence of information on  
the clinical picture)

The Netherlands

Passive, population-based  
surveillance with mandatory,  
case-based reporting

WHO criteria; Only laboratory-confirmed  
cases are reported.

Children <1 YoA and unvaccinated children <4 YoA:  
PCR and optional culture (note, culture is not in use  
as per reference [3])

[2, 5, 13-15]

Other groups:

- <3 weeks of cough symptoms: PCR  
(targeting gene *IS481*) and optional culture
- >3 weeks of cough symptoms: serology (PT  
antigen for IgG, whole bacteria for IgA; FDA  
standard serum; recent infection if anti-PT  
IgG >100 IU/mL or >125 IU/mL; in paired  
sera, a recent infection is demonstrated by  
a >3-fold rise in anti-PT IgG to a value >20  
IU/mL in the second serum)

When in doubt: PCR, followed by serology if PCR is  
negative



			In 2010–2013, serology was most frequently used for laboratory confirmation (93%), followed by PCR (6%) and culture (1%). No data were available on the method that was most frequently used since 2014.	
Norway	Passive, population-based surveillance with case-based, mandatory reporting	WHO criteria; Only laboratory-confirmed cases are registered.	<p>If disease duration &lt;2 weeks: culture (note, culture is not in use as per reference [3]), PCR (gene <i>IS481</i>), and 0-sample for antibody “parseira” (“parseira” means two paired samples taken with a sufficiently large time interval in which an increasing antibody trend indicates infection))</p> <p>If disease duration between 2 and 4 weeks: PCR and serology (possibly culture)</p> <p>If disease duration &gt;4 weeks: Serology (in case of seroconversion, significant increase of antibody values or high, specific antibody values in absence of recent vaccination) (ELISA; coating antigen from commercially available or in-house developed kit; standard sera: in-house controls or not defined; cut-off for recent infection is &gt;100 IU/mL)</p>	[2, 5, 16, 17], written communication from the Norwegian Institute of Public Health

			During the analytical period, PCR was most frequently used for laboratory confirmation, followed by serology. Culture is rarely used.	
Sweden	Enhanced passive (for 0–20-year-olds) or passive (for other age groups), population-based surveillance with mandatory, case-based reporting	WHO criteria; Only laboratory-confirmed cases are reported.  Only positive samples that are taken more than 6 months after a previous positive sample are a new episode of pertussis.	Culture (note, culture is not in use as per reference [3]), PCR, and serology (seroconversion or significant increase in IgG against PT) are all in use. During the analytical period, case confirmation in ≥11-year-olds (no older age groups provided) was primarily based on PCR and serology (same proportion until 2012 and ±80% PCR from 2013)	[2, 5, 18]

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aP, acellular pertussis vaccine; ELISA, enzyme-linked immunosorbent assay; FDA, US Food and Drug Administration; FHA, filamentous hemagglutinin; IgA, immunoglobulin A; IgG, immunoglobulin G; IU, international units; PCR, polymerase chain reaction; PT, pertussis toxin; PRN; pertactin; SSI, Statens Serum Institut (Denmark); WHO, World Health Organization; YoA, years of age.

<sup>a</sup> a passive surveillance system is defined as a system by which a health jurisdiction receives reports submitted from hospitals, clinics, public health units, or other sources [19] while an enhanced passive surveillance system is defined as a system in which further details (immunization status, contacts, hospitalizations, and complications of the cases) are usually collected following notification of the responsible authorities [20]; <sup>b</sup> in five former East German states, pertussis is notifiable according to state-specific laws, permitting the identification of outbreaks. Pertussis is not statutorily notifiable in the former West Germany and Berlin.

## References

1. Dalby T, Andersen PH, Hoffmann S. Epidemiology of pertussis in Denmark, 1995 to 2013. *Euro Surveill.* 2016;21:30334.
2. He Q, Barkoff AM, Mertsola J, *et al.* High heterogeneity in methods used for the laboratory confirmation of pertussis diagnosis among European countries, 2010: integration of epidemiological and laboratory surveillance must include standardisation of methodologies and quality assurance. *Euro Surveill.* 2012;17:20239.
3. Statens Serum Institut (SSI). Diagnosis of pertussis - choice of correct method. <https://www.ssi.dk/-/media/arkiv/dk/produkter-og-ydelsler/diagnostik/diagnostisk-haandbog/diagnostik-af-kighoste---valg-af-korrekt-metode.pdf?la=da>. Accessed on 12 May 2022.
4. Statens Serum Institut (SSI). Annual reports on disease incidence. <https://en.ssi.dk/surveillance-and-preparedness/surveillance-in-denmark/annual-reports-on-disease-incidence>. Accessed on 12 May 2022.
5. World Health Organization (WHO). Vaccine-Preventable Diseases - Surveillance Standards: Pertussis. <https://www.who.int/publications/m/item/vaccine-preventable-diseases-surveillance-standards-pertussis>. Accessed on 12 May 2022.
6. Public Health England (PHE). Guidelines for the public health management of pertussis in England. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/762766/Guidelines\\_for\\_the\\_Public\\_Health\\_management\\_of\\_Pertussis\\_in\\_England.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762766/Guidelines_for_the_Public_Health_management_of_Pertussis_in_England.pdf). Accessed on 12 May 2022.
7. United Kingdom Government. Pertussis: guidance, data and analysis. <https://www.gov.uk/government/collections/pertussis-guidance-data-and-analysis>. Accessed on 12 May 2022.
8. Finnish Institute for Health and Welfare (THL). Procedure for cases of pertussis. <https://thl.fi/fi/web/infektiaudit-ja-rokotukset/taudit-ja-torjunta/taudit-ja-taudinaiheuttajat-a-o/hinkuyska/toimenpideohje-hinkuyskatapauksiin>. Accessed on 12 May 2022.
9. Finnish Institute for Health and Welfare (THL). Notifiable diseases and microbes. <https://thl.fi/fi/web/infektiaudit-ja-rokotukset/seurantajarjestelmat-ja-rekisterit/tartuntatautirekisteri/ilmoitettavat-taudit-ja-mikrobit>. Accessed on 12 May 2022.
10. Hellenbrand W, Beier D, Jensen E, *et al.* The epidemiology of pertussis in Germany: past and present. *BMC Infect Dis.* 2009;9:22.
11. Robert Koch Institut (RKI). Falldefinitionen für die Gesundheitsbehörden der Länder, in denen zusätzlich zum IfSG eine Meldepflicht für weitere Krankheiten besteht (Ausgabe 2009). [https://www.rki.de/DE/Content/Infekt/IfSG/Falldefinition/laenderverordnungen\\_falldefs.html](https://www.rki.de/DE/Content/Infekt/IfSG/Falldefinition/laenderverordnungen_falldefs.html). Accessed on 12 May 2022.
12. Sin MA, Zenke R, Ronckendorf R, Littmann M, Jorgensen P, Hellenbrand W. Pertussis outbreak in primary and secondary schools in Ludwigslust, Germany demonstrating the role of waning immunity. *Pediatr Infect Dis J.* 2009;28:242-4.
13. Heil J, Ter Waarbeek HLG, Hoebe C, *et al.* Pertussis surveillance and control: exploring variations and delays in testing, laboratory diagnostics and public health service notifications, the Netherlands, 2010 to 2013. *Euro Surveill.* 2017;22.
14. National Institute for Public Health and the Environment (RIVM). Kinkhoest richtlijn. <https://lci.rivm.nl/richtlijnen/kinkhoest>. Accessed on 12 May 2022.

15. National Institute for Public Health and the Environment (RIVM). The National Immunisation Programme in the Netherlands: Surveillance and developments in 2018-2019. <https://www.rivm.nl/publicaties/national-immunisation-programme-in-netherlands-surveillance-and-developments-in-2018>. Accessed on 12 May 2022.
16. Norwegian Institute of Public Health (FHI). Barnevaksinasjonsprogrammet. Rapport for perioden 2001-2010. <https://www.fhi.no/publ/2012/barnevaksinasjonsprogrammet.-rappor/>. Accessed on 12 May 2022.
17. Norwegian Institute of Public Health (FHI). Notification criteria for diseases in MSIS. <https://www.fhi.no/publ/2017/meldingskriterier-for-sykdommer-i-msis/>. Accessed on 12 May 2022.
18. The Public Health Agency of Sweden. Pertussis surveillance in Sweden - 21st annual report. <https://www.folkhalsomyndigheten.se/contentassets/cd49fff196f44e6a8db234ffb9da8b80/pertussis-surveillance-sweden-twenty-first-report-19071.pdf>. Accessed on 12 May 2022.
19. Centers for Disease Control and Prevention. Introduction to Public Health Surveillance. <https://www.cdc.gov/training/publichealth101/documents/introduction-to-surveillance.pdf>. Accessed on 24 June 2021.
20. Centers for Disease Control and Prevention. Enhanced pertussis surveillance. <https://www.cdc.gov/abcs/methodology/pertussis-surveillance.html>. Accessed on 24 June 2021.

**Supplementary table S3.** Laboratory details per country as available at the time of analysis

Country	Type of laboratory that performs confirmation of pertussis infection	Are GP visits and laboratory tests reimbursed?	Do all laboratories do these tests and in the same way?	Number of pertussis reference laboratories in 2010 <sup>a</sup>	References
Denmark	The state laboratories usually test most of the suspected samples for pertussis. However, private laboratories can request to do the testing as well.	Both GP visits and laboratory tests required by GP or other HCP are free of charge for patients.	It is not clear if all laboratories in Denmark are capable to conduct the pertussis tests across the country; however, it is assumed that patients will be referred to the lab where the needed test (according to recommendation from Medical Authorities) can be done.	<10	Written communication from local medical advisor.
England and Scotland	State laboratories.	GP visits and tests are free (the UK operates a free at the point of care health service, funded through National Insurance contributions). Some private care will take place, but the	<ul style="list-style-type: none"> <li>– Culture testing is done by NHS laboratories.</li> <li>– PCR is done by regional PHE laboratories since 2014 (in both hospital and primary care settings).</li> <li>– Kit for oral fluid sampling sent to patient upon notification to PHE HPT (since Jan 2013).</li> </ul>	>100	[1, 2], written communication from local scientific advisor.

majority is done through the NHS.

- Serology is usually charged for service at Respiratory and Vaccine Preventable Bacteria Reference Unit.

The isolate that is confirmed as *Bordetella pertussis* by either of these methods is sent to, referred to, or reported by the Respiratory and Vaccine Preventable Bacteria Reference Unit.

Finland	State or private laboratories, depending on the hospital district.	<p>The cost of the laboratory test is reimbursed.</p> <p>The GP visit is either partially or fully covered by public healthcare (depends on the municipality).</p> <p>For private healthcare clinics, patients (or the patient's employer, if they have an occupational healthcare contract) pay out of pocket.</p>	The sample is sent for testing to a lab that can perform the test.	<10	[3], written communication from local scientific advisor.
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Germany	Private laboratories.	The GP or any specialist visits and the diagnostical tests are fully reimbursed by the insurance companies.	Most of the laboratories perform PCR and serology for samples from suspected cases of pertussis. Culture is predominantly performed by specialized laboratories, so called “reference laboratories” as it requires a lot of knowledge how to cultivate <i>Bordetella pertussis</i> .	>100	Written communication from GSK local head of medical affairs.
The Netherlands	State or private laboratories, depending on the patient’s place of residence.	Patients are usually reimbursed for GP costs. They are entitled to yearly “own risk” healthcare costs of at least 385 euro (in 2020–2021), so besides GP visits, patients need to pay the first 385 euro of healthcare costs by themselves. This includes laboratory tests. If their healthcare cost equals or exceeds 385 euros (as stated in the contract with the healthcare insurance), the extra	There is no consistency in which tests the different laboratories perform in the Netherlands.	30–100	[4], written communication from local medical scientific expert.

costs including for laboratory tests are usually reimbursed.

Norway	State and private laboratories.	The GP visits and laboratory test are reimbursed for pertussis.	Many laboratories test for pertussis as part of an “Airway-Panel” (Multiplex PCR).  The HCP (most frequently a GP) orders a test for the patient and/or sends the samples to the laboratory. The test that is conducted for confirmation of a pertussis infection depends on the local laboratory, but it is assumed that most laboratories can conduct all types of diagnostical tests.	10–30	[5], written communication from local scientific advisor.
Sweden	State laboratories.	Patients are usually fully reimbursed, and healthcare is covered by tax money in Sweden.	State laboratories are not different in their capability in conducting the diagnostics that are stated in the guidelines for diagnosis pertussis.	10–30	Written communication from local scientific advisor.

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GP, general practitioner; HCP, healthcare professional; HPT, health protection team; NHS, National Health Service; PCR, polymerase chain reaction; PHE, Public Health England; UK, United Kingdom.



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<sup>a</sup> from reference [6].

## References

1. Public Health England (PHE). Pertussis brief for healthcare professionals. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/762782/Pertussis\\_brief\\_for\\_health\\_care\\_professionals.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762782/Pertussis_brief_for_health_care_professionals.pdf). Accessed on 12 May 2022.
2. United Kingdom Government. Pertussis: background information on prevention and management. <https://www.gov.uk/guidance/pertussis-clinical-and-public-health-management>. Accessed on 12 May 2022.
3. Ministry of Social Affairs and Health. Health care payments. <https://stm.fi/terveydenhuollon-maksut>. Accessed on 12 May 2021.
4. The Dutch Government. Wanneer betaal ik een eigen risico voor mijn zorg? <https://www.rijksoverheid.nl/onderwerpen/zorgverzekering/vraag-en-antwoord/eigen-risico-zorgverzekering>. Accessed on 12 May 2022.
5. Norwegian Institute of Public Health (FHI). Whooping cough (pertussis) - supervisor for health professionals. <https://www.fhi.no/nettpub/smittevernveilederen/sykdommer-a-a/kikhoste-pertussis---veileder-for-h/>. Accessed on 12 May 2022.
6. He Q, Barkoff AM, Mertsola J, *et al.* High heterogeneity in methods used for the laboratory confirmation of pertussis diagnosis among European countries, 2010: integration of epidemiological and laboratory surveillance must include standardisation of methodologies and quality assurance. *Euro Surveill.* 2012;17:20239.

**Supplementary table S4.** Recommended vaccination schedules and vaccination coverage for pertussis in the countries included in the analysis from 2010 to 2020 as available at the time of analysis

Country	Vaccination schedule	Vaccination coverage	References
Denmark	<p>Primary vaccination:</p> <ul style="list-style-type: none"> <li>From 2004: DTaP-IPV-Hib (3, 5, and 12 MoA)</li> <li>In 2014: temporary switch due to vaccine shortage – DTaP-IPV-HBV-Hib (3, 5, and 12 MoA) for new vaccinees; children who already received one vaccine as per the usual schedule would complete that schedule</li> </ul> <p>Booster vaccination:</p> <ul style="list-style-type: none"> <li>From 2004: DTaP-IPV (5 YoA)</li> <li>In 2014: temporary switch due to vaccine shortage – DTaP and IPV (5 YoA)</li> </ul> <p>Vaccination in pregnancy:</p> <ul style="list-style-type: none"> <li>Nov 2019–Mar 2022: temporary offer for pregnant women in their 3rd trimester; started due to pertussis outbreak</li> </ul>	<p>Primary vaccination:</p> <ul style="list-style-type: none"> <li>2006–2013 birth cohort: 85%–91% (increasing trend)</li> <li>2015 &amp; 2016: &gt;90%</li> </ul> <p>Booster vaccination:</p> <ul style="list-style-type: none"> <li>2015 &amp; 2016 (at 5 YoA): 80%</li> </ul> <p>Vaccination in pregnancy: No data</p>	[1-5]
England and Scotland	Primary vaccination	Primary vaccination	[6-13]

- 2004–2017: DTaP-IPV(-Hib) (2, 3, 4 MoA)
- From 2017: DTaP-IPV-Hib-HBV

Booster vaccination

- From 2004: DTaP-IPV (at 3.5–5 YoA and at 13 YoA)

Vaccination in pregnancy:

- From 2012: Tdap(-IPV)

Finland

Primary vaccination:

- From 2005: DTaP-IPV-Hib (3, 5, 12 MoA)

Booster vaccination:

- From 2009: booster at 4 YoA (first introduced in 2003 at 6 YoA) + booster 14–15 YoA (first introduced in 2005 at 11–12 YoA)
- From 2012: booster for military personnel and HCPs working with infants
- From 2018: booster at 25 YoA

Germany

Primary vaccination:

- 2008–2019 (dose 3; United Kingdom): 92%–93%

Booster vaccination:

- Jul–Sep 2011: 85.4% (England; at 5 YoA) and 94.5% (Scotland; at 5 YoA)

Vaccination in pregnancy:

- Oct 2012–Q1 2020/2021: 43.7%–69.6%

Primary vaccination

[14]

- 2012–2017 (dose 1): 97.6%–98.4%
- 2012–2017 (dose 2): 96.9%–97.5%
- 2012–2017 (dose 3): 91%–93.3%

Booster vaccination

- 2012 (at 4 YoA): 89.2%

Primary vaccination:

[15-19]

- 2000–2019: four-dose aP schedule
- 2020: three-dose aP schedule

Booster vaccination:

- From 2000: booster at 9–17 YoA
- From 2003: booster for childcare workers and HCPs
- From 2004: booster for adults with close contact to infants prior to birth of the infant (cocooning strategy)
- From 2006: additional booster dose at 5–6 YoA
- From 2007: one booster dose for all adults (10 years after the last dose)

Vaccination in pregnancy:

- From 2020

The Netherlands

Primary vaccination:

- 2005: DTaP-IPV-Hib (2, 3, 4, and 11 MoA)
- From 2006: DTaP-IPV-HBV-Hib (2, 3, 4, and 11 MoA)

Booster vaccination:

- 2017 (dose 1 & dose 3): 96% & 93%

Booster vaccination:

- 2007–2016 (all adults): 32.4%

Vaccination in pregnancy: no data

Primary vaccination:

- 2006 & 2019 (at 2 YoA): 94.3% & 92.4%
- 2006 & 2019 (at 5 YoA; sufficiently protected toddlers<sup>a</sup>): 93.9% & 92.5%

[20, 21]

- From 2001: aP (4 YoA)
- From 2006: DTaP-polio/IPV (4 YoA)

Vaccination in pregnancy:

- From 2016: recommended (to be paid out-of-pocket)
- From 2019 (Dec): introduced in the NIP and offered free of charge
- Q1 2020: catch-up campaign for pregnant women who were eligible for vaccination in pregnancy prior to its introduction in the NIP

Booster vaccination:

- 92% (standardized vaccination coverage estimate before 2018 for the booster at 4 YoA)

Vaccination in pregnancy:

- 2016–2017: <2%
- 2018: 20%
- 2019: 40% (after correction for bias)
- 2020 (Apr): ±70%

Norway

Primary vaccination:

- From 1998: DTaP-IPV-Hib (3, 5, and 12 MoA)

Booster vaccination:

- From 2006: booster DTaP-IPV (7 YoA)
- From 2014 (recommendation made in 2008): Tdap-IPV (every 10 years starting at 15 YoA; to be paid out-of-pocket after 15 YoA)

Primary vaccination:

[22-24]

- 2010–2019 (dose 1): 99%–100%
- 2010–2019 (dose 3): 93%–97%

Booster vaccination:

- 2010–2020 (9 YoA; vaccine against pertussis): 93%–95.6%

		<ul style="list-style-type: none"> <li>• 2014–2020 (16 YoA; vaccine against pertussis): 88.8%–94.2%</li> </ul>	
Sweden	<p>Primary vaccination:</p> <ul style="list-style-type: none"> <li>• From 1996: DTaP (3,5, and 12 MoA)</li> <li>• From 2000: DTaP-Hib-IPV (3,5, and 12 MoA)</li> </ul> <p>Booster vaccination:</p> <ul style="list-style-type: none"> <li>• 2005 to 2011–2012: Tdap (10 YoA = dose 4)</li> <li>• From 2007: DTaP (5–6 YoA = dose 4)</li> <li>• From 2016 (recommendation made in 2007): Tdap (14–16 YoA = dose 5)</li> </ul>	<p>Primary vaccination:</p> <ul style="list-style-type: none"> <li>• 2010–2016 (dose 3): 97%–98%</li> </ul> <p>Booster vaccination:</p> <ul style="list-style-type: none"> <li>• 2016 (dose 4 at 5–6 YoA): 93.5%</li> <li>• Since 2016 (dose 5): ±90% (the actual percentage may be higher due to underreporting)</li> </ul>	[25, 26]

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DTaP, diphtheria-tetanus-acellular pertussis vaccine (component); HBV, hepatitis B vaccine component; HCP, healthcare professional; Hib, *Haemophilus influenzae* type b vaccine component; IPV, inactivated poliovirus vaccine (component); MoA, months of age; NIP, national immunization programme; Tdap, reduced-antigen-content tetanus-diphtheria-acellular pertussis vaccine (component); YoA, years of age.

<sup>a</sup> revaccinated toddlers and toddlers who reached basic immunity at age 2–5 years were therefore not eligible for revaccination at 5 YoA. Note: pertussis vaccination was not mandatory in any of the included countries. All vaccines were offered free of charge unless stated otherwise.

## References

1. Dalby T, Andersen PH, Hoffmann S. Epidemiology of pertussis in Denmark, 1995 to 2013. *Euro Surveill.* 2016;21:30334.
2. Statens Serum Institut (SSI). Temporary substitution of child vaccine to Infanrix hexa® and 5-year booster to dTap booster and separate polio vaccine (IPV). <https://en.ssi.dk/news/epi-news/2013/no-50---2013>. Accessed on 12 May 2022.
3. Statens Serum Institut (SSI). Whooping cough - 2019 report on disease occurrence. <https://en.ssi.dk/surveillance-and-preparedness/surveillance-in-denmark/annual-reports-on-disease-incidence/whooping-cough---2019-report-on-disease-occurrence#>. Accessed on 12 May 2022.
4. Statens Serum Institut (SSI). The Danish Vaccination Program - Annual report 2016 version 2. [https://en.ssi.dk/-/media/arkiv/indhold/dk-dansk/vaccination/boernevaccination/boernevaccinationsprogram\\_2016\\_v2\\_jan18](https://en.ssi.dk/-/media/arkiv/indhold/dk-dansk/vaccination/boernevaccination/boernevaccinationsprogram_2016_v2_jan18). Accessed on 12 May 2022.
5. Danish Ministry of Health. Pregnant women will still be able to get a free pertussis vaccination. <https://sum.dk/nyheder/2021/juni/gravide-vil-fortsat-kunne-faa-en-gratis-kighostevaccination->. Accessed on 12 May 2022.
6. Public Health England (PHE). Historical vaccine development and introduction of routine vaccine programmes in the UK. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/816174/Vaccine\\_Timeline\\_2019.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/816174/Vaccine_Timeline_2019.pdf). Accessed on 12 May 2022.
7. World Health Organization (WHO). United Kingdom of Great Britain and Northern Ireland: WHO and UNICEF estimates of immunization coverage: 2020 revision. [https://cdn.who.int/media/docs/default-source/country-profiles/immunization/immunization\\_gbr\\_2021.pdf?sfvrsn=353c63e3\\_9&download=true](https://cdn.who.int/media/docs/default-source/country-profiles/immunization/immunization_gbr_2021.pdf?sfvrsn=353c63e3_9&download=true). Accessed on 12 May 2022.
8. Health Protection Agency. Health protection report - weekly report volume 5 number 50. <https://webarchive.nationalarchives.gov.uk/20140714091638/http://www.hpa.org.uk/hpr/archives/2011/hpr5011.pdf>. Accessed on 12 May 2022.
9. Public Health England (PHE). Vaccine update. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/805502/PHE\\_vaccineupdate\\_294\\_May19.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/805502/PHE_vaccineupdate_294_May19.pdf). Accessed on 12 May 2022.
10. Public Health England (PHE). Vaccine update. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/653401/VU\\_271\\_october\\_2017.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/653401/VU_271_october_2017.pdf). Accessed on 12 May 2022.
11. United Kingdom Government. Pertussis Vaccination Programme for Pregnant Women: vaccine coverage estimates in England, October 2013 to March 2014. <https://www.gov.uk/government/publications/pertussis-immunisation-in-pregnancy-vaccine-coverage-estimates->

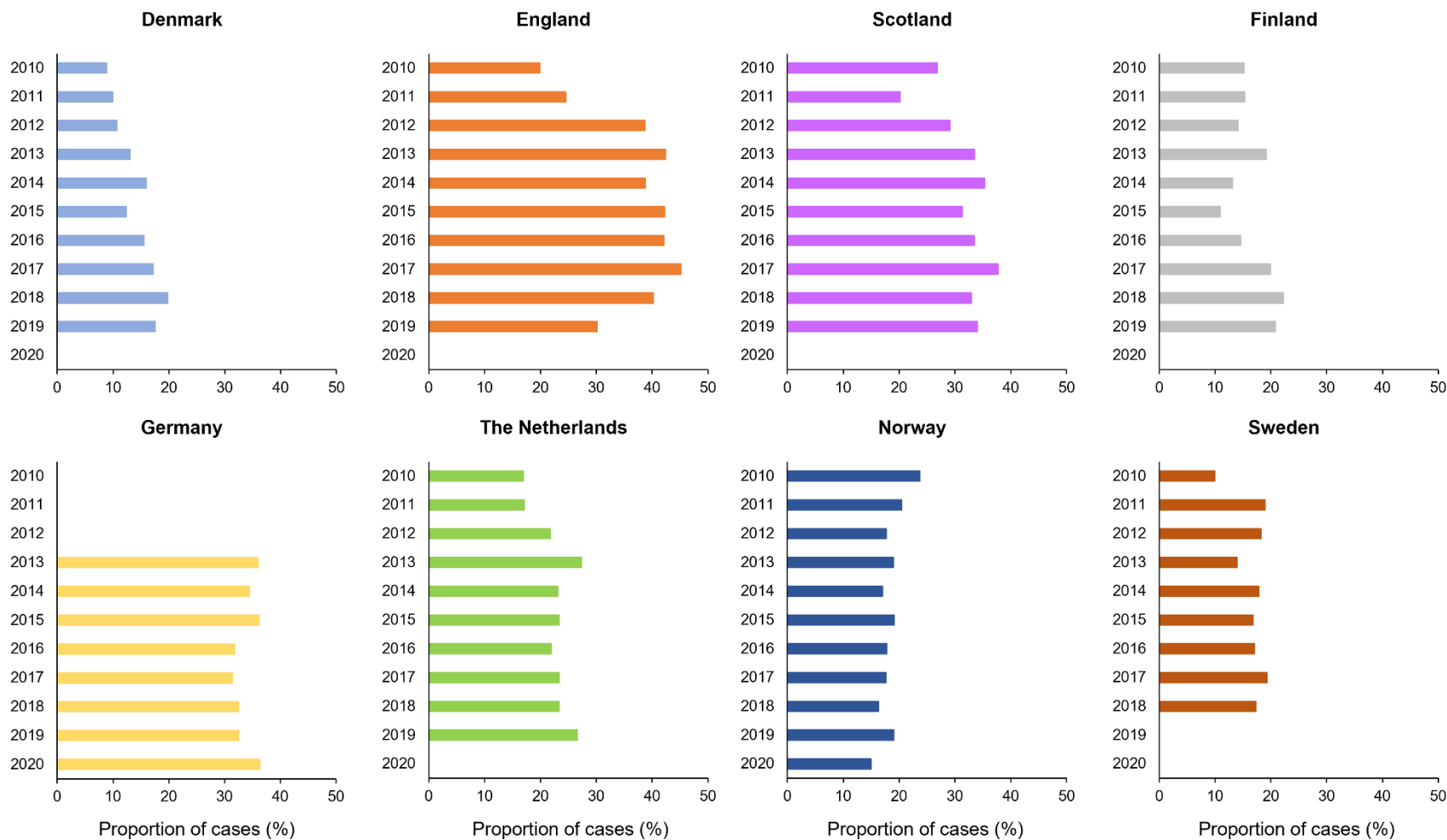
[in-england-october-2013-to-march-2014/pertussis-vaccination-programme-for-pregnant-women-vaccine-coverage-estimates-in-england-october-2013-to-march-2014](#). Accessed on 12 May 2022.

12. Public Health England (PHE). Pertussis vaccination programme for pregnant women update: vaccine coverage in England, April to June 2020. <https://webarchive.nationalarchives.gov.uk/ukgwa/20220201225652/https://www.gov.uk/government/publications/pertussis-immunisation-in-pregnancy-vaccine-coverage-estimates-in-england-october-2013-to-march-2014>. Accessed on 12 May 2022.
13. Public Health England (PHE). Pertussis: the green book, chapter 24. [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/514363/Pertussis\\_Green\\_Book\\_Chapter\\_24\\_Ap2016.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/514363/Pertussis_Green_Book_Chapter_24_Ap2016.pdf). Accessed on 12 May 2022.
14. Finnish Institute for Health and Welfare (THL). Vaccination coverage. <https://www.thl.fi/roko/rokotusrekisteri/atlas/public/atlas.html?show=infantbc>. Accessed on 12 May 2022.
15. Robert Koch Institut (RKI). Archive of the STIKO recommendations. [https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Archiv/seit\\_1972/archiv\\_tab.html](https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Archiv/seit_1972/archiv_tab.html). Accessed on 12 May 2022.
16. World Health Organization (WHO). WHO-UNICEF estimates of national immunization coverage. <https://www.who.int/teams/immunization-vaccines-and-biologicals/immunization-analysis-and-insights/global-monitoring/immunization-coverage/who-unicef-estimates-of-national-immunization-coverage>. Accessed on 12 May 2022.
17. Robert Koch Institut (RKI). SURVSTAT@RKI 2.0. <https://survstat.rki.de/Content/Query/Create.aspx>. Accessed on 12 May 2022.
18. Robert Koch Institut (RKI). Vaccination calendar (standard vaccinations). [https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Aktuelles/Impfkalender.pdf?\\_\\_blob=publicationFile](https://www.rki.de/DE/Content/Kommissionen/STIKO/Empfehlungen/Aktuelles/Impfkalender.pdf?__blob=publicationFile). Accessed on 12 May 2022.
19. Rieck T, Matysiak-Klose D, Hellenbrand W, *et al.* [Compliance with adult measles and pertussis vaccination recommendations : Analysis of data from the national monitoring system KV-Impfsurveillance]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*. 2019;62:422-32.
20. National Institute for Public Health and the Environment (RIVM). The National Immunisation Programme in the Netherlands: Surveillance and developments in 2018-2019. <https://www.rivm.nl/publicaties/national-immunisation-programme-in-netherlands-surveillance-and-developments-in-2018>. Accessed on 12 May 2022.
21. National Institute for Public Health and the Environment (RIVM). The National Immunisation Programme in the Netherlands: Surveillance and developments in 2019-2020. <https://www.rivm.nl/publicaties/national-immunisation-programme-in-netherlands-surveillance-and-developments-in-2019>. Accessed on 12 May 2022.



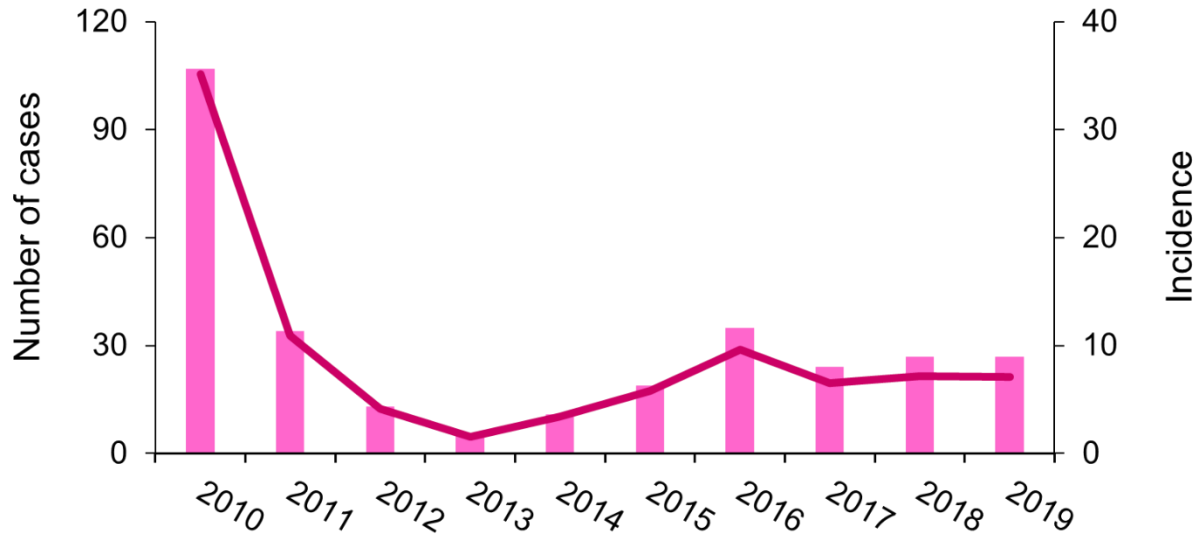
22. Norwegian Institute of Public Health (FHI). When will your child be offered vaccines? <https://www.fhi.no/en/id/vaccines/childhood-immunisation-programme/when-will-your-child-be-offered-vaccines/>. Accessed on 12 May 2022.
23. World Health Organization (WHO). WHO vaccine-preventable diseases: monitoring system. 2020 global summary - Coverage time series for Norway. [https://apps.who.int/immunization\\_monitoring/globalsummary/coverages?c=NOR](https://apps.who.int/immunization_monitoring/globalsummary/coverages?c=NOR). Accessed on 12 May 2022.
24. Norwegian Institute of Public Health (NIPH). Norhealth. <https://www.norgeshelsa.no/norgeshelsa/>. Accessed on 12 May 2022.
25. The Public Health Agency of Sweden. Pertussis surveillance in Sweden - 21st annual report. <https://www.folkhalsomyndigheten.se/contentassets/cd49fff196f44e6a8db234ffb9da8b80/pertussis-surveillance-sweden-twenty-first-report-19071.pdf>. Accessed on 12 May 2022.
26. The Public Health Agency of Sweden. Pertussis surveillance in Sweden - Eighteen-year report. <https://www.folkhalsomyndigheten.se/contentassets/dbd8cd9e157c47189d72dd8ad9f6c94b/pertussis-eighteen-year-report-16109.pdf>. Accessed on 12 May 2022.

**Supplementary figure S1.** Proportion of all cases that were reported in older adults from 2010 to 2020



For England, data from 2019 were provisional. For the Netherlands, data from 2018 and 2019 were provisional.

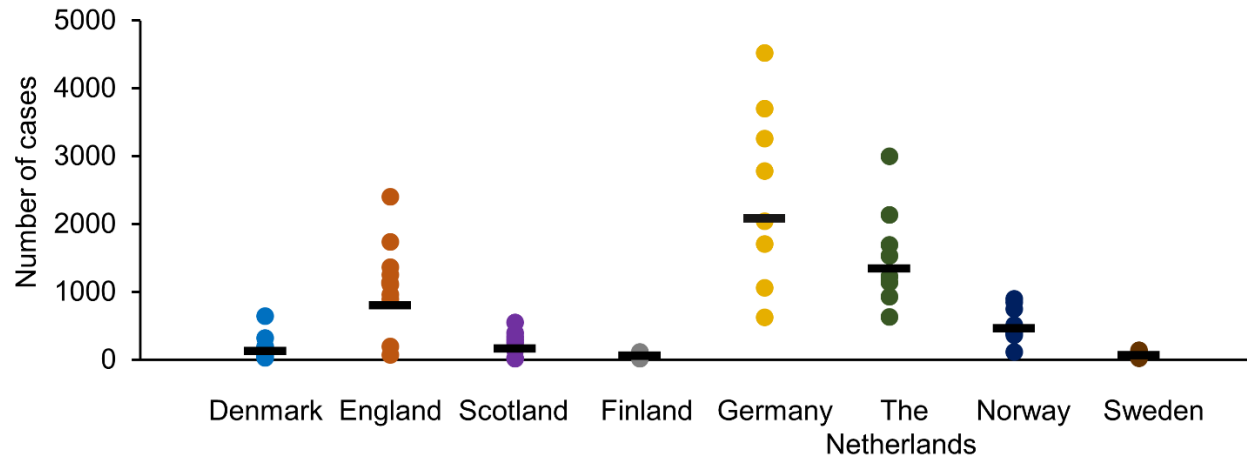
**Supplementary figure S2.** Number of pertussis cases and incidence rate per 100000 population in older adults in Estonia from 2010 to 2019



Bars represent number of cases (left y-axis) and the line represents the incidence rate per 100000 population (right y-axis).

In Estonia, the pertussis burden among older adults was highest in 2010 (incidence rate of 35.1 per 100000; 107 cases). From 2011 to 2013, the pertussis burden decreased, followed by an increase until 2016 and a plateau from 2017 onwards.

**Supplementary figure S3.** Number of pertussis cases among older adults in all countries from 2010 to 2020



The number of reported cases ranged from 22 (Scotland, 2010) to 4520 (Germany, 2017). The mean number of cases was highest in Germany (2464 cases), followed by the Netherlands (1468 cases), England (1115 cases), Norway (519 cases), Scotland (242 cases) Denmark (185 cases), Sweden (82 cases), and Finland (66 cases).

For Germany, data were available from 2013 to 2020. For Norway, data were available until November 2020. For Sweden, data were available until 2018. For other countries, data were available from 2010 to 2019 (included). For England, data from 2019 were provisional. For the Netherlands, data from 2018 and 2019 were provisional. Dots represent individual data points; geometric means are indicated with —.

**Supplementary figure S4.** Age-stratified number of pertussis cases and incidence rate per 100000 population in older adults in Austria from 2010 to 2019

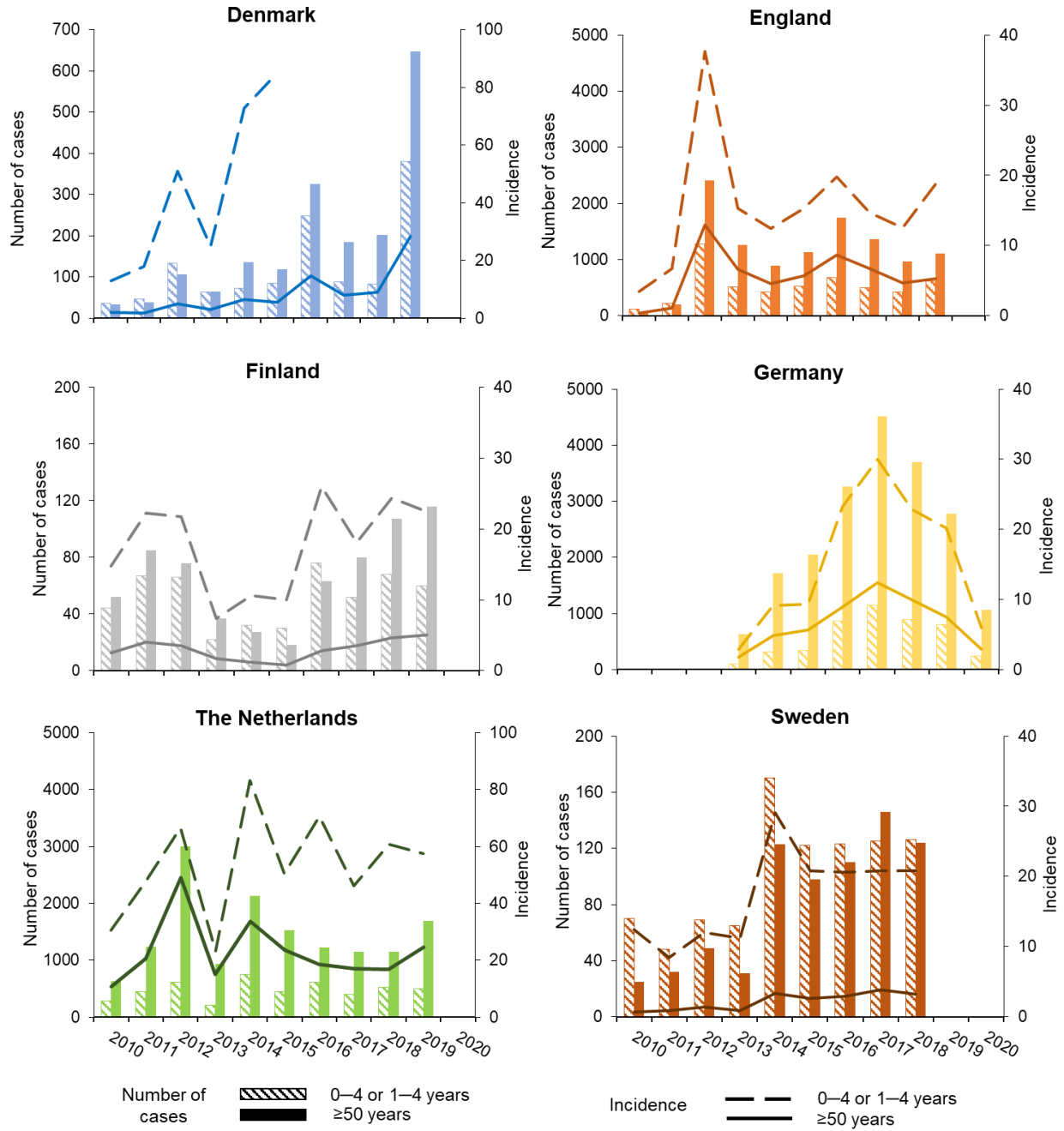
Age group	Number of cases									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
50–54	24	15	24	44	24	44	78	65	114	110
55–59	9	18	32	52	27	33	55	63	112	98
60–64	18	20	26	20	23	28	55	57	83	94
65–69	22	21	18	29	21	28	59	56	68	74
70–74	15	17	37	35	30	33	48	45	64	60
75–79	15	14	16	12	10	22	37	50	40	54
80–84	4	10	12	16	5	16	23	25	20	26
85–89	4	4	8	13	4	10	15	13	8	7
90–94	2	1	3	6	1	0	8	9	5	9
95–99	0	0	0	0	0	0	0	1	0	1
≥100	0	0	0	0	0	0	0	0	0	0

Age group	Incidence rate									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
50–54	3.92	2.38	3.69	6.54	3.47	6.24	10.95	9.09	15.93	15.37
55–59	1.80	3.46	5.94	9.32	4.65	5.47	8.83	9.77	16.79	14.70
60–64	3.81	4.18	5.50	4.25	4.85	5.78	10.89	10.89	15.28	17.30
65–69	5.21	5.21	4.36	6.90	4.94	6.26	13.03	12.49	15.25	16.59
70–74	3.92	4.10	8.57	7.89	7.03	8.49	12.94	11.84	16.52	15.49
75–79	5.67	5.35	6.14	4.50	3.31	6.48	10.05	13.04	10.19	13.76
80–84	1.84	4.59	5.49	7.37	2.33	7.57	10.92	11.88	9.23	12.00
85–89	2.86	2.83	5.70	9.24	2.82	7.01	10.44	9.00	5.54	4.85
90–94	4.99	2.10	5.56	10.13	1.59	0.00	12.30	13.87	7.70	13.85
95–99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.45	0.00	6.01
≥100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Data are formatted according to a graded colour scale with the lowest value in white and the highest value in darkest green.

**Supplementary figure S5.** Number of pertussis cases and incidence rate in older adults and children 0–4 years of age (YoA) in countries with data available from 2010 to 2020



Data for children 0–4 YoA were available for England, Finland, Germany, the Netherlands, and Sweden; for Denmark, data were available for children 1–4 YoA. The incidence rates for both populations (children and older adults) followed a similar trend in all countries.

For England, data from 2019 were provisional. For the Netherlands, data from 2018 and 2019 were provisional.

## **Supplementary text S1.** Contextual epidemiological information across countries

Pertussis surveillance was passive, population-based with mandatory, case-based reporting of laboratory-confirmed cases throughout the 2010s in all countries except for Germany. In Germany, reporting became mandatory in 2013 but was not limited to laboratory-confirmed cases. In all other countries, only laboratory-confirmed cases were reported (**Table 1; Supplementary table S2**). Case definitions followed World Health Organization-defined criteria in England and Scotland, Germany, the Netherlands, Norway, and Sweden (**Supplementary table S2**) [1]. In Finland, clinical diagnosis (and consequently the need for laboratory confirmation) was based on presence of cough symptoms only. No details on the clinical case definition used were available for Denmark. In Sweden, positive samples taken <6 months after a previous positive sample were not considered a new pertussis episode.

Laboratory tests for case confirmation were primarily conducted by state laboratories in Denmark, England and Scotland, and Sweden, primarily by private laboratories in Germany, and by both (e.g., depending on the patient's place of residence) in Finland, the Netherlands, and Norway. Visits to the general practitioner (GP) and laboratory tests were fully reimbursed in Denmark, England and Scotland, Germany, Norway, and Sweden. In Finland and the Netherlands, GP visits may not be fully reimbursed (depending on the municipality) or patients have a yearly own risk healthcare cost (applicable for laboratory testing but not for GP visits), respectively (**Table 1; Supplementary table S3**). The diagnostic method that was primarily used during the analytical period was polymerase chain reaction (PCR) and serology in Denmark ( $\pm 50\%$ – $60\%$  PCR until 2015 and  $\pm 70\%$ – $80\%$  PCR from 2016; in older adults) and in Sweden (same proportion PCR and serology until 2012 and  $\pm 80\%$  PCR from 2013; from  $\geq 11$  years of age); serology in England and Scotland (adults), Finland (no data per age group), and the Netherlands (no data per age group); and PCR in Norway (no data per age group). In all countries, culture was rarely used for confirmation of a case. No such data were available for Germany. In Finland, the Netherlands, and Norway, PCR targeted the gene *IS481* alone (which is not specific to *B. pertussis*), while the gene *ptxA-Pr*



was additionally targeted in England and Scotland, and Germany. In Denmark, an initial PCR targeted the gene *IS481*, while a confirmatory PCR targeted gene *ptxP*. Serology cut-offs for recent infections were >70 anti-pertussis toxin (PT) immunoglobulin G (IgG) international units (IU) per mL in England and Scotland, 75 IU/mL at the Statens Serum Institut in Denmark,  $\geq 100$  anti-PT IgG IU/mL in Germany, and >100 (anti-PT IgG) IU/mL in the Netherlands and Norway. The kits, enzyme-linked immunosorbent assay (ELISA) coating antigens, and standard sera used for serology also differed between countries (**Table 1; Supplementary table S2**).

There was also heterogeneity in recommendations and coverage for booster doses, primarily those recommended in adulthood (**Supplementary table S4**). Only Finland, Germany, and Norway recommended booster doses for adults outside of pregnancy; this booster only covered older adults in Norway (decennial booster since 2014) (**Table 1; Supplementary table S4**). Coverage rates for booster doses administered to older adults were not known at the time of our analysis.

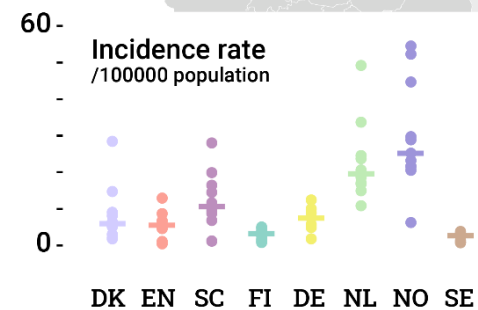
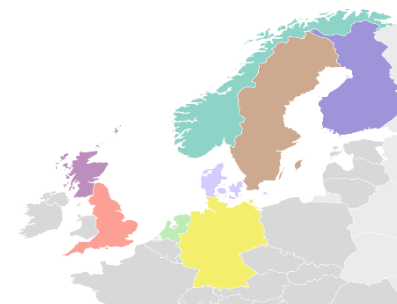
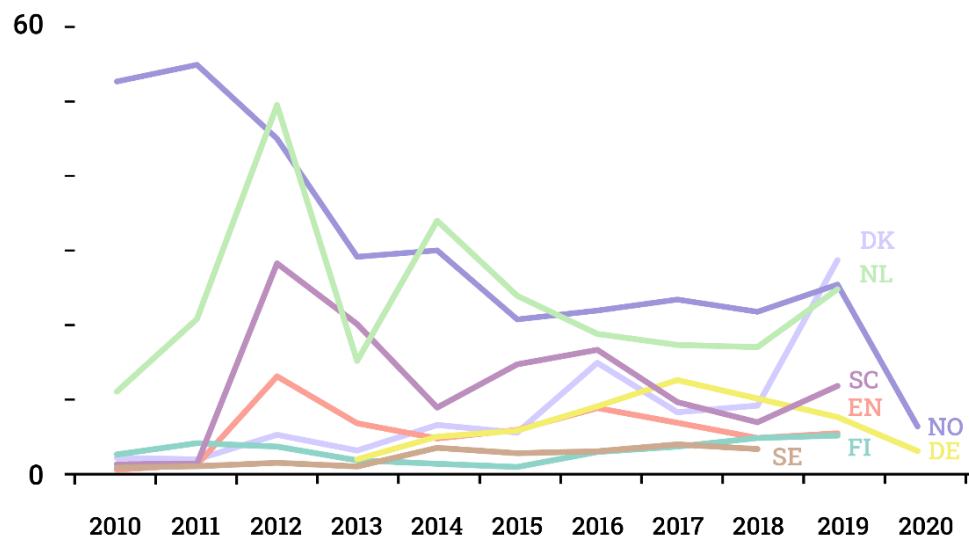
## Reference

1. World Health Organization (WHO). Vaccine-Preventable Diseases - Surveillance Standards: Pertussis. [https://www.who.int/immunization/monitoring\\_surveillance/burden/vpd/WHO\\_SurveillanceVaccinePreventable\\_16\\_Pertussis\\_R1.pdf?ua=1](https://www.who.int/immunization/monitoring_surveillance/burden/vpd/WHO_SurveillanceVaccinePreventable_16_Pertussis_R1.pdf?ua=1). Accessed on 5 January 2021.

# All countries

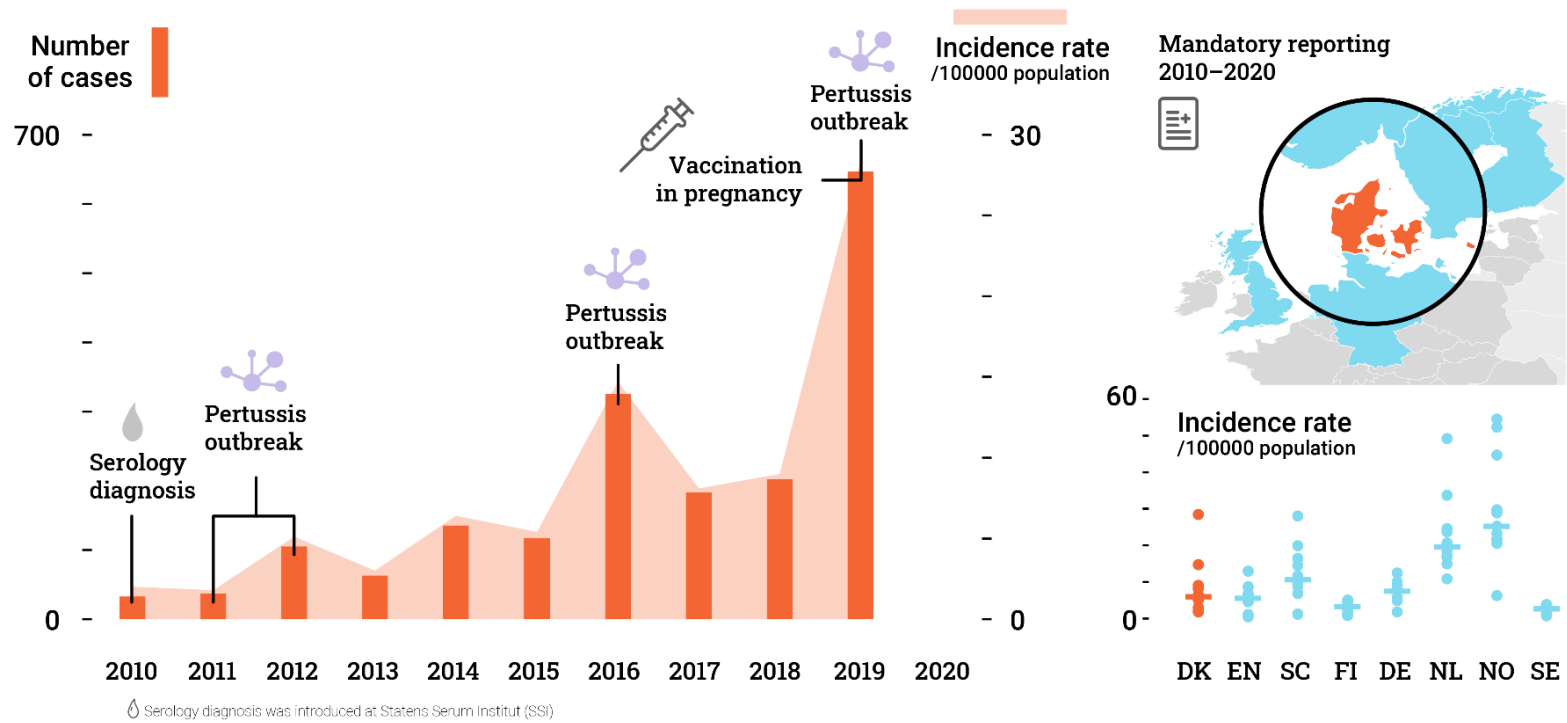
Descriptive overview of pertussis epidemiology among older adults in Europe during 2010–2020

Incidence rate  
/100000 population



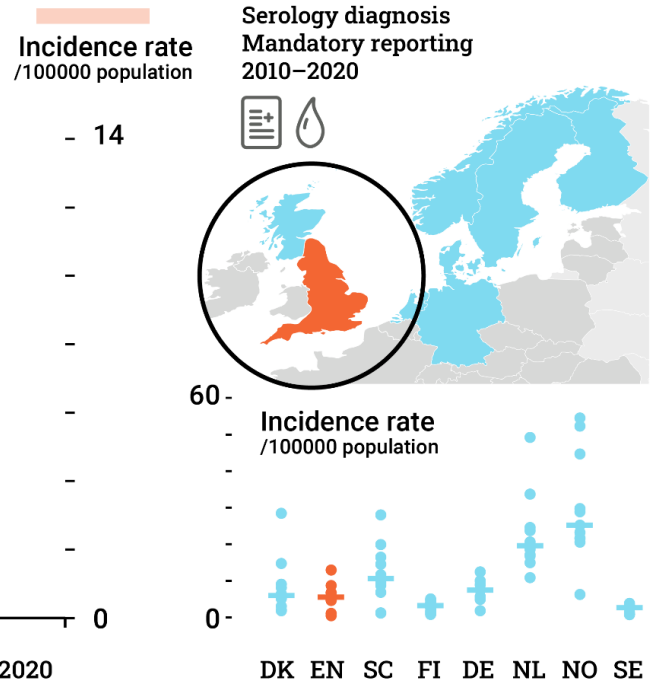
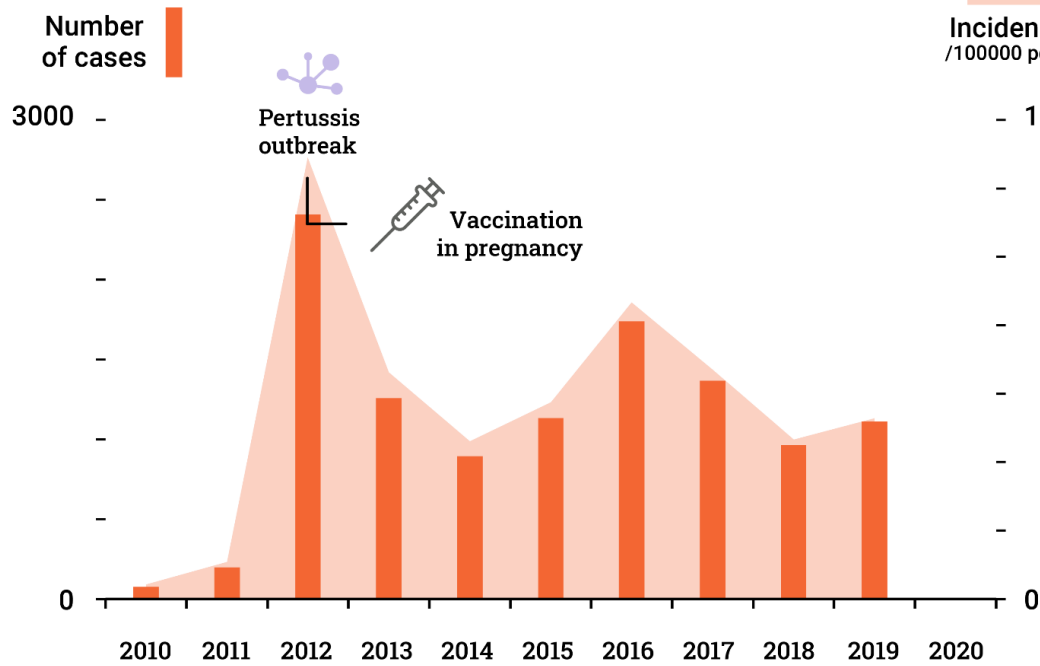
# Denmark

The reported pertussis burden among older adults increased over time



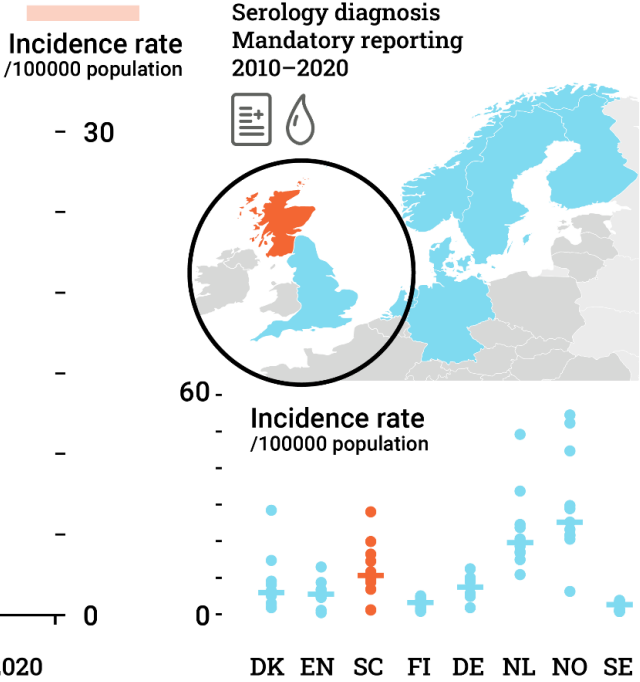
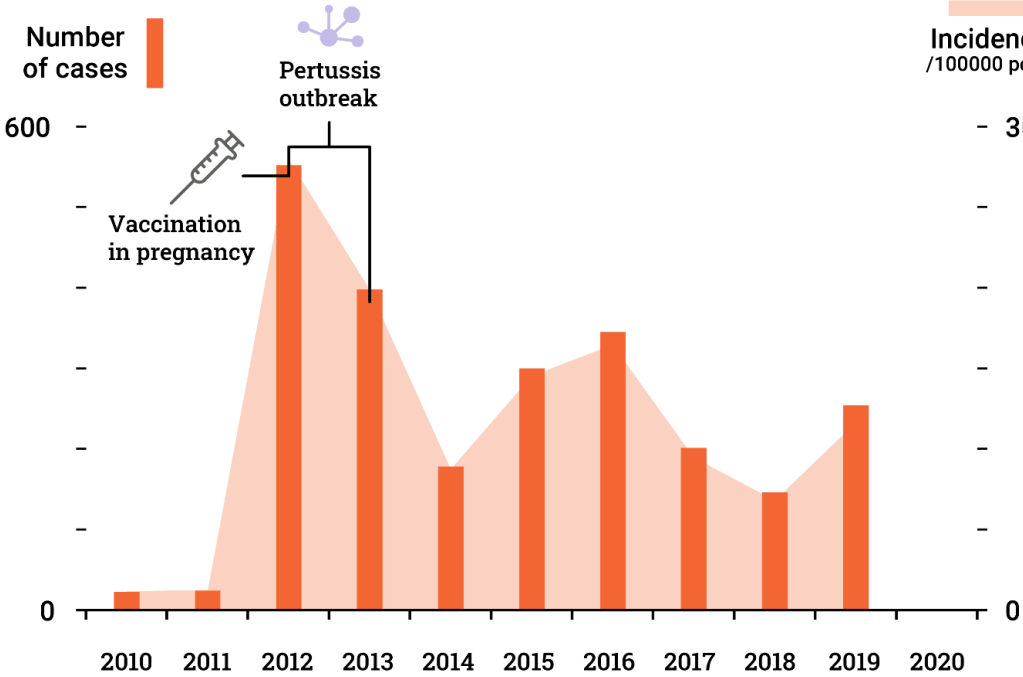
# England

The reported pertussis burden among older adults increased over time



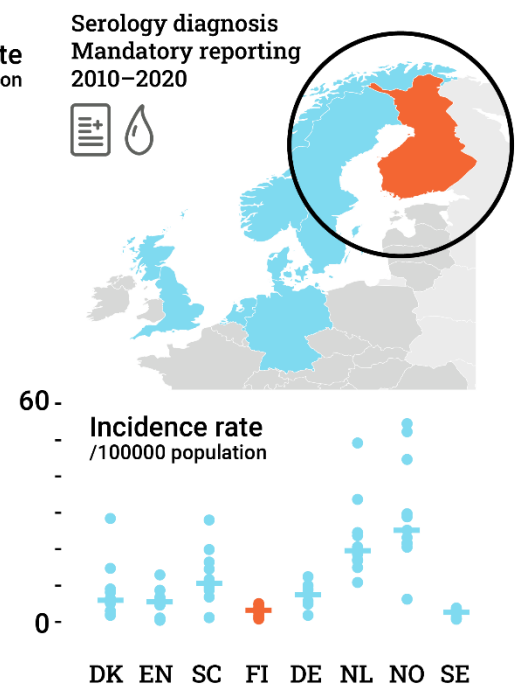
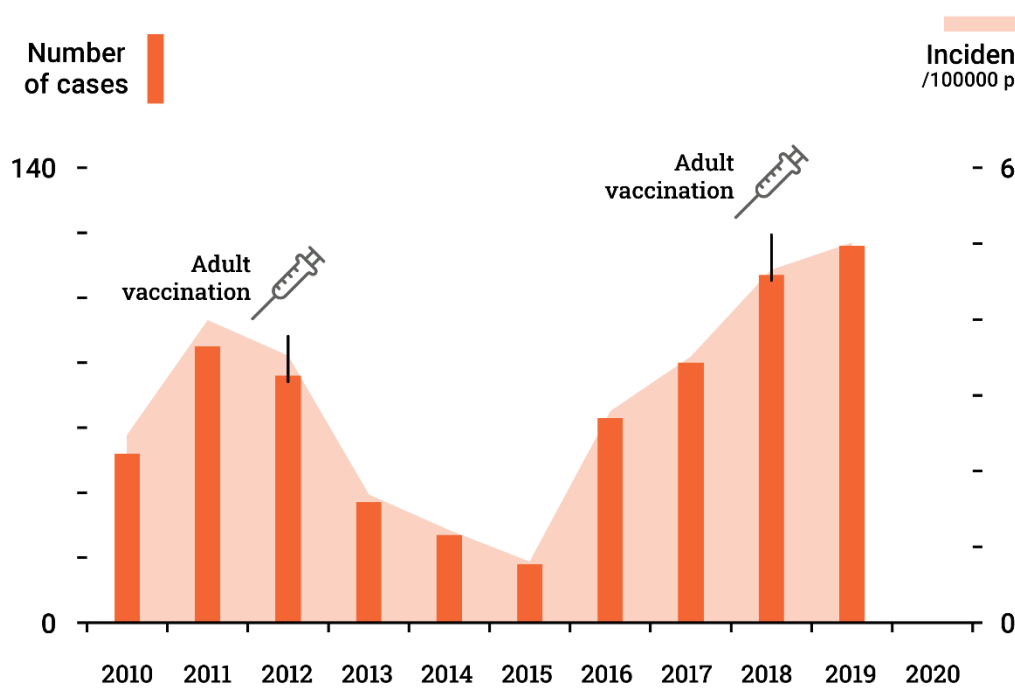
# Scotland

The reported pertussis burden among older adults increased over time



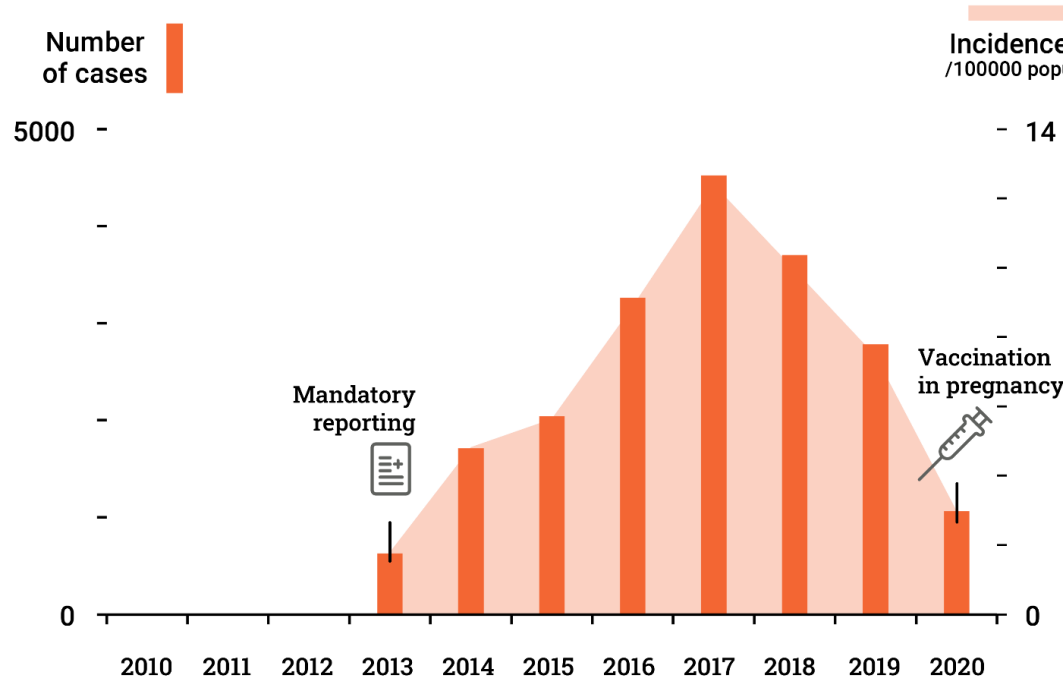
# Finland

The reported pertussis burden among older adults appeared constant over time



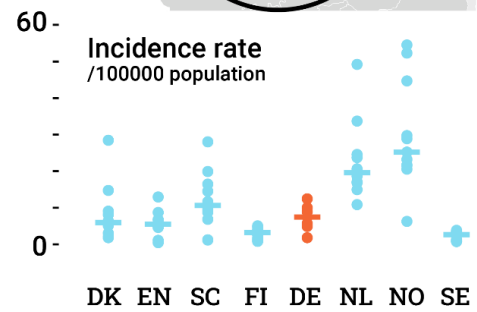
# Germany

The reported pertussis burden among older adults appeared constant over time



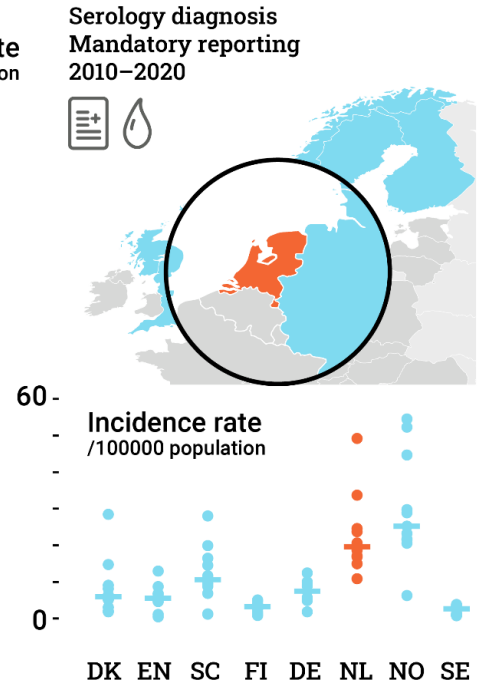
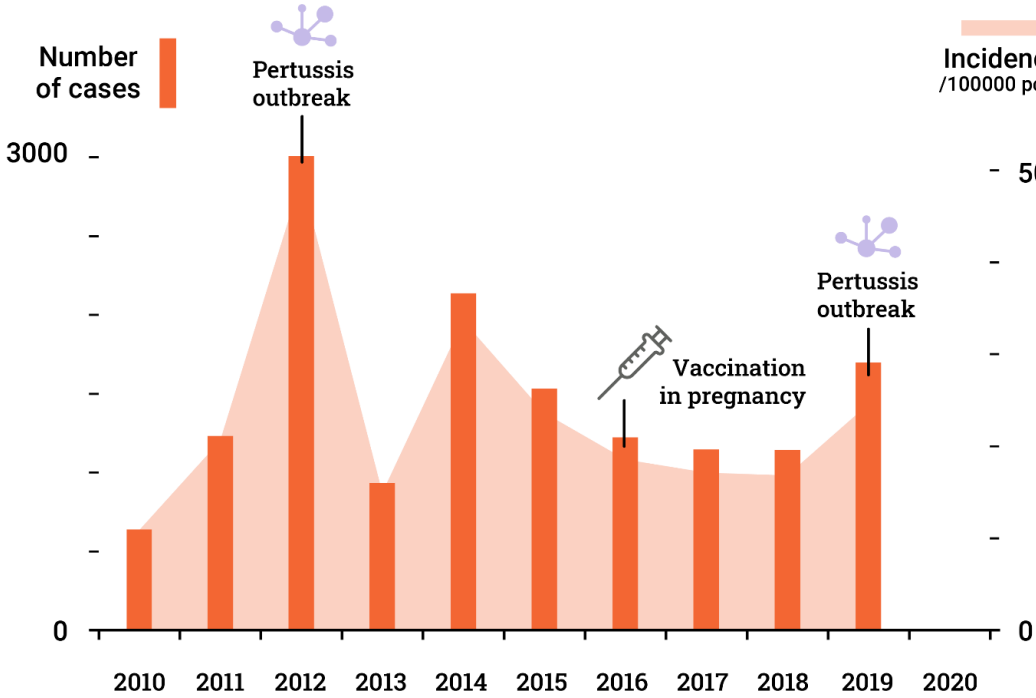
**Incidence rate**  
/100000 population

**Serology diagnosis**  
**Adult vaccination**  
2010–2020



# The Netherlands

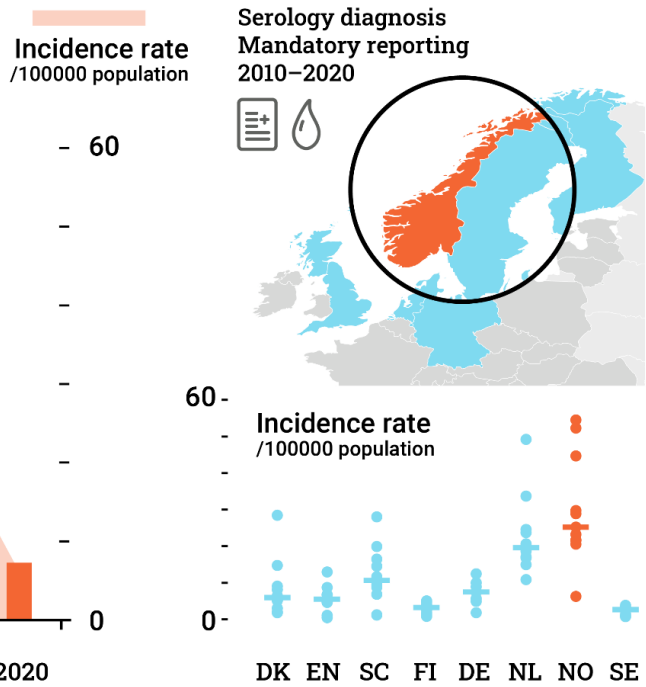
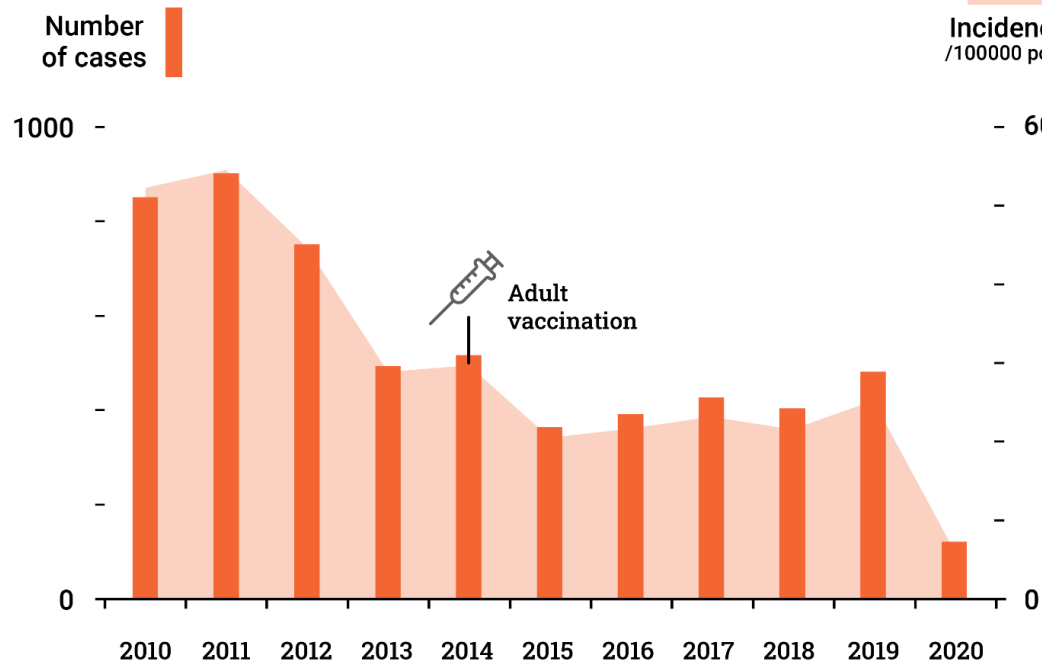
The reported pertussis burden among older adults appeared constant over time





# Norway

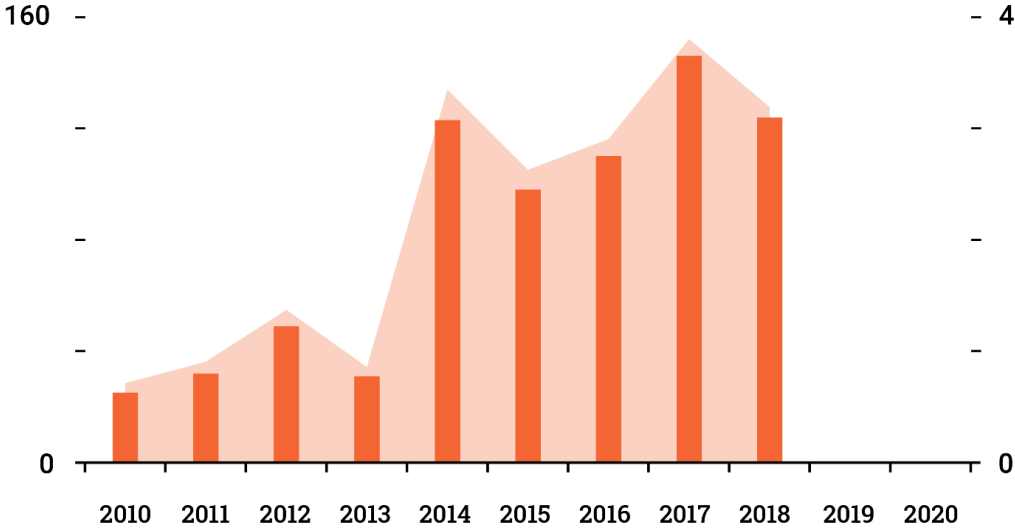
The reported pertussis burden among older adults decreased over time



# Sweden

The reported pertussis burden among older adults increased over time

Number of cases



Incidence rate /100000 population

- 4

Serology diagnosis  
Mandatory reporting  
2010–2020

