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Public health impact of the pediatric immunisation program in the Netherlands

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Background

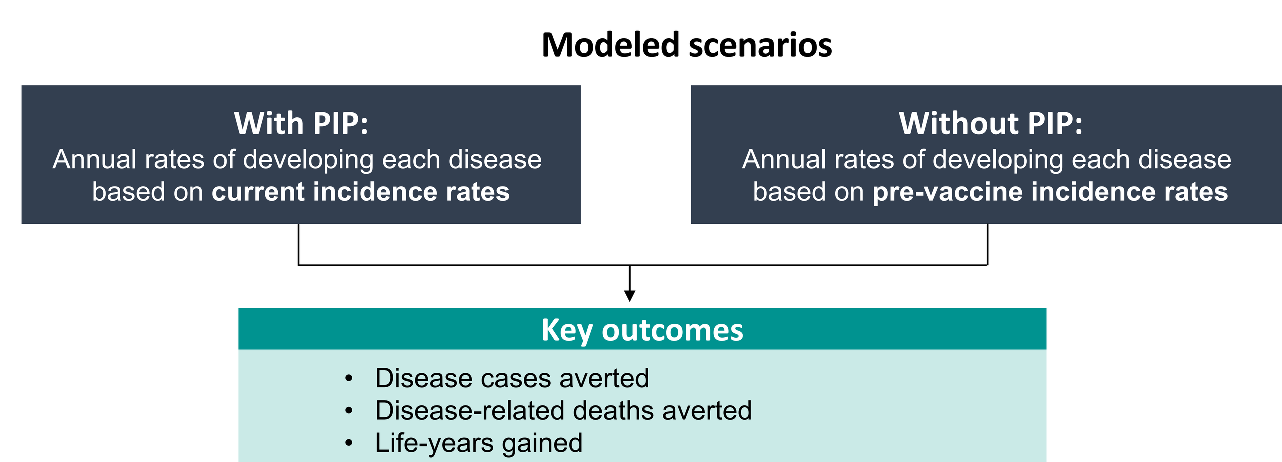
- Vaccines are one of the most successful and cost-effective public health interventions[1] with previous research in the United States,[2] Belgium,[3] and Poland[4] showing substantial cost savings of pediatric immunisation programs
- The Dutch national immunisation program was launched in 1957 and currently includes 6 vaccines covering 11 vaccine-preventable diseases for children aged 0 to 9 years (**Table 1**)[5]
- A recent study estimated the burden of disease and mortality of various vaccine-preventable diseases before the introduction of the vaccine into the Dutch national immunisation program in disability-adjusted life-years with a focus on the burden of disease of varicella[6]
- In the present study, we sought to estimate the public health impact of the pediatric immunisation program in Netherlands. This analysis extends upon the van Wijhe et al.[7] and van Lier et al.[6] studies by calculating the public health impact of vaccination in the current vaccine era vs the pre-vaccine era

Methods

Model summary

- A previously published model[2] was adapted to the Netherlands
- The model projected and compared health outcomes in scenarios with and without the pediatric immunisation program (PIP), based on Netherlands-specific current and pre-vaccine era disease incidence estimates
- The model included separate decision trees for each of the 11 vaccine-preventable diseases covered in the pediatric immunization program of the Netherlands. Following vaccination and risk of infection, model calculations distribute the cases of a given disease by severity
- Disease-related death rates were then applied (where applicable), with surviving individuals at further risk of developing long-term complications or sequelae
- The relevant vaccine-preventable diseases are each modeled separately and do not allow for interaction across the diseases (ie, diphtheria-related deaths are not accounted for within the modeled populations for the other diseases)
- The 2019 Dutch birth cohort (N=169,680 people) was followed over their lifetime
- Two analytical scenarios were constructed: one in which routine pediatric immunisation occurred according to the Dutch pediatric immunisation program reflecting current incidence rates, and one in which no immunisation occurred, reflecting incidence of modeled diseases were assumed to reflect pre-vaccine levels (**Figure 1**)

Figure 1. Scenarios assessed and key outcomes evaluated



Model inputs

- Vaccination followed the Dutch pediatric immunisation schedule as recommended by the Dutch Ministry of Health[5] (**Table 1**)
- Disease incidence estimates were used to calculate the annual number of disease cases
  - **With PIP:** Vaccine-era incidence for each disease was based on current incidence estimates, which were calculated from European Centre for Disease Prevention and Control, Dutch surveillance data, or estimates from the published literature (**Table 2**)
  - **Without PIP:** Pre-vaccine disease incidence was estimated before each routine vaccine was recommended, with data from the European Centre for Disease Prevention and Control, Dutch surveillance data, or estimates from the published literature (**Table 2**)

Model outputs

- Undiscounted health outcomes, including cases averted, premature deaths averted, and life-years gained

Table 1. Pediatric immunisation schedule and vaccine coverage estimates

Vaccine	Disease(s) protects against	Vaccination schedule	Vaccination coverage[a]		
			Dose 1	Dose 2	Dose 3
DTaP-IPV-HepB-Hib (hexavalent, 6-in-1 vaccine)	Diphtheria, Tetanus, Pertussis, Polio, Hepatitis B, *Haemophilus influenzae* type B (Hib)	3, 5, 11 months	93.7%	93.5%	92.3%
MMR (measles, mumps, rubella)	Measles, Mumps, Rubella	14 months, 9 years	93.6%	92.0%	–
Pneumococcal conjugate vaccine (PCV-10)	*S. pneumoniae*	2, 4, 11 months	93.5%	93.5%	93.0%
Meningococcal ACWY (MenACWY)	*Neisseria meningitidis* serogroups A, C, W, and Y	14 months	93.2%	–	–
DTaP-IPV (4-in-1 vaccine)	Diphtheria, Tetanus, Pertussis, Polio	4 years	89.9%	–	–
DTIPV (3-in-1 vaccine)	Diphtheria, Tetanus, Pertussis	9 years	92.1%	–	–

[a]Vaccination coverage estimates were extracted from the National Immunisation Programme in the Netherlands: Surveillance and developments in 2018-2019[8].

Table 2. Pre-vaccine and vaccine-era annual disease incidence estimates

Disease	Annual disease incidence per 100,000 individuals	
	Without PIP (pre-vaccine era)[a]	With PIP (vaccine-era)[a]
Diphtheria[6,9]	26.88	0.02
Hepatitis B[9]	0.97–25.31	0.16–16.49
H. influenzae type b[6,9]	0.23–29.64	0.03–3.76
Measles[6,9]	10.05–95.20	0.88–8.29
Mumps[6,9]	0.78–10.66	0.12–1.59
Pertussis[6,9]	100.94–536.59	18.42–97.91
S. pneumoniae[b,10]	1.70–86.00	1.03–69.20
Polio[5,6]	20.39	0.00
N. meningitidis serogroups A, C, W, and Y[9]	0.69–12.94	0.11–1.09
Rubella[9,11]	20.93	0.00
Tetanus[6,9]	0.17	0.00–0.02

A range indicates that the incidence varied by age group.
[a]Underestimation factors from vanLier[6] are applied to incidence rates for all diseases except polio, Hib, diphtheria, and tetanus.
[b]Incidence shown is for invasive pneumococcal disease. The analysis also includes pneumococcal pneumonia and pneumococcal AOM.

Results

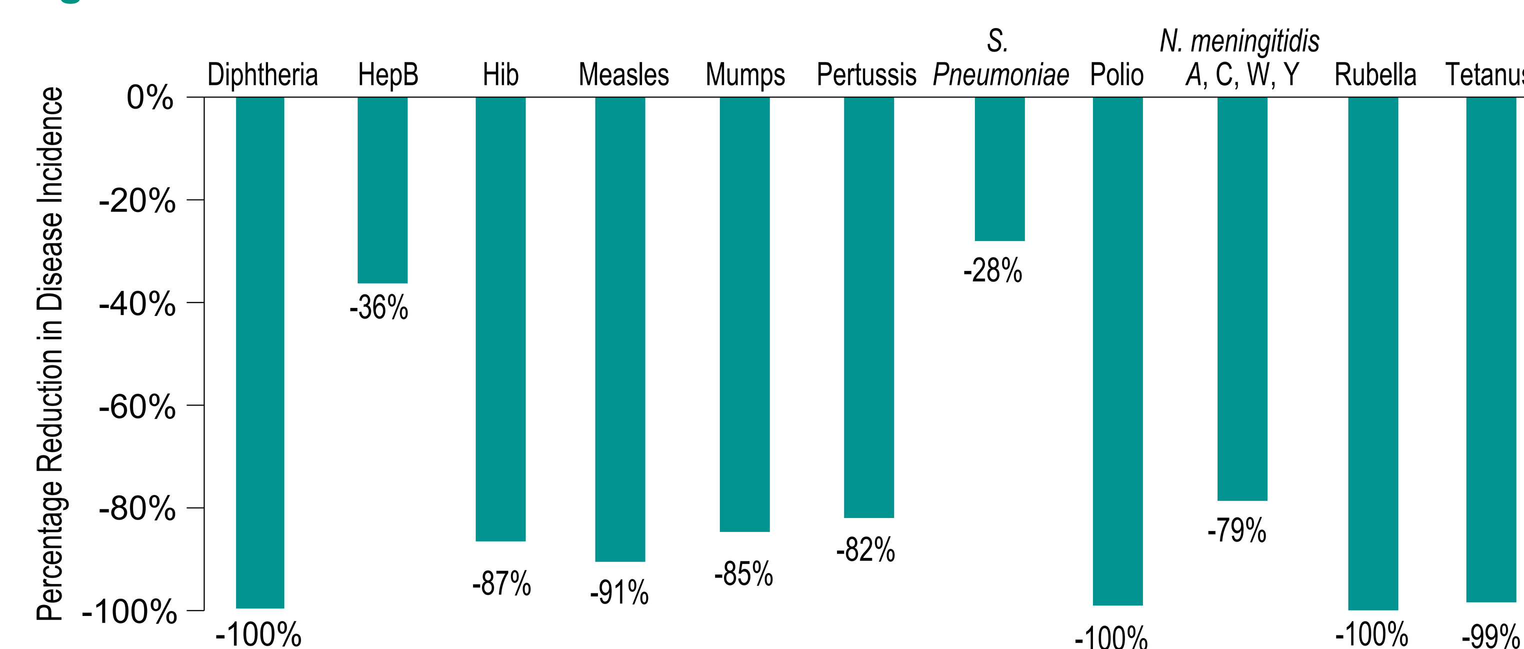
- A total of 116,501 cases of disease, 731 premature disease-related deaths, and 22,525 life-years were prevented over the lifetime of the 2019 birth cohort with the Dutch national immunisation program (**Table 3**)
- The highest number of estimated disease cases prevented was for *S. pneumoniae* followed by rubella and measles
- The greatest number of deaths prevented was from *S. pneumoniae* followed by diphtheria and polio
- The incidence of disease was reduced by more than 85% in the majority of the 11 vaccine-preventable diseases targeted in the immunisation program (**Figure 2**)
- The incidence of diphtheria, polio, and rubella were reduced by 100%

Table 3. Cases and premature deaths averted and life-years gained in the vaccine era

Disease	Cases averted	Premature deaths averted	Life-years gained
Diphtheria	3,635	218	9,282
Hepatitis B	645	39	1,509
H. influenzae type b	250	14	676
Measles	19,868	0	9
Mumps	552	0	0
Pertussis	18,733	2	94
S. pneumoniae	45,872	353	5,977
Polio	2,758	76	3,229
N. meningitidis serogroups A, C, W, and Y	274	27	1,646
Rubella	23,891	0	8
Tetanus	23	2	94
Total	**116,501**	**731**	**22,525**

Note: Total cases for *S. pneumoniae* are reported as a sum of invasive pneumococcal disease, pneumococcal pneumonia, and pneumococcal acute otitis media.

Figure 2. Percent reduction in disease incidence in the vaccine era



Limitations

- We utilized a static modeling approach, modeling each vaccine-preventable disease separately, therefore, herd immunity was not explicitly modeled here
- Published data on disease outcomes is limited, particularly for diseases that are no longer prevalent in the Netherlands
- Reductions in incidence are assumed to be fully attributed to pediatric immunisation (ie, we did not control for temperature trends, other public health improvements, or other external factors such as adolescent booster doses or adult pneumococcal vaccine)
- The present analysis did not include an economic analysis of the pediatric immunisation program

Conclusions

- Compared to the pre-vaccine period, the Dutch national immunisation program resulted in large-scale public health benefits in terms of substantially averting disease-related morbidity and premature mortality from vaccine-preventable diseases
- This analysis highlights the importance of continuous investment and expansions of the pediatric immunisation program in the Netherlands

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Disclosure

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