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ORIGINAL PAPER

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# Immunisation status of children in Germany: temporal trends and regional differences

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**Abstract** In Germany, a low coverage with hepatitis B and measles vaccines and a considerable delay in administration of all recommended vaccines were previously apparent. Whether there have been improvements and whether there are regional differences within Germany is not known. Using representative nationwide telephone interviews on 2,701 children born 1996–2003, we assessed vaccination coverage for the first dose or full primary series (2/3 doses, depending on vaccine used) at 24 months of age. The proportions vaccinated with the first dose, full priming and full immunisation (2/3 doses plus booster in the 2nd year of life) until the end of the recommended age (3, 5 and 15 months, respectively, for diphtheria, tetanus, pertussis, polio, *Haemophilus influenzae* type b (Hib) and hepatitis B vaccines (DTPPolioHibHep), and 15 for the first measles, mumps and rubella dose (MMR) were used as indicators of compliance with national guidelines. Coverage for polio, Hib and hepatitis B vaccines increased, while coverage for the first MMR dose remained constantly low at about 70%. Vaccination coverage differed substantially among the German states and was highest for the new states. Compliance with national guidelines increased from 2.5% to 15% for the full primary DTPPolioHibHep series, from 16.2% to 44.7% for the first MMR dose and from 1.0% to 19.3% for the full immunisation with all recommended vaccines (DTPPolioHibHepMMR). *Conclusion:* Vaccination coverage at 24 months and compliance with national guidelines has improved for most vaccines in Germany. However, improving coverage for measles, mumps, rubella and eliminating the regional disparities remain a major challenge for the public health sector.

**Keywords** Compliance · Germany · On-time immunisation · National recommendations · Vaccination coverage

**Abbreviations** DTPPolioHibHep: diphtheria, tetanus, pertussis, polio, *Haemophilus influenzae* type b and hepatitis B · Hib: *Haemophilus influenzae* type b · MMR: measles, mumps, rubella · STIKO: Ständige Impfkommission am Robert-Koch-Institut

## Introduction

Routine vaccinations are one of the most powerful instruments for primary prevention in childhood, saving both lives and money. The WHO European Region strategic plan aims not only to reach and maintain high levels of childhood immunisations to protect populations against vaccine-preventable diseases, but also to provide maximum protection at the earliest possible age and to reduce geographical disparities in vaccination coverage [22].

Early protection is especially important for *Haemophilus influenzae* type b (Hib) and *Bordetella pertussis* disease which have their highest morbidity and mortality in the 1st year of life [6,16]. Diseases that affect humans only may eventually be eradicated or at least eliminated through vaccination coverage levels of 90% and more. Although national coverage levels may exceed 90%, regional variation in the level of coverage may lead to pockets of undervaccinated children. These make the

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population vulnerable to major outbreaks of vaccine-preventable diseases. Monitoring of coverage at smaller geographical levels within Germany might help to ensure that these potential pockets of children are identified for further public health interventions.

German vaccination coverage rates in children have been shown to be among the lowest in Europe [18,20]. In Germany, data on vaccination coverage in childhood are derived from school health examinations. Although these data cover most children at a certain age, they have some limitations. They lag 5 to 6 years behind the current vaccination practice and do not assess types of vaccine or timing of vaccination. Furthermore, each of the 16 states in Germany is responsible for its own school health examination and has different definitions for fully immunised children. To overcome these limitations, a national representative immunisation survey was initiated in 1998 [12,13]. It was shown that administration of all recommended vaccines in children was considerably delayed. This national representative immunisation survey has now been complemented with follow-up interviews in June 2002 [10]. With ongoing interviews of younger birth cohorts, we are now able to present trends in timing and uptake of vaccines.

The aim of this study was to evaluate whether uptake and timing of childhood immunisations in Germany has improved in recent years and to detect geographical disparities in childhood immunisations between the German federal states. We used data of a nationwide representative sample of children born from mid 1996 to mid 2003 with detailed information on date of immunisation and type of vaccine.

## Subjects and methods

Representative nationwide immunisation surveys were conducted to assess precise vaccination information of children by telephone interviews applying the random digit dialling method. The first survey done in June 1999 on children born between June 1st 1996 and June 30th 1999 [12] was complemented with follow-up interviews in June 2002 [10]. A second survey on children born between July 1st 1999 and June 30th 2003 was conducted between July 2002 and January 2004 by computer assisted telephone interviews using the same sampling methods as in the first survey.

In both surveys, a combined total of 46,548 households were screened for the presence of a child born in the respective birth years and asked if they were willing to receive a second telephone call concerning questions about the health of their child and possible vaccinations. Of all 4670 households with children born in the respective years, 3322 households were willing to answer to a second telephone call. Of these, 337 households could not be contacted in the second stage due to the following reasons unlikely to be related to the subject of interest: change of the family's telephone number in the time between the first and second call; no child born in the respective year; no person reached at this number after up to 12 telephone calls. Out of the 2985 remaining households, 315 declined to participate in the second stage when contacted; main reasons were 'no interest on subject of survey' and 'no time'. Response rates were calculated as: 'number of completed interviews' divided by the result of the 'number of screened households with children born in the respective years' minus the 'number of households which could not be reached at the second telephone call because of reasons unlikely to be related to the exposure of interest'. Response rates to the telephone surveys were 62% for both surveys. In total, interviews on 2827 children out of 2670 households were realised.

Informed consent was obtained from all participating parents. A team of trained interviewers asked parents to provide the dates of vaccination and vaccine brand names from the relevant pages of the vaccination booklet. If records were unreadable, parents were asked to send a photocopy of the relevant pages, to give contact details of their paediatrician and to sign a declaration authorising the paediatrician to release the vaccination information. If no vaccination booklet was available and the child had been vaccinated at least once, parental consent was sought to approach the vaccinating physician. Additionally, birth dates, sex, age of the parents, socio-economic status, and place of residence of the child were collected.

In Germany, the immunisation calendar is recommended by the German Standing Committee on Vaccination (Ständige Impfkommission am Robert-Koch Institut; STIKO). Children are usually vaccinated by paediatricians or occasionally by general practitioners. Physicians may choose vaccines from licensed and marketed products in the country. Physicians are to check the vaccination status of a child at regular recommended well-baby visits. The recommended schedule for all vaccines containing acellular pertussis components is a three-dose primary series at age 2, 3 and 4 months with a booster dose scheduled at 11–14 months. For vaccines not containing acellular pertussis, a two-dose primary series at age 2 and 4 months is recommended [19]. As we asked for brand names, we could distinguish between the completion of these two primary schedules. For children vaccinated with Hib vaccines who did not receive the full priming and booster by the age of 12 months, a single Hib dose in the 2nd year of life is recommended. In the observed birth cohorts, the recommended immunisation schedules for diphtheria, tetanus, pertussis, polio, Hib and hepatitis B (DTPPolioHibHep) vaccines did not change. The recommended schedule for immunisation against mumps, measles and rubella (MMR) is scheduled at 11–14 months for the first dose and 15–23 months for the second dose. The recommended timing for the second measles dose was brought forward from age 4–5 years to 15–23 months in 2001.

According to the German vaccination schedule, we defined a child as 'fully primed' if he or she received at least three doses of a vaccine containing acellular pertussis components or two doses of a vaccine not

containing acellular pertussis components. A child was defined as 'fully immunised' if she or he received a booster dose at the age of 11 months or later following full priming. For Hib vaccines, in addition, a child was defined as 'fully immunised' after receiving a booster dose at the age of 11 months or later following full priming or any dose in the 2nd year of life regardless of priming. In accordance with the above definitions, we estimated the coverage of the following combined series: first dose, full priming and full immunisation against DTPPolioHibHep (DTPPolioHibHep1, DTPPolioHib-Hep-priming, DTPPolioHibHep-full); first and second dose against MMR (MMR1; MMR2); full immunisation against DTPPolioHibHep and first doses against MMR (DTPPolioHibHep-full-MMR1).

Temporal trends were analysed by comparing serial 2-year birth cohorts (1996/97; 1998/99; 2000/01; 2002/03). Regional differences were analysed by combining adjacent states (Bundesland) or town states (Schleswig-Holstein, Niedersachsen (A); Nordrhein-Westfalen (B); Hessen, Rheinland-Pfalz, Saarland (C); Baden-Württemberg (D); Bavaria (E); new states Brandenburg, Mecklenburg-Vorpommern, Sachsen-Anhalt, Thüringen, Sachsen (F); and (G) Berlin, Hamburg, Bremen).

Uptake and timing of immunisation by age in months was calculated according to the Kaplan-Meier method. Time of survival is the period from birth to receiving the respective dose or series. The inverse survival is the probability of being vaccinated at time t, which is the coverage rate at a certain age. 95% confidence intervals (CI) were calculated using the Greenwood formula [5]. The Kaplan-Meier method for vaccine uptake is described in detail by Laubereau et al. [13].

We structured the analysis in three parts: to assess (1) temporal trends and (2) regional differences in vaccination coverage we report the proportion of children vaccinated with at least one dose or with the full primary series at age 24 months. Most published studies of national immunisation status have focussed on a comparable age, usually 19 to 35 months [4,8], and (3) to assess temporal trends in the timing of immunisations, i.e. the compliance with the vaccination schedule recommended by the STIKO. We report the proportion of children with at least one dose, the full primary series and the full immunisation at the end of the recommended age, i.e. 2.9, 4.9 and 14.9 months for DTPPolioHibHep vaccines, respectively, and 14.9 months for the first measles dose.

For all statistical analyses, SAS (SAS Institute, Cary, NC) version 8.0 and STATA 8.2 (Stata Corp., College Station, Texas) were used.

## Results

### Characteristics of the study population

The analysis was restricted to 2,701 children who had their vaccination booklet available and no missing or implausible immunisation data. Median age at interview was 27.8 months (interquartile range 19.6–39.1 months) and 51.2% of the children were male.

### Immunisation status at 24 months

#### *Temporal trend*

Table 1 shows the change in the vaccination coverage at age 24 months for the first dose and the full primary series by birth cohorts. For at least one dose, coverage was consistently above 90% for all vaccines, except for hepatitis B, MMR. Whereas coverage for hepatitis B increased from 75.9% in birth cohorts 1996/97 to 88.8% in birth cohorts 2002/03, coverage for MMR was consistently at about 70%.

Regarding full primary series, the coverage was consistently at about 90% for diphtheria, tetanus and pertussis vaccination with no increase in the younger birth cohorts. In contrast, the coverage for polio, Hib and hepatitis B vaccination increased from birth cohorts 1996/97 to 2002/03: for polio vaccination the increase was from 85.7% to 91.0%, for Hib vaccination from 59.6% to 83.8% and for hepatitis B vaccination from 70.9% to 89.1%.

The coverage at 24 months achieved with the combined series of DTPPolioHibHep1 or MMR1 reflects the single component with the lowest coverage (hepatitis B; rubella), since children may receive separate injections; the combined vaccine series for the primary series (DTPPolioHibHep-priming) was lower than the lowest coverage of a single component and increased from 43.0% in birth cohorts 1996/97 to 82.2% in birth cohorts 2002/03. Coverage for the second MMR dose increased from 0.9% in birth cohorts 1996/97 to 20.2% in birth cohorts 2002/03.

Of note, coverage for immunisations not generally recommended, but recommended for special risk groups, were: at least one dose of influenza vaccine increased from 0% (0.0%–0.0%) in birth cohorts 1996/97 to 23.7% (0.0%–57.3%) in birth cohorts 2002/03, and at least one dose of pneumococcal vaccine increased from 0% (0.0%–0.0%) in birth cohorts 1996/97 to 9.2% (6.2%–12.2%) in birth cohorts 2002/03.

#### *Regional differences*

The coverage for the combined vaccine series showed substantial differences among the states in Germany (Fig. 1). Coverage with the first dose of DTPPolioHib-Hep series ranged from 71.4% (95% CI 67.1–75.5) in Bavaria to 89.6% (95% CI 86.0–92.5) in the new states. Coverage with the full primary series of DTPPolioHib-Hep ranged from 51.6% (95% CI 47.0–56.3) in Bavaria to 69.4% (95% CI 64.5–74.1) in the new states and coverage of the first MMR dose ranged from 58.4% (95% CI 53.5–63.4) in Bavaria to 74.8% (95% CI 69.7–79.8) in the new states.

**Table 1** Temporal trend in vaccination coverage at age 24 months given as percentage (95% CI) among children in Germany born between June 1996 and June 2003

| | 1996–1997 ($n = 394$) | 1998–1999 ($n = 700$) | 2000–2001 ($n = 1093$) | 2002–2003 ($n = 514$) |
|---|---|---|---|---|
| 1st dose | | | | |
| Diphtheria, tetanus | 98.4 (97.1–99.7) | 96.9 (95.5–98.3) | 96.5 (95.5–97.6) | 96.8 (95.0–98.7) |
| Polio | 96.3 (94.4–98.2) | 95.5 (93.9–97.1) | 95.4 (94.1–96.6) | 95.3 (92.9–97.7) |
| Pertussis | 96.6 (94.7-98.4) | 95.1 (93.4–96.8) | 93.5 (92.1–95.0) | 95.3 (93.0–97.6) |
| Hib | 95.8 (93.8–97.8) | 94.4 (92.6–96.2) | 93.4 (91.9–94.8) | 94.9 (92.4–97.3) |
| Hepatitis B | 75.9 (71.7–80.2) | 78.5 (75.2–81.7) | 83.0 (80.8–85.2) | 88.8 (85.2–92.4) |
| Measles | 74.5 (70.0–78.9) | 66.7 (62.8–70.6) | 69.5 (66.7–72.2) | 71.1 (61.1–81.1) |
| Mumps | 74.5 (70.0–78.9) | 66.9 (63.0–70.8) | 69.4 (66.6–72.2) | 70.1 (60.3–79.8) |
| Rubella | 72.0 (67.4–76.6) | 66.7 (62.8–70.6) | 68.6 (65.8–71.4) | 70.1 (60.3–79.8) |
| Full priming | | | | |
| Diphtheria, tetanus | 93.4 (90.8–95.9) | 90.3 (88.0–92.7) | 92.6 (91.0–94.2) | 93.3 (89.6–96.9) |
| Polio | 85.7 (82.2–89.3) | 82.9 (79.8–85.9) | 89.7 (87.9–91.5) | 91.0 (87.1–95.0) |
| Pertussis | 90.7 (87.7–93.6) | 88.7 (86.1–91.2) | 89.7 (87.9–91.5) | 91.4 (87.3–95.4) |
| Hib | 59.6 (54.8–64.5) | 71.1 (67.9–75.0) | 75.7 (73.1–78.2) | 83.8 (80.5–87.2) |
| Hepatitis B | 70.9 (66.4–75.5) | 64.1 (60.3–67.9) | 69.8 (67.1–72.5) | 89.1 (82.8–95.4) |
| Combined series[a] | | | | |
| DTPPolioHibHep-1 | 74.2 (69.8–78.5) | 77.6 (74.3–80.9) | 82.5 (80.3–84.8) | 88.8 (85.2–92.4) |
| DTPPolioHibHep-priming | 43.0 (38.1–48.0) | 48.9 (44.9–52.8) | 59.1 (56.2–62.1) | 82.2 (76.1–88.3) |
| MMR1 | 72.0 (67.4–76.5) | 66.7 (62.8–70.6) | 68.6 (65.8–71.4) | 70.1 (60.2–79.4) |
| MMR2 | 0.9 (0.3–2.7) | 6.9 (5.1–9.4) | 23.0 (20.6–25.7) | 20.2 (13.7–29.1) |

[a]See definitions in text

### Immunisation status at recommended age

The proportion of children vaccinated according to national recommendations increased between birth cohorts 1996/97 and 2002/03 for each single component from 8.6%–13.4% to 29.6%–30.2% for the first dose, from 4.6%–14.0% to 15.4%–16.4% for the full primary series and from 8.9%–19.8% to 36.1%–46.1% for the full immunisation. This increasing temporal trend is also reflected in the uptake of the combined vaccine series (Table 2).

## Discussion

We have shown a constant high uptake of diphtheria, tetanus and pertussis and an increasing uptake of polio, Hib and hepatitis B immunisations up to the age of 24 months in children during the last 8 years. Although most children in the latest birth cohorts are now adequately vaccinated by age 24 months, only 33% of them were vaccinated according to the national recommendations. This study shows that compliance with the

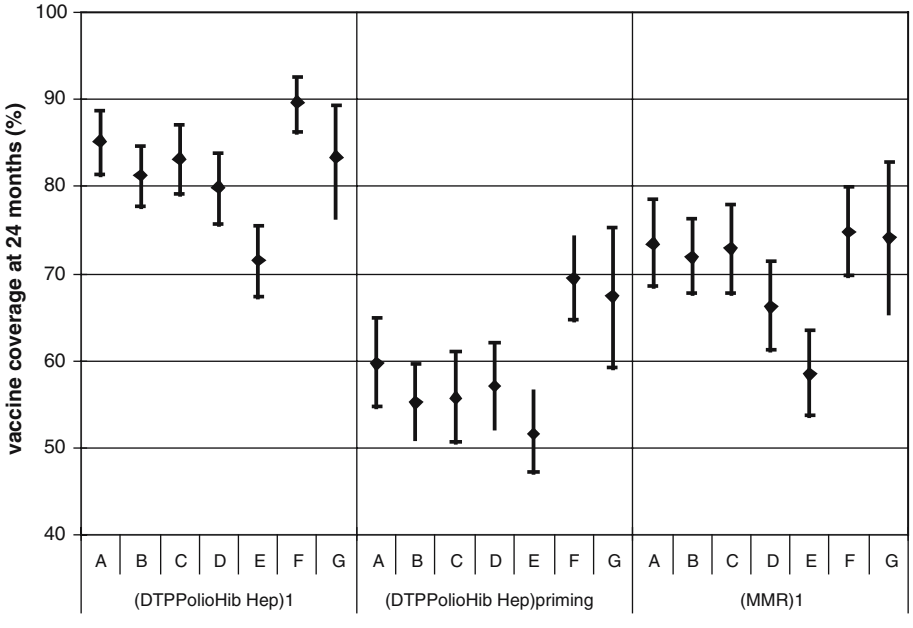


**Fig. 1** Regional differences (regions A to G) in vaccination coverage rates at 24 months for the combined vaccine series among children in Germany born between 1996 and 2003. Point estimator (*solid diamonds*) and 95% CI ( *whiskers*). **A** Schleswig-Holstein, Niedersachsen; **B** Nordrhein-Westfalen; **C** Hessen, Rheinland-Pfalz, Saarland; **D** Baden-Württemberg; **E** Bavaria; **F** new states; **G** Berlin, Hamburg, Bremen

**Table 2** Temporal trends in on-time vaccination among children in Germany born between 1996 and 2003. Percentage (95% CI) vaccinated within the age ranges recommended by national guidelines

| | Vaccinated at recommended age[a] | | | |
|---|---|---|---|---|
| | 1996–1997 ($n = 394$) | 1998–1999 ($n = 700$) | 2000–2001 ($n = 1093$) | 2002–2003 ($n = 514$) |
| 1st dose | | | | |
| Diphtheria, tetanus | 12. 9 (9.6–16.3) | 21.5 (18.4–24.6) | 25.4 (22.9–28.0) | 30.2 (26.2–34.2) |
| Polio | 11.9 (8.7–15.1) | 20.3 (17.2–23.3) | 25.4 (22.9–28.0) | 30.2 (26.2–34.2) |
| Pertussis | 12.9 (9.6–16.3) | 21.0 (17.9–24.1) | 25.4 (22.9–28.0) | 30.2 (26.2–34.2) |
| Hib | 13.4 (10.1–16.8) | 20.9 (17.8–24.0) | 25.1 (22.5–27.6) | 30.2 (26.2–34.2) |
| Hepatitis B | 8.6 (5.9–11.4) | 14.6 (12.2–17.5) | 21.0 (18.6–23.5) | 29.6 (25.7–33.6) |
| Full priming | | | | |
| Diphtheria, tetanus | 7.6 (5.0–10.2) | 7.9 (5.9–10.0) | 12.6 (10.7–14.6) | 16.4 (13.2–19.6) |
| Polio | 14.0 (10.5–17.4) | 7.5 (5.5–9.5) | 12.2 (10.2–14.1) | 16.2 (13.0–19.4) |
| Pertussis | 7.6 (5.0–10.2) | 7.6 (5.6–9.7) | 12.7 (10.7–14.7) | 16.4 (13.2–19.6) |
| Hib | 7.6 (5.0–10.2) | 8.2 (6.1–10.4) | 12.3 (10.3–14.2) | 16.4 (13.2–19.6) |
| Hepatitis B | 12.2 (9.0–15.4) | 15.2 (12.4–17.9) | 12.4 (10.5–14.4) | 15.4 (12.3–18.5) |
| Full immunisation | | | | |
| Diphtheria, tetanus | 9.9 (7.0–12.8) | 17.6 (14.5–20.7) | 28.0 (25.3–30.7) | 39.9 (32.9–46.9) |
| Polio | 8.9 (6.1–11.7) | 15.8 (12.8–18.7) | 27.3 (24.3–29.6) | 39.0 (32.1–46.0) |
| Pertussis | 11.2 (8.1–14.3) | 17.8 (14.7–20.9) | 27.8 (25.1–30.5) | 39.9 (32.9–46.9) |
| Hib | 15.7 (12.1–19.3) | 22.4 (19.0–25.8) | 33.9 (31.1–36.7) | 46.1 (38.8–53.3) |
| Hepatitis B | 19.8 (30.1–39.5) | 18.2 (15.1–21.3) | 22.4 (19.9–24.9) | 36.1 (29.2–43.1) |
| Combined series[b] | | | | |
| DTPPolioHibHep-1 | 4.3 (2.7–6.8) | 9.1 (7.2–11.5) | 17.2 (15.1–19.6) | 28.7 (25.07–32.8) |
| DTPPolioHibHep-priming | 2.5 (1.4–4.7) | 3.7 (2.5–5.4) | 8.6 (7.1–10.4) | 15.0 (12.2–18.4) |
| DTPPolioHibHep-full | 3.8 (2.3–6.2) | 6.4 (4.7–8.7) | 18.4 (16.2–20.8) | 35.5 (29.1–42.8) |
| MMR1 | 16.2 (13.0–20.3) | 22.5 (19.3–26.0) | 31.6 (28.9–34.4) | 44.7 (38.1–51.8) |
| DTPPolioHibHep-full-MMR1 | 1.0 (0.4–2.7) | 2.6 (1.5–4.2) | 9.1 (7.54–11.0) | 19.3 (13.9–26.4) |

[a]Proportion of children vaccinated within the age-frame recommended by the STIKO: at least one dose at 3 months, the full primary series at 5 months and the full immunisation at 15 months for diphtheria, tetanus, pertussis, polio, Hib and hepatitis B vaccines, respectively, and at 15 months for the first measles dose
[b]See definitions in text

national recommended guidelines is increasing but still low, and demonstrates that up-to-date status does not always correspond to appropriate timely immunisation. The constant low coverage for MMR and the huge regional differences in vaccination coverage highlight the need for further public health interventions and ongoing surveillance of immunisation coverage.

The trends and regional differences in our findings are unlikely to be caused by bias: response rate to the telephone surveys was 63% for both surveys. This response rate is similar to those conducted in other telephone surveys in Germany or the United States [3, 15,17]. Comparisons with official data provided by the Federal Statistical Office, Germany, [7] revealed that the sampled telephone interviews are representative for families with age-eligible children in Germany with regard to geographical and social distribution; however, children from households with higher income are slightly over-represented (data not shown). We cannot exclude the possibility that parents who have their children vaccinated might be more likely to answer the telephone interview, resulting in potential underestimation of the proportion of under-vaccinated children. Nevertheless, this effect should not differ between different birth cohorts.

Vaccination coverage for the first dose and full primary series was consistently above 90% for diphtheria, tetanus and pertussis. The proportion of children ever vaccinated with a hepatitis B vaccine increased progressively after it became a general vaccination recommendation in 1995. Vaccination coverage for the full primary series of polio, Hib and hepatitis B also increased during the survey period. In birth cohorts 1996/97, for example, only 62% of all children who had received their first dose went on to receive full priming for Hib. However, in 2002/03 this proportion had increased to 88%. This might be an indicator that parents do not oppose vaccinations in general but have problems with organising dates for all recommended vaccinations.

The observed increase in vaccine uptake for the first dose of hepatitis B from 75.9% in birth cohorts 1996/97 to 88.8% in birth cohorts 2002/03 might reflect an improvement in the awareness and knowledge of hepatitis B vaccination and might further improve in the future. However, the increasing coverage rates for full priming are unlikely to be explained by improved acceptance only, since this increase was observed not only for hepatitis B vaccines but also for more established vaccines such as polio and Hib. Here, the introduction of four-valent (DTPHib), pentavalent (DTPPolioHib) and hexavalent (DTPPolioHibHep) vaccines in 1996, 1998 and 2000, respectively, might have improved this uptake.

The necessity for several injections or doctor's visits to fully immunise an infant seems to be an important

reason why vaccinations are delayed or omitted. Data from a German representative survey indicate that only 0.4% (East Germany) to 1.5% (West Germany) of parents refuse vaccination on principle. In contrast, more than 70% of paediatricians name 'forgotten appointments' as the leading cause for missed vaccinations in children [11]. The problem of the necessity of multiple shots is also reflected in the low proportion of children vaccinated with all recommended doses of the nine generally recommended vaccines (DTPPolio-HibHepMMR) in birth cohorts 1996/97: only 1.0% of children were vaccinated at the recommended time. This proportion increased to 19.3% in birth cohorts 2002/03. That means that only every fifth child is adequately vaccinated with all recommended vaccines. An early as possible vaccination is especially important for Hib and pertussis, which have their highest incidence in the 1st year of life [6,16]. Although on-time vaccination for the first dose increased from ca. 13% to 30%, for the full priming from 7.6% to 16.4% and for the full immunisation from ca. 15% to ca. 40% for both vaccines, this proportion is not at all satisfying.

The introduction of higher-valent vaccines during the study period, in which polio, Hib and hepatitis B antigens were combined with DTaP-based combination vaccines, might be a likely explanation for increasing coverage and on-time vaccination. Higher-valent vaccines reduce the number of injections and the number of doctor's visits. However, this hypothesis needs to be further investigated by comparing timing of the different vaccine types used.

The consistently low coverage rates of approximately 70% for MMR immunisation at 24 months do not fulfill the required high coverage rates of 95% and more to eliminate measles disease in Europe by 2007 [21]. Comparisons with German preschool examinations, showing a proportion of 80%–90% vaccinated with MMR [18], reveal that parents decide to give the first dose just before entry to kindergarten or school, despite recommendations to do so earlier. The great increase in the uptake of the second MMR dose, in contrast, reflects the changing recommendations from a dose at 5–6 years of age to 15–23 months in 2001 and following rapid but incomplete acceptance of these recommendations.

We showed a considerable difference in vaccination coverage at 24 months between German states. The highest coverage rates were found in the new states (former East Germany) and the cities of Berlin, Hamburg and Bremen, being more than 15% higher than those in Bavaria. The high coverage rates in the new states have been found in other surveys [18], and are explained by the former public health system where vaccinations were not just recommended but compulsory. Since reunification in 1990, all vaccinations have been voluntary and the costs of vaccinations recommended by the STIKO are usually borne by the health insurance companies on a goodwill basis. There are no national vaccination targets and implemented instruments to assess their achievements. Furthermore, there are no incentives or public health services to ensure that children have received recommended vaccinations. The reasons for the lower coverage rates in Bavaria, the second largest southern state of Germany, remain unclear. However, the public health sector in Germany is regionalised and each state has its own public health policy. Similar substantial differences in coverage among districts or states has been demonstrated for France and the United States [1,4].

Due to low numbers we were not able to differentiate coverage levels in smaller geographical areas. However, differences in coverage between states have their correlate in sub-regions with corresponding consequences. School health examinations in Bavaria showed that coverage levels for measles immunisation ranged from 58% to 96% in the 77 health districts [9]. In one health district, a low coverage of 77% gave rise to a measles outbreak in children 2002, with a maximum incidence of 860 per 100,000 children [2]. This outbreak was confined to this district only because coverage of measles immunisation in the adjacent districts was 90% and above.

Although there are some difficulties in comparing data, as definitions for 'full priming' varied between countries, other European data show only slightly higher or comparably high coverage rates for full priming at 24 months compared to our youngest birth cohorts. Among British children born in 2002, mean coverage for diphtheria, tetanus and polio was 94.1%, and 93.6% for pertussis [8]. Among French children born in 1998, coverage for three doses of diphtheria, tetanus, polio and pertussis were 98.1%, 98.1%, 97.4% and 98.0%, respectively [1]. Coverage for Hib was comparable to our data in France (86.1%), but higher in Britain (93.9%). In both countries, coverage for the first MMR dose was with 81.9% in Britain and 83.5% in France ca. 10% higher than in our data. Coverage of hepatitis B was only 26% in France, as this antigen was newly introduced in 1996.

In the United States, coverage of three or more doses among children aged 19–35 months and born in 2000–02 was above 90% for diphtheria, tetanus and polio, pertussis, Hib and hepatitis B. Coverage for the first MMR dose was 93.0% for the same children, compared to ca. 70% in our data [4]. Although coverage was high, compliance with national immunisation guidelines was in a similar high deficit [14]: only 35.6% of children were fully compliant with recommended immunisation practices.

The observed deficiencies in vaccine uptake in Germany might be targeted by changes in legislation and payment regulations for vaccination: thus, the American "no shot—no school (kindergarten)" policy would no doubt be a strong incentive for parents to have their children vaccinated; relating the amount of payment to complete and timely vaccination might encourage physicians to offer vaccination at the earlier recommended time.

Vaccine coverage levels among children in Germany has improved in recent years, but are still insufficient for

Hib and MMR. Eliminating the regional disparities in immunisation coverage and improving compliance with national immunisation recommendations remain a major challenge for public health services to optimise childhood infectious disease prevention.

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