Hepatitis B vaccination timing: results from demographic health surveys in 47 countries
Aparna Schweitzer, a Manas K Akmatov b & Gérard Krause a

Objective To examine the impact of hepatitis B vaccination schedules and types of vaccines on hepatitis B vaccination timing.
Methods We used data for 211,643 children from demographic and health surveys in 47 low- and middle-income countries (median study year 2012). Data were from vaccination cards and maternal interviews. We grouped countries according to the vaccination schedule and type of vaccine used (monovalent or combination). For each country, we calculated hepatitis B vaccination coverage and timely receipt of vaccine doses. We used multivariable logistic regression models to study the effect of vaccination schedules and types on vaccination delay.
Findings Substantial delays in vaccination were observed even in countries with fairly high coverage of all doses. Median delay was 1.0 week (interquartile range, IQR: 0.3 to 3.6) for the first dose (n = 108,626 children) and 3.7 weeks (IQR: 1.4 to 9.3) for the third dose (n = 101,542). We observed a tendency of lower odds of delays in vaccination schedules starting at 6 and at 9 weeks of age. For the first vaccine dose, we recorded lower odds of delays for combination vaccines than for monovalent vaccines (adjusted odds ratio, aOR: 0.76, 95% confidence interval, CI: 0.71 to 0.81).
Conclusion Wide variations in hepatitis B vaccination coverage and adherence to vaccination schedules across countries underscore the continued need to strengthen national immunization systems. Timely initiation of the vaccination process might lead to timely receipt of successive doses and improved overall coverage. We suggest incorporating vaccination timing as a performance indicator of vaccination programmes to complement coverage metrics.

Abstract in العربية, 中文, Français, Русский and Español at the end of each article.

Introduction
Chronic hepatitis B virus (HBV) infection continues to make a substantial contribution to the global burden of disease.1,2 The risk of developing chronic HBV is inversely related to the age at acquisition of infection.3,4 Immunization is the most effective measure to prevent the transmission of HBV.5,6 In 2014, the World Health Organization (WHO) reaffirmed the need for hepatitis B vaccines to become an integral part of national immunization schedules.7 WHO recommends a birth dose within 24 hours of birth to prevent perinatal and early horizontal HBV transmission.8 The birth dose should be followed by 2 or 3 doses of monovalent or multivalent hepatitis B vaccines.8

Vaccination coverage estimates from WHO and the United Nations Children's Fund (UNICEF) capture the proportion of vaccinated children in specific age groups. However, these estimates provide little insight into the extent to which vaccinations are administered on time and they tend to underestimate the susceptibility to HBV infection in a population.9,10 In practice, vaccinations are more likely to be received late than early.11,12 When hepatitis B vaccination is delayed, children fail to receive adequate protection when they are most vulnerable. Moreover, by increasing the period of susceptibility to infection,2 late vaccinations raise the risk of HBV infection13 and hence the risk of chronicity. Furthermore, a delay in one dose may lead to delays in further doses,13 thereby extending the at-risk period. This has important implications in countries that are highly endemic for HBV infection. In this situation, catch-up vaccination of older children has relatively little impact because they might already be infected by the time they present for vaccination.9

There are multiple options for incorporating hepatitis B vaccines into national immunization programmes and the choice of vaccination schedule depends primarily on programmatic considerations.7 From a policy perspective, data from a large number of countries are necessary to evaluate the impact of existing hepatitis B vaccination schedules and vaccine types on hepatitis B vaccination timing. Thus far, analyses of hepatitis B vaccinations have been limited in scope14–17 and have not tackled this aspect. The demographic and health surveys (DHS) provide data on childhood vaccinations based on vaccination cards and maternal interviews. Data compiled through DHS are nationally representative and are considered to be the best available data on vaccination coverage.18,19 We estimated vaccination coverage and timing, and examined the impact of hepatitis B vaccination schedules and vaccine types on vaccination timing in countries for which DHS data were publicly available.

Methods
Study design
Full details of DHS methods have been reported elsewhere.20,21 DHS data on hepatitis B vaccination were available for 54 countries. For every country, we used the most recent survey available until the end of 2015. Seven surveys were excluded due to incomplete data or non-standard recording of dates. We therefore included 47 countries with survey years ranging from 2005 to 2014. We grouped countries based on their vaccination schedule and type of vaccine (monovalent or combination) in use (Table 1, available at http://www.who.int/bulletin/volumes/95/3/16.178822). In

a Helmholtz Centre for Infection Research (HZI), Inhoffenstraße 7, Brunswick 38124, Germany.
Correspondence to Aparna Schweitzer (email: aparna.schweitzer@dzne.de).
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countries that had altered their schedules before the DHS survey we limited our analyses to the more established vaccination schedule.

We identified and analysed individual vaccine doses according to the respective country’s national immunization schedule. To assess vaccination coverage, we used only documented vaccinations (with or without specific dates marked) for each vaccine dose. Vaccination coverage was categorized as complete if the child was recorded as fully immunized with three or four doses of the vaccine according to the country’s national immunization schedule. Vaccination coverage was categorized as incomplete if any of the recommended doses were recorded as 0 (not given), including when data on other doses was missing.8 We excluded children younger than 12 months to avoid the drawback of censored observations. The denominator for coverage was the DHS sample of surviving children born in the past 5 years before the survey (or sometimes 3 years, depending on the DHS interval). To address potential bias from maternal recall,24,25 we estimated crude vaccination coverage and completeness (from vaccination card plus maternal recall).

To assess vaccination timing, we compared each child’s recorded vaccination dates with those recommended in the country’s national immunization schedule. Age at vaccination was determined by subtracting the child’s date of birth from valid vaccination dates. Vaccinations were categorized as timely if administered within 4 weeks of the recommended age, or delayed if administered more than 4 weeks after the recommended age. We calculated the percentage of children receiving delayed or timely vaccinations. The denominator for calculating timing included children vaccinated early, i.e. before the recommended age. National immunization schedules often do not specify when to give the birth-dose vaccine.26 We therefore defined a timely birth dose as received within 7 days after delivery, based on the evidence on effective prevention of perinatal hepatitis B transmission.27 We also computed estimates based on the WHO recommendation of giving hepatitis B vaccine within 24 hours of birth.

Statistical analysis
We performed all analyses with the survey functions of Stata statistical software, version 14 (Stata Corp., College Station, United States of America), using a significance level of ≤ 0.05.

We took account of the complex DHS survey design and used sample weights provided in the available data sets. Using Spearman rank correlations, we analysed the relationship between vaccination timing and coverage of the third dose of vaccine across countries. We then used binary multivariable logistic regression models to calculate adjusted odds ratios (aOR) and 95% confidence intervals (CI) to investigate the impact of vaccination schedule and vaccine type on hepatitis B vaccination timing. Vaccinations were dichotomized as delayed or timely. We constructed pooled models for two outcomes: delayed first dose and delayed third dose. The main independent variables were the recommended week of the vaccination schedule and vaccine type (monovalent or combination). We categorized reported vaccination schedules as follows: starting at birth i.e. ≤ 1 week of age (reference category), 4, 6, 9 and 13 weeks, respectively. We incorporated covariates chosen for their possible or demonstrated associations with vaccination measures.24,25 In an additional pooled model, we assessed the impact of the timing of the first dose on the timing of the third dose. The dependent variable was timing of the third dose and the main independent variable was timing of the first dose.

Results
Data were analysed for 211 643 children aged 12–60 months who had valid records of date of birth and date of mother’s interview. The median survey year was 2012 (interquartile range, IQR: 2010 to 2013). Reported vaccination dates were almost all complete and valid. Overall, vaccination cards were available for 123 679 (weighted count) of the children aged 12–60 months.

At the time of the surveys, 24 countries used the three-dose standard schedule for hepatitis B vaccine (doses at 6, 10 and 14 weeks), four countries vaccinated at 9, 17 and 26 weeks and the remaining countries used other three-dose schedules, some of which included an extra dose at birth, i.e. four doses in total (Table 1). Thirteen countries reported a vaccine dose at birth; eight included a birth dose in their three-dose schedule and five used a four-dose schedule. Combination vaccine, mostly a pentavalent vaccine, was used in 29 countries, while monovalent vaccine was used in 18 countries.

Fig. 1 shows the pooled distribution of ages at vaccination for 108 626 (first dose) and 101 542 (third dose) children aged 12–60 months at the time of the mother’s interview, using data from vaccination cards only. Both the first and third doses had peak numbers of children vaccinated around the recom-
mended target ages, followed by tails to the right, indicating delays in vaccination. The different peaks in the distributions of first and third doses reflect the diverse immunization schedules and recommended target ages for these doses across the 47 countries.

Coverage of the birth dose ranged from 26% to 99% of children across the 13 countries using this dose. The percentage of children receiving birth-dose vaccinations on time ranged from 23% to 94% across countries (Fig. 2). The proportion of timely vaccinations was lower when we defined the birth dose as administered within 24 hours rather than within 7 days of birth.

Vaccination delays
We observed a substantial variation in delays in receipt of the first and third doses across countries having the same vaccination schedule and vaccine type (Table 3). We noted a drop in timely vaccinations between the first and third doses, irrespective of the vaccination schedule and vaccine type in use. For the 47 countries overall, the median of the median delays for the first vaccine dose was 1.0 week, and the 75th percentile was 3.6 weeks, i.e. in 25% of the countries the median delay was more than 3.6 weeks. For the third dose, the delays were more than twice as long (Table 4). The country-specific distribution of ages at vaccination had long tails, and delays at the 90th percentile were at least twice as long as the 75th percentile (Table 5). Overall, WHO African Region countries tended to have lower vaccination coverage and poorer timing compared with countries in the Americas and Europe. Delays were recorded even in countries with high coverage, such as Bangladesh and Burkina Faso. We found a weak positive correlation (Spearman rho = 0.28; P = 0.05) between vaccination timing and coverage. Fig. 3 shows the timing and the corresponding coverage of the third vaccine dose for each of the 47 countries, using data from vaccination cards.

Vaccination coverage
Coverage for all doses, and for complete coverage varied greatly, even across countries following the same vaccination schedule and vaccine type (Table 2, available at http://www.who.int/bulletin/volumes/95/3/16.178822). For example, complete coverage for countries using the 6-, 10-, and 14-week schedule ranged from 13% in Mali to 93% in Swaziland. Overall, we recorded a drop in coverage in particular of the third dose compared to the first dose, irrespective of the vaccination schedule and vaccine type in use. This was particularly prominent in some countries, such as Azerbaijan (where coverage dropped from 69% to 48%) and Côte d’Ivoire (from 74% to 58%).

Table 6 (available at http://www.who.int/bulletin/volumes/95/3/16.178822) shows the descriptive statistics for the pooled weighted sample used in the regression models. Table 7 shows pooled multivariable regression models for delays in the first and third doses. After
### Table 3. Time delays in the receipt of doses of hepatitis B vaccine for children aged 12–60 months in 47 countries, by national hepatitis B vaccination schedule

| Vaccination schedulea and vaccine type | Country | First dose | Third dose |
|----------------------------------------|---------|------------|------------|
|                                        |         | No. of children vaccinated | No. (%) with delayed vaccination | No. of children vaccinated | No. (%) with delayed vaccination |
| **Weeks 0, 4, 13**                     |         |            |            |
| Monovalent                             | Maldives | 2 042 427 (21) | 2 036 1 868 (92) |
| **Weeks 0, 4, 26**                     |         |            |            |
| Monovalent                             | Republic of Moldova | 1 040 66 (6) | 1 062 355 (33) |
| **Weeks 0, 6, 14**                     |         |            |            |
| Monovalent                             | Nigeria | 3 661 2 823 (77) | 3 043 1 615 (53) |
| **Weeks 0, 6, 26**                     |         |            |            |
| Monovalent                             | Armenia | 1 016 170 (17) | 943 554 (59) |
| **Weeks 0, 9, 17**                     |         |            |            |
| Monovalent                             | Azerbaijan | 760 244 (32) | 622 279 (45) |
| Monovalent                             | Tajikistan | 2 981 433 (15) | 2 750 545 (20) |
| **Weeks 0, 9, 22**                     |         |            |            |
| Monovalent                             | Kyrgyzstan | 2 244 125 (6) | 2 054 348 (17) |
| **Weeks 0, 9, 26**                     |         |            |            |
| Monovalent                             | Albania | 798 99 (12) | 758 96 (13) |
| **Weeks 4, 8, 12**                     |         |            |            |
| Tetravalent                            | United Republic of Tanzania | 3 367 996 (30) | 3 223 1 868 (58) |
| Pentavalent                            | Uganda | 801 371 (46) | 700 528 (75) |
| **Weeks 6, 10, 14**                    |         |            |            |
| Monovalent                             | Bangladesh | 3 583 818 (23) | 3 428 1 792 (52) |
| Monovalent                             | Cameroon | 1 745 366 (21) | 1 607 641 (40) |
| Monovalent                             | Gabon | 793 211 (27) | 627 320 (51) |
| Monovalent                             | Lesotho | 739 115 (16) | 643 266 (41) |
| Monovalent                             | Pakistan | 560 185 (33) | 508 322 (63) |
| Monovalent                             | Swaziland | 1 347 94 (7) | 1 315 337 (26) |
| Monovalent                             | Timor-Leste | 1 971 740 (38) | 1 853 1 112 (60) |
| Bivalent                               | Benin | 2 076 398 (19) | 1 877 879 (47) |
| Tetravalent                            | Madagascar | 1 993 524 (26) | 1 891 882 (47) |
| Tetravalent                            | Mozambique | 5 282 2 361 (45) | 4 764 3 586 (75) |
| Pentavalent                            | Burundi | 1 335 180 (13) | 1 298 517 (40) |
| Pentavalent                            | Cambodiaa | 2 443 368 (15) | 2 286 850 (37) |
| Pentavalent                            | Comoros | 1 088 255 (23) | 1 032 537 (52) |
| Pentavalent                            | Côte d’Ivoire | 1 363 396 (29) | 1 120 647 (58) |
| Pentavalent                            | Democratic Republic of the Congo | 914 255 (28) | 780 337 (43) |
| Pentavalent                            | Ghana | 1 587 220 (14) | 1 539 579 (38) |
| Pentavalent                            | Kenya | 2 413 451 (19) | 2 302 804 (35) |
| Pentavalent                            | Liberia | 862 256 (30) | 749 461 (61) |
| Pentavalent                            | Malawi | 2 341 664 (28) | 2 309 1 327 (57) |
| Pentavalent                            | Mali | 309 127 (41) | 275 188 (68) |
| Pentavalent                            | Namibia | 814 69 (8) | 796 173 (22) |
| Pentavalent                            | Niger | 1 148 400 (35) | 1 062 707 (67) |
| Pentavalent                            | Rwanda | 2 386 167 (7) | 2 351 569 (24) |
| Pentavalent                            | Senegal | 2 277 617 (27) | 2 084 1 154 (55) |
| Pentavalent                            | Sierra Leoneab | 2 072 555 (27) | 1 891 1 168 (62) |
| Pentavalent                            | Zambia | 6 136 1 883 (31) | 5 697 3 438 (60) |
| **Weeks 9, 13, 17**                    |         |            |            |
| Monovalent                             | Jordan | 3 598 381 (11) | 3 523 1 264 (36) |
| Pentavalent                            | Congo | 1 155 161 (14) | 1 014 315 (31) |
| Pentavalent                            | Burkina Faso | 3 447 502 (15) | 3 350 1 188 (35) |

*(continues...)*
adjusting for covariates, delays in the first dose for vaccination schedules starting at 6 weeks of age (aOR: 0.81; 95% CI: 0.75 to 0.88) and at 9 weeks of age (aOR: 0.50; 95% CI: 0.46 to 0.53) were lower than for vaccination schedules with a birth dose. Vaccination schedules starting at 4 weeks and at 13 weeks of age tended to have higher odds of delays. Combination vaccines tended to have lower odds of delays in the first dose than did the monovalent vaccine (aOR: 0.76; 95% CI: 0.71 to 0.81). In a separate pooled model, when controlling for the timing of the receipt of the first dose, we observed higher odds of delays in the third dose if the first dose was delayed than if it was on time (aOR: 22.89; 95% CI: 20.99 to 24.97).

**Discussion**

Our analysis of survey data from 47 low- and middle-income countries, inhabited by around 1.2 billion people, showed a wide variation in hepatitis B vaccination coverage and timing across countries. The results highlight differences in vaccination implementation, and in adherence to national immunization schedules. This may reflect differences in barriers to immunization, in inequities in health-care delivery and access, as upper-middle-income countries tended to have better coverage and timing than lower-middle and low-income countries. Most countries had fairly high coverage (>80%), in particular for the first dose, and delivered vaccines on time. Although this finding is encouraging, in most countries coverage decreased and delays increased with subsequent doses, irrespective of a country’s specific vaccination schedule. Crucially, vaccination coverage was low (<50%) and vaccinations were delayed in populous countries that are highly endemic for HBV infection, such as Nigeria.

Despite WHO recommendations on hepatitis B vaccination within 24 hours, only 13 countries in our analysis reported using a birth dose, with wide variations in its coverage and timing. Due to existing sociocultural, financial, infrastructural and logistic constraints on vaccine delivery, many countries do not require the birth dose to be strictly administered within 24 hours of birth. A major challenge, particularly in highly endemic, resource-poor countries with a high proportion of home deliveries, is ensuring the timely administration of the birth dose to every child irrespective of where he or she is born.

Most countries where the HBV epidemic is concentrated have adopted the three-dose combination vaccine delivered at 6, 10 and 14 weeks. Our analysis gave some indication that vaccination delays were lower with vaccination schedules starting at 6 or 9 weeks of age compared with those starting at or before 1 week of age, and with combination vaccines as compared with monovalent vaccines. This might be attributable to increased compliance by vaccine recipients due to the reduced number of injections and fewer visits required to health-care facilities. That said, administering combination vaccinations at 6 or 9 weeks of age, while cost-effective and simple, cannot prevent vertical and early horizontal transmission.

It has been suggested that, due to the predominantly horizontal routes of HBV transmission in Africa, the benefit of implementing a birth dose would not justify the necessary financial, human resource and infrastructure investments. This is based on the premise that perinatal transmission is not a major factor in HBV transmission due to the lower prevalence of hepatitis B e-antigen (HBeAg) positivity in pregnant women in Africa. However, studies suggest that up to 38% of pregnant African women with chronic HBV are positive for HBeAg and hence at high risk of transmitting infection to their infants. Data on the epidemiology of HBV, particularly transmission routes, and on the benefits of birth dose vaccination are scarce in Africa. Nevertheless, in our view, the benefits...
of giving a birth dose in the African setting deserve consideration, due to the high burden of HBV infection and the known high risk of infection and chronicity associated with perinatal and early horizontal infections. From a policy perspective it is important to examine current country-level modes of HBV transmission in tandem with existing vaccination schedules so that recommendations can be adapted to existing disease transmission patterns.

We found lower compliance with national schedules for the second and third vaccine doses and a weak correlation of timing with coverage. This implies that even in countries with relatively high coverage, children who achieve complete vaccination may spend a considerable period of time with no or incomplete protection. This is particularly concerning in countries with a high burden of infection.

Our analysis also indicates that the third dose of vaccine is more likely to be delayed among those who received a delayed first dose. This suggests that prioritizing timely first vaccinations could result in the timely receipt of successive doses and avert delays that would require catch-up regimens. Given the existent challenges in providing hepatitis B vaccination in resource-poor settings, catch-up regimens might decrease the likelihood of the timely completion of the hepatitis B vaccina-

Table 4. Time delays in the receipt of doses of hepatitis B vaccine for children aged 12–60 months across 47 countries

| Percentiles  | First dose delay percentiles, weeks | Third dose delay percentiles, weeks |
|-------------|------------------------------------|-------------------------------------|
|             | 25th | 50th | 75th | 25th | 50th | 75th |
| 25th        | 0.0  | 0.4  | 1.8  | 0.7  | 2.4  | 6.1  |
| 50th (median)| 0.3  | 1.0  | 3.6  | 1.4  | 3.7  | 9.3  |
| 75th        | 0.6  | 2.0  | 5.0  | 2.4  | 5.7  | 13.2 |

Notes: Total number of children (weighted counts) were 108,626 (first dose) and 101,542 (third dose). Data were extracted from the most recent demographic and health survey in each country (survey year range: 2005–2014). Delayed vaccination was a vaccine dose received more than 4 weeks after the target week in the national vaccination schedule.

Fig. 3. Scatter plot of country-specific coverage and timing of third dose of hepatitis B vaccine for children aged 12–60 months in 47 countries

Notes: Correlation between vaccination timing and coverage, Spearman rho = 0.28, P = 0.05. Data were extracted from the most recent demographic and health survey in each country (survey year range: 2005–2014). Coverage is the percentage of children receiving the third dose of vaccine based on vaccination card data (vaccination dates recorded or vaccination marked without date of administration). Timely receipt of vaccination is the percentage of children receiving the third dose within 4 weeks of the target age (weeks) of the national vaccination schedule. Denominators are those in Table 2 and Table 3. Dates of vaccination were based on observations with available vaccination dates recorded on vaccination cards. We included children vaccinated before the recommended age (early vaccinations) in the denominator when calculating delayed and timely vaccination rates. Estimates of early vaccinations are not shown in the figure. The following countries reported > 10% children vaccinated before the recommended age for the third dose: Azerbaijan (50%), Plurinational State of Bolivia (12%), Colombia (12%), Kyrgyzstan (60%), Nigeria (12%) and Tajikistan (56%).

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Interrupting transmission routes for HBV warrants comprehensive strategies to prevent mother-to-child transmission and to deliver adequate and timely immunoprophylaxis in newborns and infants. In remote, resource-constrained settings, integrating vaccine administration with assisted home deliveries and employing out-of-­chain strategies might be possible solutions to improve timely vaccination coverage. Furthermore, mathematical models, calibrated to country-specific HBV epidemiology might be useful to quantify the burden of infection attributable to delayed vaccinations. In this context, models could be developed to assess the infections and deaths averted by prioritizing timely vaccinations that use alternative vaccination schedules and diverse outreach strategies.

### Limitations

The main limitation of this analysis is related to the available data from DHS. The survey years varied substantially across countries, and therefore caution is warranted when interpreting international comparisons. Most surveys were fairly recently conducted – the median survey year was 2012 – and provide useful insights into the quality (timing) and quantity (coverage) of current hepatitis B vaccination programmes. However, some of the older surveys, notably in the Republic of Moldova and Swaziland, may not reflect the current situation.

The distribution of ages at vaccination are only crude indicators of the timing issue, since each country’s contribution was determined by the size of its survey sample, which varied among countries and did not reflect actual population sizes. Furthermore, the analysis was used only by a small number of countries, which impeded any conclusions about the effects of specific schedules. We restricted our analysis to established vaccination schedules. This might lead to underestimates or overestimates depending on the uptake of newer vaccines and schedules by countries. Data on vaccination service providers were not available which might have provided valuable insights into the issue of hepatitis B vaccination timing. We excluded undocumented vaccinations from the analysis and therefore coverage and delays may be underestimated, since undocumented vaccinations including lost or misplaced vaccination cards were not captured. Vaccination information was based only on maternal recall in approximately 30% of the observations, with higher figures in some countries (such as the Democratic Republic of the Congo and Nigeria). However, no noteworthy differences in coverage were detected for most countries when we included maternal reports (data are available from the corresponding author).

A disadvantage of cross-sectional studies is the potential for survivor bias. Our analysis did not include deceased children since the included surveys did not record vaccination data for this subgroup. We might have overestimated vaccination measures slightly since it is unlikely that deceased children would have better vaccination parameters than surviving children.

### Table 7. Multivariable pooled regression analysis for the association between vaccination schedule and vaccine type on hepatitis B vaccination timing among children aged 12–60 months in 47 countries

| Variable                  | First dose |            |                 | Third dose |            |
|---------------------------|------------|------------|-----------------|------------|------------|
|                           | No. of children vaccinated<sup>a</sup> | No. of children with delays | aOR (95% CI) | No. of children vaccinated<sup>a</sup> | No. of children with delays | aOR (95% CI) |
| Vaccination schedule start week |            |            |                 |            |            |
| ≤ 1                       | 14 437     | 4 353      | Ref.            | 9 565      | 5 602      | Ref.         |
| 4                         | 3 972      | 1 353      | 0.91 (0.80 to 1.03) | 3 810      | 2 355      | 1.14 (1.00 to 1.30) |
| 6                         | 44 647     | 12 525     | 0.81 (0.75 to 0.88) | 43 932     | 23 336     | 0.97 (0.91 to 1.03) |
| 9                         | 29 151     | 4 482      | 0.45 (0.41 to 0.50) | 33 273     | 10 688     | 0.50 (0.46 to 0.53) |
| 13                        | 791        | 338        | 1.11 (0.92 to 1.34) | 1 016      | 565        | 1.21 (1.03 to 1.42) |
| Vaccine type              |            |            |                 |            |            |
| Monovalent                | 37 763     | 8 305      | Ref.            | 32 297     | 14 007     | Ref.         |
| Combination               | 60 053     | 14 746     | 0.76 (0.71 to 0.81) | 59 299     | 28 538     | 0.99 (0.94 to 1.05) |

<sup>a</sup> The number of children included in the analyses were adjusted for the covariates stated below.

Notes: Data were extracted from the most recent demographic and health survey (DHS) in each country (survey year range: 2005–2014). Total number of children (weighted counts) were 97 818 (first dose) and 93 807 (third dose). Total observations were 100 167 (first dose) and 93 807 (third dose). Denominators vary across countries and therefore caution is warranted when interpreting international comparisons.20 Most surveys were fairly recently conducted – the median survey year was 2012 – and provide useful insights into the quality (timing) and quantity (coverage) of current hepatitis B vaccination programmes. However, some of the older surveys, notably in the Republic of Moldova and Swaziland, may not reflect the current situation.
nature of the data also precluded our drawing causal inferences. Additionally, it is likely that there was residual confounding that was not adjusted for in our models. To enable more in-depth analyses, future surveys need to incorporate sufficiently detailed questions on barriers to immunization, e.g., vaccine availability in the health system, and on parental and provider vaccination practices.

Lastly, the surveyed countries were not randomly sampled. Hence the external validity of the results for other low- and middle-income countries might be limited, particularly for those using different vaccination schedules than those in the current analysis. The available data were primarily from countries in the WHO African, European and Americas Regions, with limited data from the Eastern Mediterranean, South-East Asian and Western Pacific Regions.

Conclusion
The substantial inequities in the implementation and adherence to national immunization schedules for hepatitis B vaccine underscore the continued need for strengthening immunization systems. Strategies that focus on the timely initiation of hepatitis B immunization might lead to the timely receipt of successive doses and hence improve overall coverage. Our findings indicate that timing should be incorporated as a performance indicator of routine immunization services, as a complement to coverage assessments.

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Résumé

Date des vaccinations contre l’hépatite B: résultats d’enquêtes démographiques et sanitaires menées dans 47 pays

Objectif Étudier l’impact des calendriers de vaccination et des types de vaccins contre l’hépatite B sur la date des vaccinations contre l’hépatite B.

Méthodes Nous avons eu recours à des données concernant 211 643 enfants qui étaient issus d’enquêtes démographiques et sanitaires menées dans 47 pays à revenu faible et intermédiaire (année médiane: 2012). Ces données provenaient de carnets de vaccination et d’entretiens avec les mères. Nous avons regroupé les pays en fonction du calendrier de vaccination et du type de vaccin utilisé (monovalent ou combiné). Pour chaque pays, nous avons calculé la couverture vaccinale contre l’hépatite B ainsi que l’administration en temps voulu des doses du vaccin. Nous avons utilisé des modèles de régression logistique multivariée pour étudier l’effet des calendriers de vaccination et des types de vaccins sur les retards de vaccination.

Résultats D’importants retards de vaccination ont été observés, y compris dans les pays où la couverture vaccinale était relativement élevée, pour toutes les doses. Le retard moyen était de 1,0 semaine (intervalle interquartile, IQR: 0,3 à 3,6) pour la première dose (n = 108 626 enfants) et de 3,7 semaines (IQR: 1,4 à 9,3) pour la troisième dose (n = 101 542). Nous avons observé que la probabilité de retards avait tendance à être plus faible pour les calendriers de vaccination qui débutaient à l’âge de 6 et de 9 semaines. Pour la première dose vaccinale, nous avons noté une probabilité de retard plus faible lorsqu’il s’agissait de vaccins combinés que de vaccins monovalents (rapport des cotes ajusté: 0,76, intervalle de confiance de 95%: 0,71 à 0,81).

Conclusion Les écarts importants au niveau de la couverture vaccinale contre l’hépatite B et du respect des calendriers de vaccination dans les différents pays soulignent la nécessité de continuer à renforcer les systèmes nationaux de vaccination. Débuter les vaccinations en temps voulu pourrait permettre d’administrer les rappels en temps voulu également et d’améliorer la couverture globale. Nous suggérons d’intégrer la date des vaccinations comme indicateur de performance des programmes de vaccination, en complément de la mesure de la couverture vaccinale.

Resumen

Fecha de vacunación de la hepatitis B: resultados de encuestas sobre demografía y salud en 47 países

Objetivo Examinar el impacto de los calendarios de vacunación de la hepatitis B y los tipos de vacunas en los plazos de vacunación de la hepatitis B.

Métodos Se utilizaron datos de 211 643 niños de encuestas demográficas y de salud en 47 países con ingresos bajos y medios (año promedio de estudio 2012). La información provenía de las tarjetas de vacunación y de entrevistas a las madres. Se agruparon los países según el calendario de vacunación y el tipo de vacuna utilizada (monovalente o combinada). Para cada país, se calculó una cobertura de vacunación contra la hepatitis B y la recepción oportuna de las dosis de la vacuna. Se utilizaron modelos de regresión logística multivariada para estudiar el efecto de los calendarios de vacunación y los tipos en el retraso en la administración de vacunas.

Resultados Se observaron grandes retrasos en la vacunación, incluso en países con una cobertura bastante alta de todas las dosis. El retraso medio era de 1,0 semanas (rango intercuartílico, IQR: 0,3 a 3,6) para la primera dosis (n = 108 626 niños) y de 3,7 semanas (IQR: 1,4 a 9,3) para la tercera dosis (n = 101 542). Se observó una tendencia de menores probabilidades de retraso en los calendarios de vacunación que empezaban a las 6 y 9 semanas de edad. Para la primera dosis de la vacuna, se registraron menos probabilidades de retraso para las vacunas combinadas que para las monovalentes (coeficiente de posibilidades ajustado: 0,76, intervalo de confianza (IC) del 95%: 0,71 a 0,81).

Conclusión Las grandes diferencias en la cobertura de vacunación contra la hepatitis B y la adherencia a los calendarios de vacunación entre países destacan la continua necesidad de mejorar los sistemas
nacionales de inmunización. La iniciación oportuna del proceso de vacunación puede dar lugar a la recepción oportuna de dosis sucesivas y a la mejora de la cobertura general. Sugerimos la incorporación de la fecha de vacunación como un indicador de rendimiento de los programas de vacunación para completar el cálculo de la cobertura.

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| Vaccination schedule\(^a\) and vaccine type | Country               | WHO Region     | Gavi financing\(^b\) | Income level\(^c\) | Population\(^d\) | HBsAg prevalence, (%)\(^e\) | Country data | DHS survey year | Sample of children aged 12\textendash{}60 months, no.\(^f\) |
|-------------------------------------------|----------------------|----------------|----------------------|---------------------|------------------|---------------------------|--------------|----------------|------------------|
| Weeks 0, 4, 13                            | Maldives             | SEAR           | No                   | Upper-middle        | 332 575          | N/A                       | 2009         | 2 498          |
| Weeks 0, 4, 26                            | Republic of Moldova  | EUR            | No                   | Lower-middle        | 3 573 024        | 7.4                       | 2005         | 1 165          |
| Weeks 0, 6, 14                            | Nigeria              | AFR            | No                   | Lower-middle        | 159 707 780      | 9.8                       | 2013         | 20 799         |
| Weeks 0, 6, 26                            | Armenia              | EUR            | Yes                  | Lower-middle        | 2 963 496        | N/A                       | 2010         | 1 114          |
| Weeks 0, 9, 17                            | Azerbaijan           | EUR            | Yes                  | Upper-middle        | 9 094 718        | 2.8                       | 2006         | 1 707          |
| Weeks 0, 9, 22                            | Tajikistan           | EUR            | Yes                  | Lower-middle        | 7 627 326        | 7.2                       | 2012         | 3 797          |
| Weeks 0, 9, 26                            | Kyrgyzstan           | EUR            | Yes                  | Lower-middle        | 5 334 223        | 10.3                      | 2012         | 3 174          |
| Weeks 4, 8, 12                            | Albania              | EUR            | Yes                  | Upper-middle        | 3 150 143        | 7.8                       | 2008         | 1 303          |
| Tetravalent                              | United Republic of Tanzania | AFR | Yes | Low | 44 973 330 | 7.2 | 2010 | 5 444 |
| Pentavalent                              | Uganda               | AFR            | Yes                  | Low                 | 33 987 213       | 9.2                       | 2011         | 1 586          |
| Weeks 6, 10, 14                           | Bangladesh           | SEAR           | Yes                  | Lower-middle        | 151 125 475      | 3.1                       | 2011         | 6 400          |
| Monovalent                               | Cameroon             | AFR            | Yes                  | Lower-middle        | 20 624 343       | 12.2                      | 2011         | 3 803          |
| Monovalent                               | Gabon                | AFR            | No                   | Upper-middle        | 1 556 222        | 11.5                      | 2012         | 2 605          |
| Monovalent                               | Lesotho              | AFR            | Yes                  | Lower-middle        | 2 010 586        | N/A                       | 2009         | 1 263          |
| Monovalent                               | Pakistan             | EUR            | Yes                  | Lower-middle        | 173 149 306      | 2.8                       | 2012         | 2 865          |
| Monovalent                               | Swaziland            | AFR            | No                   | Lower-middle        | 1 193 148        | 19.0                      | 2006         | 1 610          |
| Monovalent                               | Timor-Leste          | SEAR           | No                   | Lower-middle        | 1 057 122        | N/A                       | 2009         | 7 168          |
| Monovalent                               | Benin                | AFR            | Yes                  | Low                 | 9 509 798        | 15.6                      | 2011         | 6 571          |
| Pentavalent                              | Madagascar           | AFR            | Yes                  | Low                 | 21 079 532       | 4.6                       | 2008         | 4 269          |
| Tetravalent                              | Mozambique           | AFR            | Yes                  | Low                 | 23 967 265       | 8.3                       | 2011         | 7 412          |
| Pentavalent                              | Burundi              | AFR            | Yes                  | Low                 | 9 232 753        | 9.1                       | 2010         | 2 625          |
| Pentavalent                              | Cambodia\(^g\)       | WPR            | Yes                  | Lower-middle        | 14 364 931       | 4.1                       | 2014         | 3 487          |
| Pentavalent                              | Comoros              | AFR            | Yes                  | Low                 | 698 695          | N/A                       | 2012         | 2 100          |
| Pentavalent                              | Côte d'Ivoire        | AFR            | Yes                  | Lower-middle        | 18 976 588       | 9.4                       | 2011         | 2 383          |
| Pentavalent                              | Democratic Republic of the Congo | AFR | Yes | Low | 62 191 161 | 6.0 | 2013 | 6 462 |
| Pentavalent                              | Ghana                | AFR            | Yes                  | Lower-middle        | 24 262 901       | 12.9                      | 2014         | 2 103          |
| Pentavalent                              | Kenya                | AFR            | Yes                  | Lower-middle        | 40 909 194       | 5.2                       | 2008         | 3 965          |
| Pentavalent                              | Liberia              | AFR            | Yes                  | Low                 | 3 957 990        | 17.6                      | 2013         | 2 469          |
| Pentavalent                              | Malawi               | AFR            | Yes                  | Low                 | 15 013 694       | 12.2                      | 2010         | 3 945          |
| Pentavalent                              | Mali                 | AFR            | Yes                  | Low                 | 13 985 961       | 13.1                      | 2012         | 3 700          |
| Pentavalent                              | Namibia              | AFR            | No                   | Upper-middle        | 2 178 967        | 8.6                       | 2013         | 1 357          |
| Pentavalent                              | Niger                | AFR            | Yes                  | Low                 | 15 893 746       | 15.5                      | 2012         | 2 282          |
| Pentavalent                              | Rwanda               | AFR            | Yes                  | Low                 | 10 836 732       | 6.7                       | 2010         | 3 259          |
| Pentavalent                              | Senegal              | AFR            | Yes                  | Low                 | 12 950 564       | 11.1                      | 2014         | 4 246          |
| Pentavalent                              | Sierra Leone\(^i\)  | AFR            | Yes                  | Low                 | 5 751 976        | 8.4                       | 2013         | 3 606          |
| Pentavalent                              | Zambia               | AFR            | Yes                  | Lower-middle        | 13 216 985       | 6.1                       | 2013         | 9 562          |

(continues . . .)
| Vaccination schedule\(^a\) and vaccine type | Country | WHO Region | Gavi financing\(^b\) | Income level\(^c\) | Population\(^d\) | HBsAg prevalence, (%)\(^e\) | DHS survey year | Sample of children aged 12–60 months, no.\(^f\) |
|------------------------------------------|---------|------------|---------------------|-----------------|----------------|-----------------|----------------|--------------------------|
| **Weeks 9, 13, 17**                     |         |            |                     |                 |                |                 |                |                          |
| Monovalent                              | Jordan  | EMR        | No                  | Upper-middle    | 6 454 554      | 1.9             | 2012           | 5 380                     |
| Pentavalent                             | Burkina Faso | AFR      | Yes                 | Low             | 15 540 284     | 12.1            | 2010           | 5 113                     |
| Pentavalent                             | Congo   | AFR        | Yes                 | Lower-middle    | 4 111 715      | 11.0            | 2011           | 3 508                     |
| **Weeks 9, 17, 26**                     |         |            |                     |                 |                |                 |                |                          |
| Monovalent                              | Egypt   | EMR        | No                  | Lower-middle    | 78 075 705     | 1.7             | 2014           | 11 639                    |
| Monovalent                              | Colombia\(^g\) | AMR | No                  | Upper-middle    | 46 444 798     | 2.3             | 2010           | 12 615                    |
| Pentavalent                             | Bolivia | AMR        | No                  | Lower-middle    | 10 156 601     | 0.4             | 2008           | 6 396                     |
| Pentavalent                             | Dominican Republic\(^h\) | AMR | No                  | Upper-middle    | 10 016 797     | 4.1             | 2013           | 2 597                     |
| Pentavalent                             | Guyana  | AMR        | Yes                 | Upper-middle    | 753 362        | N/A             | 2009           | 1 449                     |
| Pentavalent                             | Honduras | AMR    | No                  | Lower-middle    | 7 503 875      | N/A             | 2011           | 7 998                     |
| Pentavalent                             | Peru\(^i\) | AMR | No                  | Upper-middle    | 29 262 830     | 2.1             | 2012           | 7 513                     |
| **Weeks 13, 17, 22**                    |         |            |                     |                 |                |                 |                |                          |
| Pentavalent                             | Zimbabwe | AFR      | Yes                 | Low             | 13 076 978     | 14.4            | 2010           | 3 331                     |
| **Overall**                             | N/A     | N/A        | N/A                 |                 | 1 161 836 962  | N/A             | N/A            | 211 643                   |

\(^a\) Schedule is the target weeks after birth to administer the first, second and third doses of vaccine. Details of national immunization schedules were obtained from relevant annual joint World Health Organization (WHO) and United Nations Children’s Fund (UNICEF) immunization reports and demographic and health surveys for each country. Vaccine types were: monovalent (hepatitis B); bivalent (hepatitis B and Haemophilus influenzae type b); tetravalent (hepatitis B and diphtheria–tetanus–pertussis); pentavalent (diphtheria–tetanus–pertussis, hepatitis B and Haemophilus influenzae type b).

\(^b\) Gavi financing was recorded as “Yes” if the country received new and underused vaccine support for either monovalent or pentavalent vaccines (http://www.gavi.org/country/).

\(^c\) Country income level was defined as per the World Bank.\(^{22}\)

\(^d\) Population estimates were obtained from the United Nations.\(^{23}\)

\(^e\) Data on HBsAg prevalence (general population aged 0–85 years) are the most recent global prevalence estimates from 1965–2014 obtained from Schweitzer et al.\(^2\)

\(^f\) Sample sizes (number of children aged 12-60 months) are unweighted.

\(^g\) Vaccination schedule in these countries includes a birth dose of hepatitis B vaccine (monovalent), i.e. four doses in total.

Notes: We examined data quality for all children covered by the surveys. Vaccination dates were counted as invalid if day, month or year were missing, or if the date was implausible, e.g. before the date of birth of the child or after the date of mother’s interview or with erroneous dates (e.g. as year 9998). We only considered vaccination cards as available if seen by the interviewer. Excluded surveys: Ethiopia (non-standard date recording), Indonesia (date of birth not available), Morocco (only first dose reported), Nepal (non-standard date recording), Nicaragua (key missing variables, e.g. wealth index), Philippines (date of birth not available), and Turkey (date of birth not available). Countries that altered their national immunization schedules within 5 years of the survey were: Armenia (pentavalent introduced in 2009), Gabon (pentavalent introduced in 2010), Kyrgyzstan (pentavalent introduced in 2009) and Tajikistan (pentavalent introduced in 2008–09). Hence, we adopted the previous immunization schedule for these nations in our analysis. For Cambodia and Colombia, and the United Republic of Tanzania, data on multiple vaccine types (monovalent and combination) were reported. We based our estimates on monovalent vaccination in Colombia, pentavalent in Cambodia, and tetravalent in the United Republic of Tanzania. The decision was based on schedules (vaccines) reported in the relevant annual UNICEF/WHO immunization reports and the available data sets.
Table 2. Coverage of doses of hepatitis B vaccine for children aged 12–60 months in 47 low- and middle-income countries based on vaccination cards, by national hepatitis B vaccination schedule

| Vaccination schedule<sup>a</sup> and vaccine type | Country            | First dose |             | Second dose |             | Third dose |             | Complete<sup>b</sup> |             |
|-----------------------------------------------|--------------------|------------|-------------|-------------|-------------|------------|-------------|----------------------|-------------|
|                                               |                    | No. of children with vaccination data | No. (% vaccinated) | No. of children with vaccination data | No. (% vaccinated) | No. of children with vaccination data | No. (% vaccinated) | No. of children with vaccination data | No. (% vaccinated) |
| **Weeks 0, 4, 13**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Maldives           | 2 073      | 2 042 (99)  | 2 078       | 2 037 (98)  |            |            |                      |             |
| Monovalent                                   | Republic of Moldova| 1 045      | 1 040 (100) | 1 095       | 1 062 (97)  |            |            |                      |             |
| **Weeks 0, 6, 14**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Nigeria            | 14 623     | 3 735 (26)  | 15 223      | 3 442 (23)  |            |            |                      |             |
| **Weeks 0, 6, 26**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Armenia            | 1 041      | 1 016 (98)  | 1 049       | 943 (90)    |            |            |                      |             |
| **Weeks 0, 9, 17**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Azerbaijan         | 1 106      | 760 (69)    | 1 229       | 721 (65)    |            |            |                      |             |
| Monovalent                                   | Tajikistan         | 3 323      | 3 026 (91)  | 2 953       | 2 780 (94)  |            |            |                      |             |
| **Weeks 0, 9, 22**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Kyrgyzstan         | 2 393      | 2 247 (94)  | 2 207       | 2 136 (97)  |            |            |                      |             |
| **Weeks 0, 9, 26**                           |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Albania            | 848        | 813 (99)    | 886         | 814 (92)    |            |            |                      |             |
| **Weeks 4, 8, 12**                           |                    |            |             |             |             |            |             |                      |             |
| Tetravalent                                  | United Republic of Tanzania | 4 424 | 3 394 (77) | 4 466 | 3 351 (75) | 4 565 | 3 247 (71) | 4 556 | 3 230 (71) |
| Pentavalent                                  | Uganda             | 905        | 809 (89)    | 957         | 770 (80)    |            |            |                      |             |
| **Weeks 6, 10, 14**                          |                    |            |             |             |             |            |             |                      |             |
| Monovalent                                   | Bangladesh        | 3 790      | 3 592 (95)  | 3 817       | 3 532 (93)  |            |            |                      |             |
| Monovalent                                   | Cameroon          | 2 457      | 1 751 (71)  | 2 618       | 1 697 (65)  |            |            |                      |             |
| Monovalent                                   | Gabon             | 1 732      | 802 (46)    | 1 838       | 741 (41)    |            |            |                      |             |
| Monovalent                                   | Lesotho           | 877        | 747 (85)    | 849         | 697 (82)    |            |            |                      |             |
| Monovalent                                   | Pakistan          | 1 636      | 561 (34)    | 1 704       | 527 (31)    |            |            |                      |             |
| Monovalent                                   | Swaziland        | 1 395      | 1 346 (97)  | 1 400       | 1 335 (95)  |            |            |                      |             |
| Monovalent                                   | Timor-Leste       | 4 165      | 2 107 (51)  | 4 416       | 2 068 (47)  |            |            |                      |             |
| Bivalent                                     | Benin             | 6 390      | 2 355 (37)  | 6 385       | 2 263 (35)  |            |            |                      |             |
| Tetravalent                                  | Madagascar        | 2 643      | 2 030 (77)  | 2 748       | 1 994 (73)  |            |            |                      |             |
| Tetravalent                                  | Mozambique        | 6 249      | 5 539 (89)  | 6 326       | 5 330 (84)  |            |            |                      |             |
| Pentavalent                                  | Burundi           | 1 418      | 1 377 (97)  | 1 418       | 1 354 (95)  |            |            |                      |             |
| Pentavalent                                  | Cambodia<sup>c</sup> | 2 646 | 2 443 (92) | 2 702 | 2 382 (88) | 2 798 | 2 287 (82) | 2 701 | 1 872 (69) |
| Pentavalent                                  | Comoros           | 1 509      | 1 090 (72)  | 1 556       | 1 065 (68)  |            |            |                      |             |

(continues . . .)
### Vaccination schedule and vaccine type

| Vaccine schedule | Country | First dose | Second dose | Third dose | Complete |
|------------------|---------|------------|-------------|------------|----------|
|                  |         | No. of children with vaccination data | No. (%) vaccinated | No. of children with vaccination data | No. (%) vaccinated | No. of children with vaccination data | No. (%) vaccinated | No. of children with vaccination data | No. (%) vaccinated |
| Weeks 9, 13, 17  | Pentavalent | Democratic Republic of the Congo | 2 246 | 1 017 (45) | 2 590 | 962 (37) | 3 305 | 894 (27) | 3 301 | 888 (27) |
|                  | Pentavalent | Côte d’Ivoire | 1 846 | 1 364 (74) | 1 893 | 1 273 (67) | 1 929 | 1 122 (58) | 1 917 | 1 114 (58) |
|                  | Pentavalent | Ghana | 1 672 | 1 588 (95) | 1 716 | 1 580 (92) | 1 829 | 1 541 (84) | 1 819 | 1 526 (84) |
|                  | Pentavalent | Kenya | 2 647 | 2 430 (92) | 2 733 | 2 403 (88) | 2 892 | 2 321 (80) | 2 851 | 2 276 (80) |
|                  | Pentavalent | Liberia | 1 079 | 863 (80) | 1 164 | 812 (70) | 1 411 | 751 (53) | 1 405 | 745 (53) |
|                  | Pentavalent | Malawi | 2 547 | 2 395 (94) | 2 599 | 2 404 (92) | 2 665 | 2 367 (89) | 2 642 | 2 331 (88) |
|                  | Pentavalent | Mali | 3 627 | 498 (14) | 3 623 | 479 (13) | 3 629 | 464 (13) | 3 629 | 454 (13) |
|                  | Pentavalent | Namibia | 893 | 855 (96) | 934 | 849 (91) | 971 | 835 (86) | 969 | 834 (86) |
|                  | Pentavalent | Niger | 1 504 | 1 155 (77) | 1 560 | 1 113 (71) | 1 693 | 1 066 (63) | 1 694 | 1 062 (63) |
|                  | Pentavalent | Rwanda | 3 030 | 2 417 (80) | 3 044 | 2 406 (79) | 3 063 | 2 375 (78) | 3 056 | 2 366 (77) |
|                  | Pentavalent | Senegal | 2 472 | 2 290 (93) | 2 463 | 2 240 (90) | 2 473 | 2 108 (85) | 2 467 | 2 098 (85) |
|                  | Pentavalent | Sierra Leone | 2 325 | 2087 (90) | 2 397 | 2 040 (85) | 2 666 | 1 909 (72) | 2 521 | 882 (35) |
|                  | Pentavalent | Zambia | 6 872 | 6 468 (94) | 6 917 | 6 307 (89) | 7 133 | 6 021 (84) | 7 105 | 5 929 (83) |
| Weeks 9, 13, 26  | Monovalent | Jordan | 3 645 | 3 620 (99) | 3 642 | 3 584 (98) | 3 646 | 3 567 (98) | 3 647 | 3 558 (98) |
|                  | Monovalent | Congo | 1 684 | 1 170 (69) | 1 841 | 1 142 (62) | 2 128 | 1 026 (48) | 2 118 | 1 017 (48) |
|                  | Monovalent | Burkina Faso | 3 823 | 3 450 (90) | 3 845 | 3 399 (88) | 3 945 | 3 352 (85) | 3 936 | 3 341 (85) |
| Weeks 13, 22     | Pentavalent | Egypt | 4 875 | 4 722 (97) | 4 655 | 4 424 (95) | 4 663 | 4 214 (90) | 4 559 | 4 083 (90) |
|                  | Pentavalent | Colombia | 9 036 | 8472 (94) | 9 101 | 8 335 (92) | 10 189 | 8 199 (80) | 9 910 | 6 576 (66) |
|                  | Pentavalent | Bolivia (Plurinational State of) | 4 846 | 4 668 (96) | 4 955 | 4 546 (92) | 5 126 | 4 338 (85) | 5 109 | 4 316 (84) |
|                  | Pentavalent | Dominican Republic | 1 797 | 1 441 (80) | 1 824 | 1 338 (73) | 1 997 | 1 228 (61) | 2 039 | 1 018 (50) |
|                  | Pentavalent | Guyana | 1 149 | 1 044 (91) | 1 170 | 1 049 (90) | 1 198 | 1 018 (85) | 1 183 | 1 004 (85) |
|                  | Pentavalent | Honduras | 6 561 | 6 521 (99) | 6 581 | 6 486 (99) | 6 631 | 6 448 (97) | 6 563 | 6 369 (97) |
|                  | Pentavalent | Peru | 5 576 | 4 260 (76) | 5 727 | 4 190 (73) | 5 962 | 4 080 (68) | 5 888 | 2 926 (50) |
| Weeks 13, 22     | Pentavalent | Zimbabwe | 2 503 | 1 842 (74) | 2 559 | 1 777 (69) | 2 654 | 1 682 (63) | 2 660 | 1 661 (62) |
| Overall (weighted counts) | N/A | 146 943 | 111 261 (76) | 149 432 | 108 229 (72) | 156 819 | 104 209 (66) | 155 798 | 98 655 (63) |

Notes: Data were extracted from the most recent demographic and health survey in each country (survey year range: 2005–2014). Denominators are weighted counts of the number of children and are based on children with vaccination dates or vaccinations marked as administered in the vaccination card but without dates. Denominators for individual vaccine doses vary due to the number of observations (children) reporting specific doses as not received and the number of children for whom doses were reported as received.

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*a* Schedule is the target weeks after birth to administer the first, second and third doses of vaccine.

*b* Vaccination coverage was categorized as complete if the child was recorded as fully immunized with at least three doses of monovalent or combination hepatitis B vaccine. Incomplete coverage was if any of the recommended doses was recorded as 0 (not given), irrespective of whether other doses were missing response items; for instance, if dose 1 and 2 were missing but dose 3 was recorded as 0 we considered the individual as incompletely vaccinated.

*c* Vaccination schedule in these countries includes a birth dose of hepatitis B vaccine (monovalent), i.e. four doses in total.

N/A: not applicable.
### Table 5. Time delays, in percentiles, in the receipt of doses of hepatitis B vaccine for children aged 12–60 months in 47 countries, by national hepatitis B vaccination schedule

| Vaccination schedule and vaccine type | Country or median for vaccination schedule | No. of children vaccinated | First dose | Delay percentiles, weeks | Third dose | Delay percentiles, weeks |
|--------------------------------------|--------------------------------------------|---------------------------|------------|--------------------------|------------|----------------------------|
|                                      | No. of children vaccinated | Delays 25th 50th 75th IQR | No. of children vaccinated | Delays 25th 50th 75th IQR |
| **Weeks 0, 4, 13**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Maldives                      | 2042                      | 0.1 0.3 1.0 0.9         | 2036                    | 5.9 7.9 11.9 6.0        |
|                                      | Republic of Moldova           | 1040                      | 0.0 0.0 0.1 0.1         | 1062                    | 0.6 2.3 5.6 5.0         |
| **Weeks 0, 4, 26**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Nigeria                       | 3661                      | 1.7 4.7 7.7 9.4        | 3043                    | 1.0 5.4 14.7 13.7       |
| **Weeks 0, 6, 14**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Armenia                       | 1 016                     | 0.1 0.3 0.6 0.4        | 943                     | 2.0 6.1 13.0 11.0       |
| **Weeks 0, 6, 26**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Azerbaijan                    | 760                       | 0.0 0.0 4.4 4.4        | 622                     | 0.9 3.1 10.1 9.3        |
|                                      | Tajikistan                    | 2981                      | 0.0 0.0 0.3 0.3        | 2750                    | −3.3 −1.1 3.0 6.3       |
|                                      | Median                        | 1541                      | 0.0 0.0 2.4 2.4        | 1499                    | −1.2 1.0 6.6 7.8        |
| **Weeks 0, 9, 17**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Kyrgyzstan                    | 2244                      | 0.0 0.1 0.1 0.1        | 2054                    | −6.1 −3.3 2.1 8.3       |
| **Weeks 0, 9, 22**                   |                               |                           |                         |                          |                         |
| Monovalent                           | Albania                       | 798                       | 0.1 0.1 0.3 0.2        | 758                     | 0.4 1.1 2.7 2.3         |
| **Weeks 4, 8, 12**                   |                               |                           |                         |                          |                         |
| Tetravalent                          | United Republic of Tanzania   | 3367                      | 0.9 2.3 5.1 4.3        | 3223                    | 2.4 5.6 11.9 9.4        |
|                                      | Uganda                        | 801                       | 2.7 4.1 7.9 5.2        | 700                     | 4.6 8.6 17.7 13.1       |
|                                      | Median                        | 2084                      | 1.8 3.2 6.5 4.7        | 1962                    | 3.5 7.1 14.8 11.3       |
| **Weeks 6, 10, 14**                  |                               |                           |                         |                          |                         |
| Monovalent                           | Bangladesh                    | 3583                      | 1.0 2.6 4.3 3.3        | 3428                    | 2.6 4.7 8.7 6.1         |
|                                      | Cameroon                      | 1745                      | 0.3 1.1 3.9 3.6        | 1607                    | 1.1 3.1 7.7 6.6         |
|                                      | Gabon                         | 793                       | 0.4 1.1 5.1 4.7        | 627                     | 1.9 4.7 13.0 11.1       |
|                                      | Lesotho                       | 739                       | 0.4 1.1 2.9 2.4        | 643                     | 2.0 3.7 7.9 5.9         |
|                                      | Pakistan                      | 560                       | 1.0 2.7 6.1 5.1        | 508                     | 3.1 5.9 13.4 10.3       |
|                                      | Swaziland                     | 1347                      | 0.1 0.4 1.3 1.2        | 1315                    | 0.7 1.7 4.6 3.9         |
|                                      | Timor-Leste                   | 1971                      | 0.4 3.0 7.6 7.1        | 1853                    | 2.6 6.1 12.9 10.3       |
|                                      | Benin                         | 2076                      | 0.1 1.0 3.4 3.3        | 1877                    | 1.3 4.0 9.4 8.1         |
| Tetravalent                          | Madagascar                    | 1993                      | 0.4 2.0 4.7 4.3        | 1891                    | 1.9 4.0 9.3 7.4         |
| Tetravalent                          | Mozambique                    | 5282                      | 2.7 4.0 7.7 5.0        | 4764                    | 4.6 9.3 19.3 14.7       |
| Pentavalent                          | Burundi                       | 1335                      | 0.6 1.1 2.6 2.0        | 1298                    | 2.0 3.4 6.6 4.6         |
| Pentavalent                          | Cambodia†                     | 2443                      | 0.6 0.9 2.7 2.1        | 2286                    | 1.6 3.0 6.9 5.3         |
| Pentavalent                          | Comoros                       | 1088                      | 0.4 1.1 4.0 3.6        | 1032                    | 2.0 5.0 13.6 11.6       |
| Pentavalent                          | Côte d’Ivoire                 | 1363                      | 0.6 2.0 5.6 5.0        | 1120                    | 2.9 5.9 14.3 11.4       |
| Pentavalent                          | Democratic Republic of the Congo | 914              | 0.3 1.7 5.0 4.7        | 780                     | 1.3 3.7 9.7 8.4         |
| Pentavalent                          | Ghana                         | 1587                      | 0.3 1.1 3.1 2.9        | 1539                    | 1.4 3.3 6.6 5.1         |
| Pentavalent                          | Kenya                         | 2413                      | 0.1 1.0 3.4 3.3        | 2302                    | 0.9 2.6 6.6 5.7         |
| Pentavalent                          | Liberia                       | 862                       | 0.4 1.7 5.0 4.6        | 749                     | 2.1 6.4 17.0 14.9       |
| Pentavalent                          | Malawi                        | 2341                      | 0.7 2.4 5.0 4.3        | 2309                    | 2.6 5.6 11.0 8.4        |
| Pentavalent                          | Mali                          | 309                       | 0.7 2.9 8.3 7.6        | 275                     | 3.9 7.3 19.4 15.6       |
| Pentavalent                          | Namibia                       | 814                       | 0.0 0.4 1.0 1.0        | 796                     | 0.6 1.4 3.9 3.3         |
| Pentavalent                          | Niger                         | 1148                      | 0.6 2.6 7.0 6.4        | 1062                    | 3.1 7.3 16.6 13.4       |
| Pentavalent                          | Rwanda                        | 2386                      | 0.4 1.0 2.3 1.9        | 2351                    | 1.1 2.4 4.4 3.3         |
| Pentavalent                          | Senegal                       | 2277                      | 0.6 1.7 4.7 4.1        | 2084                    | 2.1 5.3 11.1 9.0        |
| Pentavalent                          | Sierra Leoneb                 | 2072                      | 0.0 1.3 4.9 4.9        | 1891                    | 2.4 7.3 17.0 14.6       |

(continues...)
| Vaccination schedule and vaccine type | Country or median for vaccination schedule | First dose | Third dose | Delay percentiles, weeks | Delay percentiles, weeks |
|--------------------------------------|--------------------------------------------|------------|------------|--------------------------|--------------------------|
|                                      |                                            | No. of children vaccinated | No. of children vaccinated | 25th | 50th | 75th | IQR | 25th | 50th | 75th | IQR |
| Pentavalent                           | Zambia                                    | 6136       | 5697       | 0.4 | 2.0 | 5.4 | 5.0 | 2.4 | 6.3 | 15.0 | 12.6 |
|                                      | Median                                     | 1587       | 1573       | 0.4 | 1.5 | 4.7 | 4.2 | 2.0 | 4.7 | 10.4 | 8.4 |
|                                      | **Weeks 9, 13, 17**                        |            |            |            |            |            |            |            |            |            |
| Monovalent                            | Jordan                                    | 3598       | 3523       | 0.0 | 0.7 | 2.1 | 2.1 | 1.6 | 3.1 | 6.1 | 4.6 |
| Pentavalent                           | Congo                                      | 1155       | 1014       | −0.1 | 0.4 | 2.7 | 2.9 | 0.7 | 2.1 | 5.6 | 4.9 |
| Pentavalent                            | Burkina Faso                               | 3447       | 3350       | −0.4 | 0.4 | 2.4 | 2.9 | 0.7 | 2.7 | 6.4 | 5.7 |
| N/A                                   | Median                                     | 3447       | 3350       | −0.1 | 0.4 | 2.4 | 2.9 | 0.7 | 2.7 | 6.1 | 4.9 |
|                                      | **Weeks 9, 17, 26**                        |            |            |            |            |            |            |            |            |            |
| Monovalent                            | Egypt                                      | 4612       | 4093       | −0.3 | 0.1 | 0.9 | 1.2 | 0.3 | 0.9 | 2.3 | 2.0 |
| Monovalent                            | Colombia<sup>a</sup>                       | 8431       | 8161       | −0.1 | 0.3 | 2.1 | 2.3 | 0.4 | 1.7 | 6.1 | 5.7 |
| Pentavalent                           | Bolivia<sup>(Plurinational State of)</sup> | 4631       | 4292       | −0.1 | 1.0 | 4.3 | 4.4 | 0.4 | 3.0 | 10.0 | 9.6 |
| Pentavalent                            | Dominican Republic<sup>b</sup>             | 1434       | 1224       | −0.1 | 0.1 | 1.4 | 1.6 | 1.0 | 2.1 | 6.0 | 5.0 |
| Pentavalent                            | Guyana                                     | 1044       | 1018       | −0.1 | 1.0 | 3.6 | 3.7 | 1.1 | 3.3 | 8.1 | 7.0 |
| Pentavalent                            | Honduras                                   | 6516       | 6445       | −0.3 | 0.0 | 1.0 | 1.3 | 0.6 | 1.7 | 4.7 | 4.1 |
| Pentavalent                            | Peru<sup>b</sup>                           | 4225       | 4065       | −0.3 | 0.0 | 1.4 | 1.7 | 0.3 | 1.7 | 5.7 | 5.4 |
| N/A                                   | Median                                     | 4612       | 4093       | −0.1 | 0.1 | 1.4 | 1.7 | 0.4 | 1.7 | 6.0 | 5.4 |
|                                      | **Weeks 13, 17, 22**                       |            |            |            |            |            |            |            |            |            |
| Pentavalent                            | Zimbabwe                                   | 1246       | 1082       | 0.3 | 1.7 | 4.9 | 4.6 | 1.1 | 5.3 | 14.0 | 12.9 |

IQR: interquartile range; N/A: not applicable.

<sup>a</sup> Schedule is the target week after birth to administer the first, second and third doses of vaccine.

<sup>b</sup> Vaccination schedule in these countries includes a birth dose of hepatitis B vaccine (monovalent), i.e. four doses in total.

Notes: Data were extracted from the most recent demographic and health survey (survey year range: 2005–2014) in each country. Denominators are weighted. Delayed vaccination was vaccine dose received more than 4 weeks after the target week in the national vaccination schedule. Negative values indicate vaccination before the recommended target week; 0.0 indicates no delays.
Table 6. Descriptive characteristics of children aged 12–60 months included in the study on the association between vaccination schedules (vaccine type) and hepatitis B vaccination timing in 47 countries

| Characteristic                        | No. (%) of children |
|---------------------------------------|---------------------|
| **Child's sex**                       |                     |
| Male                                  | 105 351 (51)        |
| Female                                | 102 095 (49)        |
| **Residence**                         |                     |
| Urban                                 | 75 470 (36)         |
| Rural                                 | 131 976 (64)        |
| **Birth order**                       |                     |
| First child                           | 53 614 (26)         |
| Second or higher child                | 153 832 (74)        |
| **Place of delivery**                 |                     |
| Home                                  | 64 666 (31)         |
| Institution                           | 138 963 (67)        |
| Missing data                          | 3817 (2)            |
| **Mother’s education**                |                     |
| None                                  | 55 907 (27)         |
| Primary                               | 67 851 (33)         |
| Secondary or higher                   | 83 642 (40)         |
| Missing                               | 45 (< 1)            |
| **Mother’s marital status**           |                     |
| Unmarried                             | 55 614 (27)         |
| Married                               | 151 832 (73)        |
| **Wealth index**                      |                     |
| Poorest                               | 46 606 (22)         |
| Poor                                  | 44 791 (22)         |
| Medium                                | 42 917 (21)         |
| Rich                                  | 39 492 (19)         |
| Richest                               | 33 641 (16)         |
| **Family size, mean (95% CI)**        | 6.62 (6.57 to 6.67) |
| **Country income level**             |                     |
| Low                                   | 68 224 (33)         |
| Lower-middle                          | 103 415 (50)        |
| Upper-middle                          | 35 807 (17)         |
| **Total (weighted)**                  | 207 446 (100)       |
| **Population size (unweighted)**      | 211 643             |

CI: confidence interval.  
* Wealth index as an indicator of economic status of the household, categorized into five quintiles ranging from the poorest 20% to the richest 20%.  
* Country income level as per the World Bank.  
Notes: Missing observations (non-responses) were excluded from the analysis. Numbers are weighted counts.