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Coverage and determinants of full immunization coverage among children aged 12 to 59 months in Bangladesh

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Title: Coverage and determinants of full immunization coverage among children aged 12 to 59 months in Bangladesh

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Abstract

Objective To estimate the extent of full immunization coverage and to assess the factors associated with full immunization coverage using the nationally representative data of Bangladesh.

Settings Children aged 12-59 month in Bangladesh

Participant The socioeconomic characteristics and immunisation status of the children were obtained from the latest Bangladesh Demographic and Health Survey (BDHS). A cross-sectional survey was conducted, and Participants were randomly selected through a two-stage stratified sampling design. A total of 6,230 children were eligible and therefore included in the analysis. Multivariable logistic regression models were constructed to determine the significant influencing factors for full immunization coverage of children. Results were presented in terms of adjusted odds ratio (s) with 95% confidence intervals.

Results Among the total, about 86% of the children were found fully immunized. Coverage was highest in Rangpur division (92%) and lowest in Sylhet division (69.81%). Findings emphasized that full immunization coverage was significantly associated with parental education, age of the children, family size, woman autonomy, regional variation, and wealth quintiles. Children aged 48 to 59 months had the highest odds of being fully vaccinated (AOR=1.32; CI: 1.06 – 1.64; *p=0.013)*. Compare to the children from the poorest households, children from the richest households had higher likelihood of being fully immunized (AOR= 2.20; CI: 1.50 – 3.21; *p<0.001*).

Conclusions The findings of this study indicate significant variations of child immunization coverage across socio-economic and demographic factors. These findings will serve to inform and support innovative approach for immunization programs, and the introduction of relevant policies including regular monitoring and evaluation of immunization coverage particularly for performing regions so that the broader benefit of immunization program could be achieved to all strata of society.

Strengths and limitations of this study

- Our study investigated, for the first time, the full immunization coverage of across various regions in Bangladesh
- Multivariable logistic regression models were constructed to assess the potential factors with full immunization coverage
- The study results can be generalized at the country level because of its large sample size using latest the nationally representative demographic and health survey data of Bangladesh
- Due to nature of the study, there might be the potential effect of recall bias on our results cannot be ignored.
- The selection of variables included in this study also relied on the information available from the dataset.

BACKGROUND

Universal immunization program of children against six vaccine-preventable diseases (VPD) is recognized as one of the most cost-effective programs to diminish childhood mortalities and morbidities across the world.[1,2] Every year, vaccination against VPDs prevents debilitating illness and disability and saves millions of child lives globally.[3] Over the decades, remarkable improvement has been made toward the development of national immunization programs whilst the Extend Program on Immunization (EPI) of WHO has the major contribution to this success.[4] EPI was formally established in 1974 with the support of World Health Organization (WHO) with the goal of immunizing every child against six vaccine-preventable diseases (i.e., diphtheria, pertussis, tetanus, poliomyelitis, measles, and tuberculosis) by 1990.[5] Top priority was given to developing countries because of the higher prevalence, and inadequate service delivery for immunization in these settings.[4] The government of Bangladesh had initiated the EPI with the support of UNICEF and WHO through various outreach activities since 1979 with the overall objective to immunize all children by 1990 to prevent the VPDs and to eradicate poliomyelitis.[5,6] Later in 1995, National Immunization Day (NID) was initiated by EPI to sustain the polio-free status and also to increase the immunization coverage achieved through different operational activities.[6,7] The implementation of the EPI has already been shown to be a great success globally; such as, significant improvement in the child immunization coverage and eradicating poliomyelitis.[8] In the line of success, Bangladesh has experienced impressive improvements in increasing immunization coverage and a significant contribution to the reduction of childhood morbidity, mortality and also maintaining its polio-free status.[9,10] Despite the success of reducing child mortality rate by two-thirds since 1990, Bangladesh had experienced 0.1 million child deaths in 2016 [11] and enlisted in the top 10 countries with the highest childhood mortality globally.[12] A recent study revealed that almost half of this child deaths could be prevented by immunization only.[3,13] Therefore, greater focus on completion of all recommended EPI vaccines are needed to achieve further gains in decreasing childhood morbidities and mortalities.[7] Unquestionably, improving the utilization of routine immunization services, and easy access to all vaccines is the best option to improve the immunization coverage.

A number of studies reported findings on child vaccination, few of them generated evidence about the socio-demographic factors associated with fully-vaccination among children 12 to 59 months of age.[14–16] Furthermore, the available studies focused either specified geographical settings, age groups or ethnic groups rather than the nation-wide setting or identified the determinants of each antigen separately.[15–22] This study tried to capture the full immunization status using latest country representative Demographic and Health Survey (DHS) dataset. DHS provides a reliable information on individual-level immunization coverage as well as a range of factors that might influence immunization practices. As such, the objective of this study was to estimate the extent of fully immunization coverage and to investigate the determinants of full immunization using the nationally representative data of Bangladesh. Analysis of a nationally representative

dataset would be able to generate the current evidence of vaccination practices that could be useful for international comparison and will help to adopt the relevant immunization policies and priorities for betterment of child's health against vaccine preventable disease in Bangladesh.

METHODS

Data source

Secondary dataset extracted from the Bangladesh Demographic and Health Survey (BDHS) 2014 was used for this analysis. The survey was a nationally representative cross-sectional survey that provides up-to-date information on socio-demographic, maternal, and child health indications including individual-level vaccination coverage. Childhood immunization history was collected for all surviving children over last five years. Immunization data were collected based on the records from vaccine cards, and maternal recall in those cases when the mother was not able to show child health card or vaccination history was not available in the immunization card. Face-to-face interviews with the reproductive-age women (15-49 years) were conducted for collecting data using the structured questionnaire and based on the MEASURE DHS program model.[23] A two-stage stratified random sampling technique was used for this survey. This survey used the sampling frame provided by the Bangladesh Bureau of Statistics. Details about sampling technique, survey design, and quality control have been described elsewhere.[24] The survey was carried out during June to November 2014 by the experienced and trained data collection teams. All the DHS data are publicly accessible and were made available upon request by MEASURE DHS. Furthermore, approval was sought from and given by the MEASURE DHS program office to use this data set. According to the DHS, written informed consent was obtained from all participants before the interview.

Outcome variable

The outcome variable of the analysis was children's immunization status and categorized as fully immunized and unimmunized. Vaccination status was categorized as 'fully immunized' if the children had received doses of all the standard eight antigens; one dose of the vaccine against tuberculosis (BCG), three doses of pentavalent (DPT, Hib, and HepB), three doses of polio vaccine (OPV), and one dose of measles vaccines. Children aged 12 to 59 months of age were included in this analysis to capture the vaccination status of the children. Children younger than 12 months were excluded as they were not old enough to receive the full schedule of routine vaccines. Immunization histories for all vaccines were coded as dummy responses as 1 for fully immunized and 0 otherwise. In a small number of cases, where health cards were unavailable and mothers indicated that they did not know about their children's vaccination status was considered as "not fully immunized" since such responses reflect the negative response about immunization.[15]

Explanatory variables

Explanatory variables were selected based on the published literature, prior knowledge, and availability of variables in the BDHS 2014 dataset. Area of residence, administrative division, sex and age of children, birth order, family size, parental education, mass media exposure, household wealth index and mother's decision-making ability on both children and own health care matters were included as explanatory variables. In this analysis, categorization of continuous variables was done on the light of previous literature where child age was categorized into four groups at twelve months of interval, and maternal age was categorized into three groups (less than 20 years, 20-34 years and more than 34 years). Self-reported parental (both mother and father) educational attainment was used and categorized as "no education," "primary," "secondary," and "higher." No education refers to not attaining any formal education, primary was defined as completing grade 5, secondary as completing grade 10, and higher was defined as attaining more than grade 10. We utilized the predetermined wealth index category provided in the dataset where it was generated from selected household assets using principal component analysis (PCA) and classified into five groups as: "poorest," "poorer," "middle," "rich," and "richest." Moreover, both the decision-making ability of mothers for both children and own health care were categorized into four groups as "herself," "jointly with husband," "husband alone" and "other." Beside this, childbirth order, family size and access to mass media were also categorized and included as the explanatory variables in this analysis.

Statistical analysis

The original dataset comprised of 8,092 children aged 0 to 59 months of age and for our analysis 1,555 children were excluded as they were under 12 months of age and were not old enough to have received the full schedule of routine immunization. Moreover, 307 missing data on vaccination information were also excluded from the analysis, and finally, a total of 6,230 children were eligible and included in the analysis. A proper sampling weight was used in this analysis to make the sample more representative of the population at the national level. Descriptive statistics such as the frequency with percentage were executed to represent the background characteristics of study participants, and proportion with 95% confidence interval (CI) was used for presenting the coverage rate of fully vaccinated children. Multivariable logistic regression models were constructed to determine the significant influencing factors for fully vaccination with all the antigens and results were presented in terms of adjusted odds ratio (s) (AOR) with 95% confidence intervals (CI). Before the execution of a multivariate regression model, bivariate analysis was also conducted to trace out the significant factors and then these were retained for the regression models. Two separate logistic regression models; Model I and Model II were constructed to obtain unadjusted odds ratio and adjusted odds ratio (adjusted with other explanatory variables) and presented with 95% confidence interval (CI). Variance Inflation Factor (VIF) was calculated to detect multicollinearity in the model. Linktest command through

Stata/SE 13.0 indicated that the constructed model was well specified. Data cleaning, validation, and all statistical analyses were performed using Stata/SE 13.0 (Stata Corporation, College Station, TX, USA).

RESULTS

Descriptive statistics

Distribution of study participants across socio-demographic variables is presented in table 1. Among the total included children, about 86% were found as fully vaccinated. A greater portion of the participants was from the rural areas (74.68%) and from Dhaka division (35.11%). Participants were almost equally distributed by sex and age categories. Among the participants, 37.66% was the first-born child, and most of the children's families consisted of 4 to 6 members. Majority of the mothers (80.43%) were aged between 20 to 34 years. About 46% of the mothers and 30% of fathers had secondary level education. Less than half of the mothers (40.87%) had access to mass media, e.g., radio and television. Majority of mothers reported that they had the ability of decision-making for their own as well as their children's healthcare.

(Table 1 will be inserted here)

Vaccination coverage rate among study participants

The immunization coverage rate of study participants is also presented in table 1. Findings revealed that vaccination coverage was slightly higher in urban areas (88.5%) than the rural (85.11%) and highest in Rangpur division (91.48%) followed by Khulna (89.01%), Dhaka (88.81%) and the lowest in Sylhet division (69.81%). The immunization coverage across antigens are shown in Figure 1. Full immunization coverage was similar across sex and age categories of the children. However, first born child had slightly higher vaccine coverage rate (88.35%) than the other (87.66% for second and 81.59% for third or more birth order).

(Figure 1 will be inserted here)

Findings also found that vaccination coverage was the highest among the children whose parents had higher educational attainment (94.22% and 93.69% for higher educated mother and father respectively). Vaccine coverage rate was also higher among the children of mothers who have access to mass media. The fully-vaccination coverage was found to be increased as the economic status of the children's family increased (73.85% for the poorest to 93.16% for the richest quintile). It was observed from the analysis that vaccination coverage rate was higher among the children whose mother had the involvement in the decision-making ability for their own and also their children's healthcare. Among the participants, the overall coverage rate of BCG vaccine was the highest (97.08%) followed by OPV-1 (97.02%), Pentavalent-1 (96.57%), OPV-2 (95.78%) and Pentavalent-2 (95.35%) where the coverage of measles was the lowest (87.97%) (Figure 2). Furthermore, the coverage of each vaccine by urban and rural areas are also presented in the following figure 2.

(Figure 2 will be inserted here)

Associated factors for the vaccination coverage

Table 2 shows the potential factors those are associated with the full-immunization coverage among the children aged 12 to 59 months in terms of both the unadjusted (Model I) and adjusted (Model II) odds ratios. The analysis shows that several socio-demographic factors like administrative divisions, age of children, family size, parental education, wealth index, and child healthcare decision makers were associated with the full-immunization status in both models. From univariate analysis (Model I), we found that area of residence, childbirth order, access to mass media and mothers' healthcare decision maker were significant factors for fully-immunization. In model II (from multivariate analysis), no such association was observed when adjusted with all potential confounders. In model I, urban children were significantly 1.35 times more likely to be fully-vaccinated than the rural (CI: 1.13-1.60; *p=0.001*), and the 1st born child was significantly 1.71 times more likely to be fully-vaccinated than the child of third or more birth order (CI: 1.45-2.03; *p<0.000*). We observed that mothers of the children who had access to the mass media, and decision-making ability, had higher odds than the counterparts. Similarly, parental education and wealth status played a significant role for the full coverage.

In the adjusted model (model II), the likelihood of being fully vaccinated was significantly lower in Sylhet division than other the counterparts. We found that, the number of full immunized children were significantly higher in Rangpur division (AOR: 3.46; CI: 2.45-4.88; *p< 0.000*) followed by the children from Dhaka (AOR: 2.59; CI: 2.05-3.28; *p< 0.000*), Khulna (AOR: 2.33; CI: 1.62-3.33; *p< 0.000*) and Rajshahi (AOR: 1.96; CI: 1.46-2.64; *p< 0.000*) division. The odds of being full immunization differed across the age groups of the children. For instance, children aged 48 to 59 months had the highest odds of being fully vaccinated (AOR=1.32; CI: 1.06 – 1.64; *p=0.013*) compared to the children aged 12 to 23 months. Family size appeared as a significant factor for full immunization as medium households (4 to 6 members) often immunized more than counterpart (AOR=1.56; CI: 1.32 – 1.86). Findings also revealed that parental education was significantly associated with full-immunization. It was observed that, the odds of being full immunization were increased, as the educational attainment of parents increased; and the children from higher educated mother were significantly 1.96 (CI: 1.21 – 3.17; *p=0.006*) times more likely and the children of the higher educated father were 1.55 (CI: 1.05 – 2.29; *p=0.026*) times more likely to be fully vaccinated compared to the reference category (no education). Compare to the children from the poorest households, children from the richest households had the highest odds of being fully immunized (AOR= 2.20; CI: 1.50 – 3.21; *p<0.000*) followed by the middle wealth quintile (AOR= 1.78; CI: 1.37–2.30; *p<0.000*). Lowest odds were found among the children whose health care decision was made only by their father (AOR=0.69; CI: 0.51 – 0.92; *p=0.012*) compared to the children where children's healthcare decision were made by mothers.

(Table 2 will be inserted here)

DISCUSSION

Immunization against vaccine-preventable diseases through the Expanded Program on Immunization is one of the most cost-effective health investments by reducing child mortality, morbidity, and disability.[25] As consequences, Bangladesh has had a successful history of immunization and coverage is remarkably increased over the 10-year period 2004–2014. However, the coverage varies across different strata of the society and geographic locations. The present study examined the immunization coverage and determinants those have potential impact on full-immunization status.

We found that the overall full immunization coverage is impressive (86%) within South East Asia Region.[26] The underneath success is due to the nature of a pluralistic health system of Bangladesh where the public, private sector, and non-governmental organizations actively participate to deliver healthcare services. In addition, the introduction of systematic outreach approaches helped to increase accessibility to routine immunization where community health workers directly involved for delivering vaccines.[27] Further community mobilization and public awareness related programs also played significant role in generating demand for vaccine uptake.[28] Despite the success, vaccination coverage is not similar throughout the country, for instance, the full immunization coverage is high in Rangpur while still low coverage in Sylhet region. Our study showed that various factors such as parental education particularly mothers' education, age of the children, family size, regional variation, and wealth quintiles played a significant role for fully immunization coverage. The importance of parental education in improving child's health is universally recognized. Like many studies we found parental education appeared as a significant factor for childhood immunization.[15,29] This is due to their better understanding of the recommended immunization schedule than non-educated parents.[30] Further, educated parents are likely to be wealthier and able to have better access to health facilities and immunization services.[29] Like other studies in various settings, we observed that children of educated mothers are often fully immunized than non-educated mothers.[15,29,31] It is well established between the positive relationship of level of education and public health awareness. Therefore, community-based behavior change program such as immunization announcement through radio, television and using local drama and public announcement through miking (loud speaker) should be approached targeting uneducated mother for better understanding the beneficial role of immunization so that they encourage their children to vaccinated timely.

This study observed that the immunization coverage is highest for children aged 48 to 59 months than the counterpart. This is may be due to the mobility of the children as they come to the vaccination centre with any of the household member than younger children. However, such findings was not observed in other settings and found children of older age group often unimmunized.[15] Again, size of the family appeared as a significant factor of fully immunized children and those who belong to larger family size were more likely

to be unimmunized which is also similar to another study as if household size exceeds six members they become unimmunized.[15] This might also reflect the socioeconomic status of the households as in larger family consumed more resources which is troublesome for resource-poor families which has impact on their livelihoods. Therefore, policy should address the beneficial role of immunization especially for larger family size to increase the full immunization coverage. Wealth status of the household played a significant role on immunizing their children. Our results are in similar line with many earlier studies which had shown that there is a significant positive relationship between wealth index, and childhood immunization completion rates; the chance of being fully immunized children's is increased as wealth index of household increased.[15,29,31] The immunization services in Bangladesh are completely free of pay, however, the indirect cost of vaccination such as income loss and transportation cost might be associated with low demand for vaccination specially for poorest households.[32,33] Earlier study in Bangladesh indicated that along with free cost of vaccination, approximately US$ 3671 is required for vaccination as recipient cost during vaccination program.[34] From univariate analysis, we found that fully immunized coverage was better in urban children than rural like earlier studies.[15,35] This is due to better health services available in urban area compared to rural, however, such relationship was not observed in our multivariate analysis.[36]

Our study observed that child healthcare decision making by mothers contributed a significant role for fully immunization coverage and the child is more likely to be fully immunized if mother is the decision maker. This might be due to more consciousness of the mothers for their child's health than the fathers. Therefore, mothers' autonomy is essential for their child's immunization. Based on the findings, community-based behavior change program targeting parents might be helpful for developing conscious for their childhood immunization. However, an earlier study showed that if the parents jointly decide healthcare decision, their children are often fully immunized.[15] Thus, there is a need to disseminate information about women autonomy in making health care decisions about their children to increase the immunization coverage. Like many low and middle-income countries, we also observed that geographical disparities may contribute to the immunization coverage in Bangladesh.[5,37,38] Our study found that, children who lived in Sylhet region often unimmunized compared with other parts of the country. This is may be due to various supply side and demand side factors such as distances of health facilities and vaccination centres, fragile communication system in some remote areas, afraid of side effects of vaccines, religious conservatism, a low level of literacy and even the absent of mother in home during the time of vaccination and even lack of awareness about benefit of vaccination for their children.[39] Therefore, policy should target divisions with low immunization coverage with innovative immunization approach addressing both supply and demand side barriers. Households which are located away from or have difficulty in accessing immunization services, especially in hilly areas; arranging outreach or mobile immunization strategy can be useful. Further, use of mobile

phones may be important vehicles for tracking and improving immunization coverage in such rural hard to reach areas of Bangladesh.[40]

Strengths and limitations

The study has several limitations. The study was based on secondary data and immunization cards and mother's report as a source of information for their child's immunization status. Therefore, the potential effect of recall bias on our results cannot be ignored. Nonetheless, mother's report is considered a valid measure of coverage in the absence of a health card, especially in developing countries.[41] The explanatory variables were selected based on previous studies and relied on the information available from the dataset. Therefore, there might be some other potential predictors that might be influenced fully immunization which was not captured in this study. Despite limitations, the study results can be generalized at the country level because the study utilized data from the latest nationally representative household survey. Thus, our findings are still significant and relevant in drawing attention to the health policy makers for ensuring the benefit of vaccination for the betterment of child health.

CONCLUSION

Our results suggested that immunization coverage is suboptimal among antigens and across various regions of Bangladesh. Findings emphasized that full immunization status was significantly associated with parental education, the age of the children, family size, woman autonomy, regional variation, and wealth quintiles. The findings of this study will serve to inform and support innovative approach for immunization programs, and the introduction of relevant policies including regular monitoring and evaluation of immunization coverage particularly for low performing regions of Bangladesh and targeting various antigen so that the broader benefit of immunization program could be achieved to all strata of society.

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Contributors ARS and MS participated in the design of the study. ARS, MS, NA, RA performed the analysis and prepared the manuscript. ARS, RA, MS provided data analysis advice and revision of the manuscript. All authors read and approved the final manuscript.

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Ethics approval This study did not require ethical approval as it used unidentifiable secondary DHS data set. According to the DHS, written informed consent was obtained from mothers/caretakers on behalf of the children enrolled in the survey. The DHS data are publicly accessible and were made available to us upon

request by Measure DHS. No identifiable information was included in the dataset and no attempt was made to identify any individual interviewed in the survey.

Data sharing statement The electronic datasets analysed in this study are available for legitimate research purposes from the Measure DHS website.

References

1. World Health Organization (WHO). *Protecting people from Vaccine Preventable Diseases: Strategic Plan (2010-2013)*. (2013).
2. Andre, F. E. *et al.* Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bull. World Health Organ.* **86,** 140–146 (2008).
3. WHO, UNICEF & World Bank. *State of the World's Vaccine and Immunization, 3rd ed.* (2009).
4. Jamil, K., Bhuiya, A., Streatfield, K. & Chakrabarty, N. The immunization programme in Bangladesh: impressive gains in coverage, but gaps remain. *Health Policy Plan.* **14,** 49–58 (1999).
5. Keja, K., Chan, C., Hayden, G. & Henderson, R. Expanded programme on immunization. *World Heal. Stat. Q.* **41,** 59–63 (1988).
6. Quaiyum, M. *et al.* Research report. Impact of national immunization days on polio-related knowledge and practice of urban women in Bangladesh. *Health Policy and Planning* **12,** 363–371 (1997).
7. Sarkar, P. K., Sarker, N. K., Doulah, S. & Bari, T. I. A. Expanded Programme on Immunization in Bangladesh : A Success Story. *Bangladesh J. Child Heal.* **39,** 93–98 (2015).
8. World Health Organization (WHO). *Polio-free certification: WHO South-East Asia*
9. Sk, M. I. K., Sk, M. F., Kurlikar, P. R. & Chourase, M. Status and determinants of child immunisation coverage in three South Asian countries , India , Bangladesh and Nepal : Evidence from the Demographic and Health Survey. *Sri Lanka J. Child Heal.* **47,** 56–63 (2018).
10. Expanded Program on Immunization (EPI). *Bangladesh EPI Coverage Evaluation Survey 2016*. (2017).
11. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). *Levels & Trends in Child Mortality: Report 2017, Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation*. (2017).
12. Boulton, M. L., Carlson, B. F., Power, L. E. & Wagner, A. L. Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. *Int. J. Infect. Dis.* **69,** 35–40 (2018).
13. Liu, L. *et al.* Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: An updated systematic analysis. *Lancet* **385,** 430–440 (2015).
14. Rahman, M. & Obaida-Nasrin, S. Factors affecting acceptance of complete immunization coverage of children under five years in rural Bangladesh. *Salud Publica Mex.* **52,** 134–140 (2010).
15. Herliana, P. & Douiri, A. Determinants of immunisation coverage of children aged 12-59 months in Indonesia: A cross-sectional study. *BMJ Open* **7,** 1–14 (2017).
16. Oleribe, O., Kumar, V., Awosika-Olumo, A. & Taylor-Robinson, S. D. Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. *Pan Afr. Med.*

J. **26,** 1–14 (2017).

17. Meleko, A., Geremew, M. & Birhanu, F. Assessment of Child Immunization Coverage and Associated Factors with Full Vaccination among Children Aged 12–23 Months at Mizan Aman Town, Bench Maji Zone, Southwest Ethiopia. *Int. J. Pediatr.* **2017,** 1–11 (2017).

18. Sheikh, N. *et al.* Coverage , Timelines , and Determinants of Incomplete Immunization in Bangladesh. *Trop. Med. Infect. Dis.* **3,** 1–14 (2018).

19. Uddin, M. J. *et al.* Child immunization coverage in urban slums of Bangladesh: impact of an intervention package. *Health Policy Plan.* **25,** 50–60 (2010).

20. Rahman, A. *et al.* Equity and determinants of routine child immunisation programme among tribal and non-tribal populations in rural Tangail subdistrict, Bangladesh: a cohort study. *BMJ Open* **8,** e022634 (2018).

21. Adhikary, M., Haque, R. & Tanira, S. Determinants of child immunization under expanded programme on immunization (EPI) in a rural setting of Bangladesh. *J. Dhaka Med. Coll.* **22,** 201–206 (2013).

22. Nasrin Afzal, B. Z. Determinants and Status of Vaccination in Bangladesh. *Dhaka Univ.J.Sci.* **60,** 47–51 (2012).

23. Rutstein, S. O. & Rojas, G. *Guide to DHS statistics: Demographic and Health Surveys Methodology*. (2006).

24. National Institute of Population Research and Training (NIPORT), Mitra and Associates, and I. I. 2016. *Bangladesh Demographic and Health Survey 2014*. (2014).

25. WHO. World Health Organization. State of the world's vaccines and immunization. *World Heal. Organ. 3rd ed. Geneva* 1–13 (2009).

26. WHO. WHO South-East Asia:Expanded Programme on Immunization (EPI) REGIONAL FACT SHEET 2017. *World Heal. Organ.* **6,** 1–98 (2017).

27. Adams, A. M. *et al.* Bangladesh: Innovation for Universal Health Coverage 4: Explaining equity gains in child survival in Bangladesh: Scale, speed, and selectivity in health and development. *The Lancet* (2013). doi:10.1016/S0140-6736(13)62060-7

28. El Arifeen, S. *et al.* Community-based approaches and partnerships: Innovations in health-service delivery in Bangladesh. *The Lancet* (2013). doi:10.1016/S0140-6736(13)62149-2

29. Holipah, Maharani, A. & Kuroda, Y. Determinants of immunization status among 12- to 23-month-old children in Indonesia (2008-2013): A multilevel analysis. *BMC Public Health* **18,** 1–11 (2018).

30. Schoeps, A. *et al.* Socio-demographic determinants of timely adherence to BCG, Penta3, measles, and complete vaccination schedule in Burkina Faso. *Vaccine* (2013). doi:10.1016/j.vaccine.2013.10.063

31. Abadura, S. A., Lerebo, W. T., Kulkarni, U. & Mekonnen, Z. A. Individual and community level determinants of childhood full immunization in Ethiopia: A multilevel analysis Global health. *BMC Public Health* **15,** 1–10 (2015).

32. Mitchell, S. *et al.* Equity and vaccine uptake: a cross-sectional study of measles vaccination in Lasbela District, Pakistan. *BMC Int. Health Hum. Rights* (2009). doi:10.1186/1472-698X-9-S1-S7

33. Lanaspa, M. *et al.* The performance of the expanded programme on immunization in a rural area of Mozambique. *Acta Trop.* (2015). doi:10.1016/j.actatropica.2015.06.007

34. Sarker, A. R. *et al.* Estimating the cost of cholera-vaccine delivery from the societal point of view: A case of introduction of cholera vaccine in Bangladesh. *Vaccine* **33,** 4916–4921 (2015).

35. Shrivastwa, N., Gillespie, B. W., Kolenic, G. E., Lepkowski, J. M. & Boulton, M. L. Predictors of Vaccination in India for Children Aged 12-36 Months. *Am. J. Prev. Med.* (2015). doi:10.1016/j.amepre.2015.05.008

36. Fernandez, R., Rammohan, A. & Awofeso, N. Correlates of first dose of measles vaccination delivery and uptake in Indonesia. *Asian Pac. J. Trop. Med.* (2011). doi:10.1016/S1995-7645(11)60055-2

37. Clouston, S., Kidman, R. & Palermo, T. Social inequalities in vaccination uptake among children aged 0-59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. *Vaccine* (2014). doi:10.1016/j.vaccine.2014.04.030

38. Antai, D. Inequitable childhood immunization uptake in Nigeria: A multilevel analysis of individual and contextual determinants. *BMC Infect. Dis.* (2009). doi:10.1186/1471-2334-9-181

39. Uddin, M. J., Koehlmoos, T. P., Saha, N. C., Khan, I. A. & Shamsuzzaman. Child immunization coverage in rural hard-to-reach areas of Bangladesh. *Vaccine* **28,** 1221–1225 (2010).

40. Uddin, M. J. *et al.* Use of mobile phones for improving vaccination coverage among children living in rural hard-to-reach areas and urban streets of Bangladesh. *Vaccine* (2016). doi:10.1016/j.vaccine.2015.11.024

41. Langsten, R. & Hill, K. The accuracy of mothers' reports of child vaccination: evidence from rural Egypt. *Soc. Sci. Med.* (1998). doi:10.1016/S0277-9536(97)10049-1

Table 1: Sample distribution and fully immunization coverage of study participants (n=6,230)

Characteristics of Sample	Frequency (%)	Fully immunized % (95% CI)
Immunization status		
Unimmunized	874 (14.03)	
Fully immunized	5,356 (85.97)	
Area of residence		
Urban	1,577 (25.32)	88.50 (86.83, 89.98)
Rural	4,653 (74.68)	85.11 (84.06, 86.10)
Division		
Rajshahi	642 (10.30)	86.16 (83.26, 88.62)
Barisal	352 (5.65)	84.89 (80.75, 88.27)
Chittagong	1,336 (21.45)	85.38 (83.38, 87.18)
Dhaka	2,187 (35.11)	88.81 (87.42, 90.07)
Khulna	468 (7.51)	89.01 (85.84, 91.55)
Rangpur	624 (10.01)	91.48 (89.01, 93.43)
Sylhet	622 (9.98)	69.81 (66.08, 73.30)
Sex		
Male	3,236 (51.94)	85.57 (84.31, 86.73)
Female	2,994 (48.06)	86.40 (85.13, 87.58)
Age category (in months)		
12 - 23	1,630 (26.17)	83.97 (82.10, 85.67)
24 - 35	1,560 (25.04)	86.68 (84.90, 88.28)
36 - 47	1,529 (24.55)	86.63 (84.83, 88.24)
48 - 59	1,510 (24.24)	86.72 (84.91, 88.34)
Birth order		
1	2,346 (37.66)	88.35 (86.99, 89.59)
2	1,880 (30.18)	87.66 (86.09, 89.07)
>=3	2,003 (32.16)	81.59 (79.83, 83.22)
Mother's age		
< 20 years	690 (11.07)	86.85 (84.12, 89.18)
20 - 34 years	5,011 (80.43)	85.97 (84.98, 86.91)
35 years and more	529 (8.50)	84.75 (81.43, 87.57)
Family size (members)		
Small (<4)	772 (12.39)	86.35 (83.74, 88.59)
Medium (4 - 6)	3,609 (57.93)	87.88 (86.77, 88.90)
Large (>6)	1,849 (29.68)	82.08 (80.26, 83.76)
Mother's education		
No education	1,053 (16.91)	76.77 (74.13, 79.23)
Primary	1,740 (27.93)	81.17 (79.27, 82.94)
Secondary	2,870 (46.07)	90.62 (89.50, 91.64)
Higher	566 (9.09)	94.22 (91.97, 95.87)
Father's education		
No education	1,683 (27.02)	78.64 (76.61, 80.53)
Primary	1,843 (29.58)	84.84 (83.13, 86.41)
Secondary	1,857 (29.81)	90.21 (88.77, 91.48)
Higher	847 (13.60)	93.69 (91.83, 95.14)
Mass media access		
Yes	2,546 (40.87)	90.62 (89.42, 91.69)
No	3,684 (59.13)	82.75 (81.50, 83.94)
Wealth index		
Poorest	1,438 (23.08)	76.13 (73.85, 78.26)
Poorer	1,160 (18.62)	85.32 (83.16, 87.24)
Middle	1,184 (19.01)	89.07 (87.17, 90.73)
Richer	1,260 (20.23)	88.10 (86.20, 89.78)
Richest	1,187 (19.05)	93.16 (91.58, 94.46)

Child's healthcare decision maker		
Herself	934 (15.25)	88.08 (85.84, 90.01)
Jointly with husband	3,577 (58.37)	87.94 (86.84, 88.97)
Husband alone	1,249 (20.38)	79.08 (76.73, 81.25)
By other	368 (6.00)	88.30 (84.59, 91.21)
Mother's healthcare decision maker		
Herself	764 (12.46)	89.23 (86.82, 91.24)
Jointly with husband	3,208 (52.33)	87.91 (86.74, 88.99)
Husband alone	1,797 (29.32)	81.78 (79.93, 83.50)
By other	361 (5.88)	86.23 (82.27, 89.42)

Table 2: Unadjusted and adjusted effects of factors that are associated with full immunization coverage

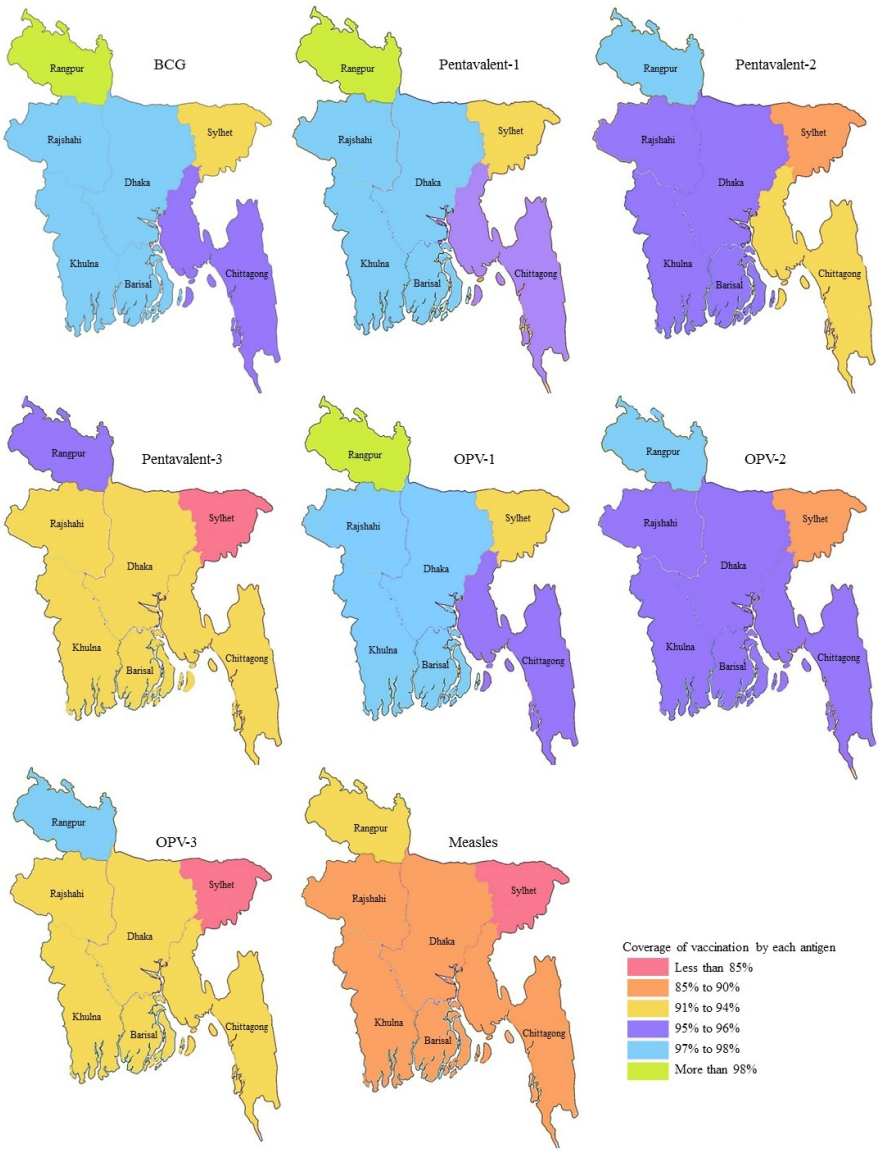
Characteristics	Model I		Model II	
	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Area of residence				
Urban	1.35 (1.13, 1.6)	**0.001**	0.83 (0.68, 1.03)	0.092
Rural	1.00		1.00	
Division				
Rajshahi	2.69 (2.03, 3.57)	**0.000**	1.96 (1.46, 2.64)	**0.000**
Barisal	2.43 (1.73, 3.41)	**0.000**	1.9 (1.33, 2.71)	**0.000**
Chittagong	2.53 (2.01, 3.18)	**0.000**	1.77 (1.39, 2.26)	**0.000**
Dhaka	3.43 (2.76, 4.26)	**0.000**	2.59 (2.05, 3.28)	**0.000**
Khulna	3.5 (2.5, 4.9)	**0.000**	2.33 (1.62, 3.33)	**0.000**
Rangpur	4.64 (3.34, 6.45)	**0.000**	3.46 (2.45, 4.88)	**0.000**
Sylhet	1.00		1.00	
Sex				
Male	0.93 (0.81, 1.08)	0.342	0.92 (0.79, 1.07)	0.294
Female	1.00		1.00	
Age categories (in months)				
12 - 23	1.00		1.00	
24 - 35	1.24 (1.02, 1.51)	**0.031**	1.26 (1.02, 1.56)	**0.033**
36 - 47	1.24 (1.01, 1.51)	**0.035**	1.22 (0.99, 1.52)	0.064
48 - 59	1.25 (1.02, 1.52)	**0.030**	1.32 (1.06, 1.64)	**0.013**
Birth order				
1	1.71 (1.45, 2.03)	**0.000**	1.16 (0.92, 1.46)	0.204
2	1.6 (1.34, 1.91)	**0.000**	1.18 (0.96, 1.45)	0.113
>=3	1.00		1.00	
Mothers age				
< 20 years	1.19 (0.86, 1.64)	0.295	0.75 (0.5, 1.12)	0.164
20 - 34 years	1.1 (0.86, 1.42)	0.443	0.71 (0.53, 0.95)	**0.021**
More than 35 years	1.00		1.00	
Family size (members)				
Small (<4)	1.38 (1.09, 1.75)	**0.008**	1.29 (0.97, 1.72)	0.074
Medium (4 - 6)	1.58 (1.36, 1.85)	**0.000**	1.56 (1.32, 1.86)	**0.000**
Large (>6)	1.00		1.00	
Mothers education				
None	1.00		1.00	
Primary	1.3 (1.08, 1.57)	**0.005**	1.21 (0.98, 1.49)	0.076
Secondary	2.92 (2.42, 3.54)	**0.000**	1.85 (1.45, 2.35)	**0.000**
Higher	4.93 (3.37, 7.22)	**0.000**	1.96 (1.21, 3.17)	**0.006**
Fathers education				
None	1.00		1.00	
Primary	1.52 (1.28, 1.81)	**0.000**	1.18 (0.97, 1.43)	0.099
Secondary	2.5 (2.07, 3.03)	**0.000**	1.35 (1.06, 1.71)	**0.014**
Higher	4.03 (2.98, 5.44)	**0.000**	1.55 (1.05, 2.29)	**0.026**
Wealth index				
Poorest	1.00		1.00	
Poorer	1.82 (1.49, 2.23)	**0.000**	1.41 (1.13, 1.75)	**0.002**
Middle	2.56 (2.05, 3.18)	**0.000**	1.78 (1.37, 2.3)	**0.000**
Richer	2.32 (1.88, 2.86)	**0.000**	1.38 (1.03, 1.84)	**0.030**
Richest	4.27 (3.31, 5.52)	**0.000**	2.2 (1.5, 3.21)	**0.000**
Access to mass media				
Yes	2.01 (1.72, 2.36)	**0.000**	1.15 (0.92, 1.43)	0.214
No	1.00		1.00	
Mothers healthcare decision maker				
Herself	1.00		1.00	

Jointly with husband	0.88 (0.68, 1.13)	0.312	0.89 (0.66, 1.2)	0.431
Husband alone	0.54 (0.42, 0.7)	**0.000**	0.77 (0.57, 1.06)	0.107
By other	0.76 (0.52, 1.1)	0.146	0.67 (0.42, 1.08)	0.098
Child healthcare decision maker				
Herself	1.00		1.00	
Jointly with husband	0.99 (0.79, 1.23)	0.910	1.06 (0.82, 1.39)	0.641
Husband alone	0.51 (0.4, 0.65)	**0.000**	0.69 (0.51, 0.92)	**0.012**
By other	1.02 (0.7, 1.49)	0.912	1.3 (0.81, 2.07)	0.277
Mean VIF			*3.07*	
LR chi2			*438.82*	
Prob > chi2			*0.000*	
Pseudo R2			*0.089*	
linear predicted value (_hat)			*0.000*	
linear predicted value squared (_hatsq)			*0.885*	

Abbreviations: OR, odds ratios; CI, confidence interval; LR, likelihood ratio; VIF, variance inflation factor;
Model I and II shows the unadjusted and adjusted association of variables with fully vaccination respectively

Figure 1: Full immunization coverage rate (BCG, PCV, OPV, and MR) by administrative divisions

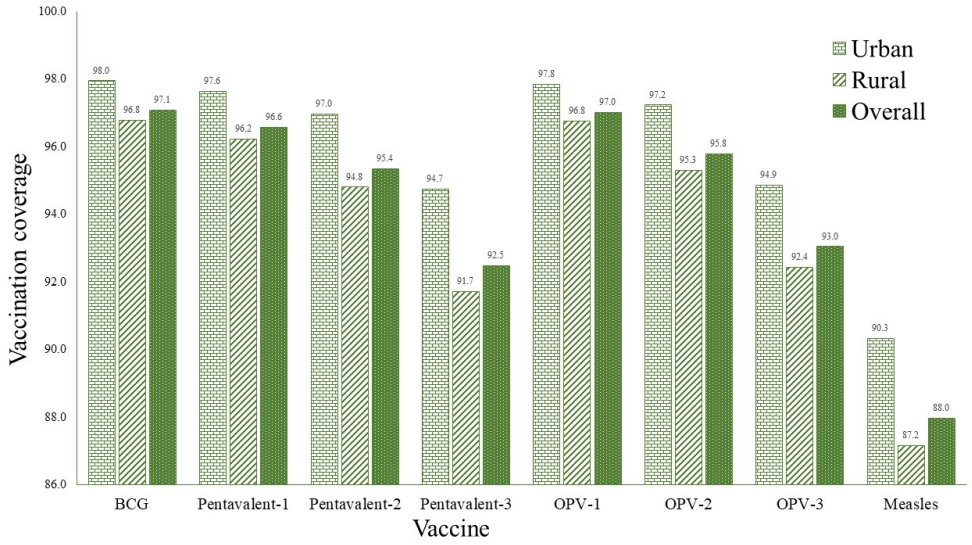
Figure 2: Distribution of immunization coverage across residence of respondent (urban vs. rural)



Map of Bangladesh by administrative division

Full immunization coverage rate (BCG, PCV, OPV, and MR) by administrative divisions

292x387mm (96 x 96 DPI)



Distribution of immunization coverage across residence of respondent (urban vs. rural)

338x190mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	*5*
Study size	10	Explain how the study size was arrived at	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	6,7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6,7
		(*b*) Report category boundaries when continuous variables were categorized	6,7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8,9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Coverage and factors associated with full immunization among children aged 12 to 59 months in Bangladesh: insights from the nationwide cross-sectional demographic and household survey

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Abstract

Objective To estimate the extent and factors associated with full immunization coverage among children aged 12 to 59 months in Bangladesh.

Study design This is a cross-sectional study, with the secondary dataset from Bangladesh Demographic and Health Survey. Vaccination status was categorized as 'fully immunized' if the children had received the eight recommended vaccine doses. Multivariable logistic regression models were constructed to determine the significant influencing factors of full immunization. Results were presented in terms of adjusted odds ratios with 95% confidence intervals.

Settings The study was conducted in Bangladesh.

Participant Children aged 12 to 59 months were the study participants. A total of 6,230 children were eligible and were therefore included in the analysis.

Results About 86% (n=5,356) of the children were fully immunized. BCG has the highest coverage rate (97.1%) followed by OPV 1 (97%) and Pentavalent 1 (96.6%), where the lowest coverage rate was by measles vaccine (88%). Coverage was higher in urban areas (88.5%) when compared to rural ones (85.1%). Full immunization coverage was significantly higher among children who lived in the Rangpur division (AOR=3.46; CI: 2.45-4.88), were 48 to 59 months old (AOR=1.32; CI:1.06-1.64), lived in a medium size family (AOR=1.56; CI:1.32-1.86), had parents with a higher level of education (AOR=1.96; CI:1.21-3.17 and AOR=1.55; CI:1.05-2.29) and belonged to the richest families (AOR=2.2; CI:1.5-3.21). However, the likelihood of being partially or unimmunized was higher among children who had the father as their sole healthcare decision maker (AOR=0.69; CI:0.51-0.92).

Conclusions There were significant variations of child immunization coverage across socio-economic and demographic factors. These findings will inform innovative approaches for immunization programs, and the introduction of relevant policies, including regular monitoring and evaluation of immunization coverage - particularly for performing regions, so that the broader benefit of immunization programs can be achieved in all strata of society.

Strengths and limitations of this study

- Our study did a pioneer investigation of full immunization coverage across various regions in Bangladesh using the latest nationwide demography and health survey dataset
- Multivariable logistic regression models were constructed to assess with the potential factors associated with full immunization coverage
- The study results can be generalized at the country level because of its large sample size and using the latest nationally representative demographic and health survey data of Bangladesh
- Due to nature of the study, the possibility of a recall bias with our results cannot be ignored.

BACKGROUND

Universal immunization program of children against vaccine-preventable diseases (VPD) has been recognized as one of the most cost-effective programs to diminish childhood mortalities and morbidities across the world.[1,2] Every year, vaccination against VPDs prevents debilitating illness and disability, saving millions of young lives globally.[3] Over the decades, remarkable improvements have been made toward the development of national immunization programs, with the Expanded Program on Immunization (EPI) being a major contribution to this success.[4] EPI was formally established in 1974, with the support of World Health Organization (WHO), with the goal of immunizing every child against six vaccine-preventable diseases (i.e., diphtheria, pertussis, tetanus, poliomyelitis, measles, and tuberculosis) by 1990.[5] The utmost priority was given to developing countries because of the higher prevalence and inadequate service delivery for immunization within these settings.[4] The government of Bangladesh had initiated the EPI with the support of UNICEF and WHO through various outreach activities from 1979, with the overall objective to immunize all children by 1990 to prevent the VPDs and to eradicate poliomyelitis.[5,6] Later, in 1995, National Immunization Day (NID) was initiated by EPI to sustain the polio-free status and also to increase the immunization coverage that was achieved through different operational activities.[6,7] The implementation of the EPI has already been shown to be a great success globally. This can be seen through the significant improvement in child immunization coverage and the eradication of poliomyelitis.[8] In the line of success, Bangladesh has experienced impressive improvements in increasing immunization coverage and a significant contribution to the reduction of childhood morbidity, mortality and also maintaining its polio-free status.[9,10] Despite the success in reducing the child mortality rate by two-thirds since 1990, Bangladesh recorded 0.1 million child deaths in 2016 [11] and was among the top 10 countries that had the highest childhood mortality globally.[12] A recent study revealed that almost half of this deaths could be prevented through immunization alone.[3,13] Therefore, a greater focus on completion of all recommended EPI vaccines are needed to further achieve gains in decreasing childhood morbidities and mortalities.[7] Unquestionably, improving the utilization of routine immunization services, and easy access to all vaccines is the best option to improve the immunization coverage.

Although the number of studies have reported findings on child immunization, few of them have generated evidence about the socio-demographic factors associated with full vaccination among children aged 12 to 59 months.[14–16] Furthermore, available studies have either focused on specified geographical settings, age groups or ethnic groups rather than the nationwide setting, and have not identified the determinants of individual vaccines separately.[15–22] This study thus sought to capture the full immunization status using the latest country representative Demographic and Health Survey (DHS) dataset. The DHS provides reliable information on individual-level immunization coverage, as well as a range of factors that might influence immunization practices. As such, the objective of this study was to estimate the extent of full immunization

coverage and to investigate the determinants of full immunization using the nationally representative data of Bangladesh. Analysis of a nationally representative dataset would thus allow for a generation of the current evidence of vaccination practices that could be useful for international comparison and will help in implementing the relevant immunization policies and priorities for the betterment of the child's health against vaccine-preventable diseases in Bangladesh.

METHODS

Study design and population

This study was based on a secondary analysis of the latest Bangladesh Demographic and Health Survey (DHS) 2014 dataset. The DHS is a nationally representative cross-sectional survey which uses a two-stage stratified sampling design to cover the data of the entire country. This survey was carried out for 6 months, from June 2014 to November 2014. The BDHS-2014 used three types of questionnaires: household questionnaire, woman's questionnaire, and community questionnaire. Through the women's questionnaire, up-to-date information on socio-demographic, maternal, and child health indications including individual-level vaccination coverage were collected. Participants of this study were children aged between 1 to 5 years. Childhood immunization history was collected for all surviving children over the last five years. Immunization data were collected based on the records of vaccine cards, and maternal recall in those cases where the mother was not able to show the child health card or vaccination history was not available in the immunization card. Face-to-face interviews with reproductive-age women (15-49 years) were conducted for the collection of data using the structured questionnaire and based on the MEASURE DHS program model.[23] A two-stage stratified random sampling technique was used for this survey. This survey used the sampling frame provided by the Bangladesh Bureau of Statistics. Details about sampling technique, survey design, and quality control have been described elsewhere.[24] All the DHS data was publicly accessible and were made available upon request by the MEASURE DHS. Furthermore, approval was sought from and given by the MEASURE DHS program office in the use of this data set for this specific study. According to the DHS, written informed consent was obtained from all participants prior to the interviews.

Outcome variable

The outcome variable of the analysis was the children's immunization status and categorized as fully immunized and partially/unimmunized. Vaccination status was categorized as 'fully immunized' if the children had received doses of all the eight recommended vaccines; one dose of the vaccine against tuberculosis (BCG), three doses of pentavalent (DPT, Hib, and HepB), three doses of polio vaccine (OPV), and one dose of measles vaccines.[24] Children aged 12 to 59 months of age were included in this analysis to capture the vaccination status of the children. Children younger than 12 months of age were excluded as they were not old enough to receive the full schedule of the routine vaccines. The WHO recommended

vaccination schedule for Bangladesh [25] is presented in table 1. Immunization histories for all vaccines were coded as dummy responses, with 1 for fully immunized and 0 otherwise. In a small number of cases, the immunization cards were not available, and mothers responded with "don't know" while asked about their children's vaccination status on certain vaccines. In that cases, the vaccination status of children was considered as "not fully immunized" since such responses reflect a negative response regarding immunization.[15]

Explanatory variables

Explanatory variables were selected based on the published literature, prior knowledge, and availability of variables in the BDHS 2014 dataset. Area of residence, administrative division, sex and age of children, birth order, family size, parental education, mass media exposure, household wealth index and the mother's decision-making ability for both the children and their own healthcare matters were included as explanatory variables. In this analysis, the categorization of continuous variables was done in light of previous literature where the child's age was categorized into four groups at twelve-month intervals, and maternal age was categorized into three groups (less than 20 years, 20-34 years and more than 34 years). Self-reported parental (both mother and father) educational attainment was used and categorized as "no education," "primary," "secondary," and "higher." No education refers to there not having any formal education, with primary was defined as completing grade 5, secondary as completing grade 10, and higher was defined as attaining more than grade 10. Family size was determined by the number of family members who lived together in a household, and defined by the BDHS. Family size was categorized on the basis of other published literature and categorized as "small", "medium" and "large". A "Small" family size refers to the family consisting of less than 4 members, "medium" as 4 to 6 members and "large" if the family member exceeds 6 members. Mass media access was categorized as "Yes" if the family had access to televisions and radios and "No" otherwise. We utilized the predetermined wealth index category provided in the dataset generated from selected household assets using principal component analysis (PCA) and classified it into five groups, namely: "poorest," "poorer," "middle," "rich," and "richest." Moreover, both the decision-making ability of the mothers for both their children and personal healthcare were categorized into four groups as "herself," "jointly with husband," "husband alone" and "other."

Statistical analysis

The original dataset comprised of 8,092 children, aged 0 to 59 months of age. In the case of our analysis, 1,555 children were excluded as they were under the age of 12 months and were not old enough to have received the full schedule of routine immunization. Moreover, 307 cases of missing data were present, and these were cases where no information were present (no responses, neither "yes", "no" nor "don't know") on vaccination information, and thus also excluded from the analysis. Finally, a total of 6,230 children were

eligible and included in the analysis. A proper sampling weight was used in this analysis to make the sample more representative of the population at the national level. Descriptive statistics, such as the frequency with percentages, were executed to represent the background characteristics of study participants, and a proportion with 95% confidence interval (CI) was used for presenting the coverage rate of fully vaccinated children. The association between each independent variable and the full vaccination uptake was investigated using a univariate analysis. Multivariable logistic regression that adjusted for all the selected independent variables was also constructed to determine the significant influencing factors for fully vaccination and results were presented in terms of adjusted odds ratio(s) with a 95% confidence intervals (CI). Before the execution of a multivariate regression model, a bivariate analysis was conducted to trace out the significant factors for full immunization. Variables significant at p value ≤0.05 were included in the multivariate logistic regression analysis. Variance Inflation Factor (VIF) was calculated to detect any multicollinearity in the model. The low value of average VIF (3.07) confirms no notable multicollinearity among variables. Linktest command through Stata/SE 13.0 indicated that the constructed model was well specified where the Hosmer-Lemeshow test statistics of goodness-of-fit indicates the acceptance of the model. Data cleaning, validation, and all statistical analyses were performed using Stata /SE 13.0 (Stata Corporation, College Station, TX, USA).

Patient and public involvement

No patients were involved in developing the research question, outcome measure, and design of the study. We are unable to disseminate the results of the research directly to study participants

RESULTS

Descriptive statistics

Distribution of study participants across the socio-demographic variables is presented in table 2. The proportion of full vaccination was 86% (n=5,356). Among the participants, 74.7% (n=4,653) were from rural areas and 35.1% were from the Dhaka division. Participants were almost equally distributed by sex and age categories. Among the participants, 37.7% was the first-born child, and most of the children's families (57.9%, n=3,609) consisted of 4 to 6 members. Majority of the mothers (80.4%) were aged between 20 to 34 years. 46.1% of the mothers and 29.8% of fathers had secondary level education. Less than half of the mothers (40.9%) had access to mass media, e.g., radio and television. In addition, a majority of the mothers reported that they had the capacity for decision-making with regards to both their own as well as their children's healthcare.

Vaccination coverage rate among study participants

The immunization coverage rate of study participants is also presented in table 2. Findings revealed that vaccination coverage was slightly higher in urban areas (88.5%) as compared to rural areas (85.1%) and was found to be the highest in the Rangpur division (91.5%) followed by Khulna (89%), Dhaka (88.8%) and the lowest in Sylhet division (69.8%). The immunization coverage across individual vaccines are shown in Figure 1. Full immunization coverage was similar across sex and age categories of the children. However, first born child had slightly higher vaccine coverage rates (88.4%) than the other (87.7% for second and 81.6% for third or more birth order).

Immunization coverage was the highest among children whose parents had higher educational attainment (94.2% and 93.7% for higher educated mother and father, respectively). Vaccine coverage rate was also higher among the children of mothers who have access to mass media. Full vaccination coverage was found to increase in accordance with a higher economic status of the children's family (73.9% for the poorest to 93.2% for the richest quintile). Immunization coverage rate was higher among the children whose mother had her own healthcare decision-making ability, including that of her children's healthcare. The overall coverage rate of BCG vaccine was the highest (97.1%) followed by OPV-1 (97%), Pentavalent-1 (96.6%), OPV-2 (95.8%) and Pentavalent-2 (95.4%) where the coverage of measles was the lowest (88%) (Figure 2). Furthermore, the coverage of each vaccine by urban and rural areas is also presented in the following figure 2.

Factors associated with full immunization coverage

Table 3 shows factors associated with the full-immunization coverage among children aged 12 to 59 months in terms of both unadjusted and adjusted odds ratios. The analysis shows that several socio-demographic factors, like administrative divisions, age of children, family size, parental education, wealth index, and child healthcare decision makers were associated with the full-immunization status in both models. From the univariate analysis, we found that area of residence, childbirth order, access to mass media and mothers' healthcare decision maker were significant factors for fully-immunization. Urban children were significantly 1.35 times more likely to be fully-vaccinated than rural ones (CI: 1.13-1.60; $p=0.001$), and the 1st born child was 1.71 times more likely to be fully-vaccinated than the child of third or more birth order (CI: 1.45-2.03; $p<0.001$). We also observed that mothers of the children who had access to the mass media had higher odds than their counterparts (OR= 2.01; CI: 1.72-2.36; $p< 0.001$). Similarly, parental education and wealth status played a significant role for full coverage in cases where children of higher educated mother and father were a significant 4.93 times (CI: 3.37-7.22) and 4.03 times (CI: 2.98-5.44) more likely to be vaccinated than children of uneducated mothers.

In the adjusted model, the likelihood of being fully vaccinated was significantly lower in the Sylhet division than other regions. We found that the number of full immunized children was significantly higher in Rangpur

division (AOR: 3.46; CI: 2.45-4.88; *p< 0.001*) followed by the children from Dhaka (AOR: 2.59; CI: 2.05-3.28; *p< 0.001*), Khulna (AOR: 2.33; CI: 1.62-3.33; *p< 0.001*) and Rajshahi (AOR: 1.96; CI: 1.46-2.64; *p< 0.001*) division. The odds of full immunization differed across the age groups of the children. For instance, children aged 48 to 59 months had the highest odds of being fully vaccinated (AOR=1.32; CI: 1.06 – 1.64; *p=0.013*) compared to children aged 12 to 23 months. Family size also appeared to be a significant factor for full immunization as medium households (4 to 6 members) often immunized more than their counterpart (AOR=1.56; CI: 1.32–1.86). The findings also revealed that parental education was significantly associated with full-immunization. It was observed that the odds of being full immunization were increased as the educational attainment of parents increased; and that children from higher educated mother (AOR=1.96; CI: 1.21 – 3.17; *p=0.006*) and higher educated father (AOR=1.55; CI: 1.05 – 2.29; *p=0.026*) were more likely to be full vaccinated compared to those with uneducated parents. Children from the richest households had the highest odds of being fully immunized (AOR= 2.20; CI: 1.50 – 3.21; *p<0.001*) followed by the middle wealth quintile (AOR= 1.78; CI: 1.37–2.30; *p<0.001*). The lowest odds were found among the children whose health care decision was made only by their father (AOR=0.69; CI: 0.51 – 0.92; *p=0.012*) compared to children with healthcare decisions that were made by the mothers.

DISCUSSION

The present study examined the immunization coverage and determinants of full-immunization status. We found that the overall full immunization coverage is impressive (86%) within South East Asia Region.[26] The underlying success is due to the nature of a pluralistic health system of Bangladesh, where the public, private sector, and non-governmental organizations actively participate to deliver healthcare services. In addition, the introduction of systematic outreach approaches helped to increase accessibility to routine immunization where community health workers are directly involved in delivering vaccines.[27] Further community mobilization and public awareness related programs have also played a significant role in generating demand for vaccine uptake.[28]

Despite the success, immunization coverage is not similar throughout the country. For instance, the full immunization coverage is high in Rangpur while still showing low coverage in the Sylhet region. Our study showed that various factors, such as parental education particularly mothers' education, age of the children, family size, regional variation, and wealth quintiles played a significant role for fully immunization coverage. The importance of parental education in improving child's health is universally recognized. As earlier studies on childhood vaccination in Indonesia have shown, we found that parental education appeared to be a significant factor for childhood immunization.[15,29] This is due to their better understanding of the recommended immunization schedule than non-educated parents.[30] Furthermore, educated parents are likely to be wealthier and have better access to health facilities and immunization services.[29] Like other studies in

various settings, we observed that children of educated mothers were often fully immunized when compared to non-educated mothers.[15,29,31] It is well established that there is a positive relationship between level of education and public health awareness. Therefore, community-based behaviour changes programs, such as immunization announcement through radio, television and using local drama and public announcement through miking (loud speaker), should be approached to target uneducated mothers in order to provide a better understanding of the beneficial role of immunization so that they are encouraged to vaccinate their children in a timely fashion.

Unlike other studies, we observed higher immunization coverage rate among children aged 48 to 59 months, which indicates the poor performance of current immunization programs. Therefore, strong commitment would be necessary to increase the number of full immunization coverage.[15] Again, the size of the family appeared to be a significant factor of fully immunized children. Those who belonged to larger family size were more likely to be unimmunized. This is similar to the findings in other earlier studies conducted in Indonesia, Greece, and Angola, where it was also reported that children form larger family size were less likely to be fully immunized.[15,32,33] This might also reflect the socioeconomic status of the households as larger families consume more resources, which is troublesome for resource-poor families and would thus impact on their livelihoods. Therefore, policies should focus on awareness development, especially in targeting the larger family to increase the full immunization coverage. Wealth status of the household plays a significant role in the immunizing of their children. Our results are similar to many earlier studies which have shown that there is a significant positive relationship between wealth index, and childhood immunization completion rates; the chance of having fully immunized children increases in accordance with the wealth index of household.[15,29,31] While the immunization services in Bangladesh are completely free of charge, the indirect cost of vaccination, such as income loss and transportation cost might be associated with the low demand for vaccination specially for poorest households.[34,35] Children from urban areas have been reported to have better immunization status compared to their rural counterparts. This result confirmed previous findings where similar association was also reported.[15,36] This is due to better health services available in urban areas compared to the rural.[37]

Our study observed that child healthcare decision making by mothers also contributed, playing a significant role in immunization coverage, with the child more likely to be fully immunized if the mother was the decision maker. This might be due to more awareness of the mothers for their child's health than the fathers. Therefore, the mothers' autonomy is essential for their child's immunization. However, an earlier study showed that if the parents jointly decided on healthcare decision, their children were often fully immunized.[15] Thus, there is a need to disseminate information about women autonomy in making health care decisions about their children to increase immunization coverage. Based on the findings, community-based behaviour change program that target parents might be helpful for developing awareness for their childhood

immunization. Like many low and middle-income countries, we also observed that geographical disparities may contribute to the immunization coverage in Bangladesh.[15,38–40] Our study found that children who lived in Sylhet region were more often unimmunized when compared with other parts of the country. This is may be due to various supply side and demand side factors, such as the distance of health facilities and vaccination centres, fragile communication systems in some remote areas, a fear of the side effects of vaccines, religious conservatism, a low level of literacy, and even lack of awareness about the benefit of vaccination for their children.[40] Therefore, policy should target divisions with low immunization coverage with an innovative immunization approach that addressing both supply and demand side barriers. For instance, households which are located away from or have difficulty in accessing immunization services, especially in hilly areas might benefit from outreach or mobile immunization strategies. Furthermore, the use of mobile phones may be important vehicles for tracking and improving immunization coverage in these rural, hard to reach areas of Bangladesh.[41]

Strengths and limitations

The study has several limitations. The study was based on secondary data and immunization cards and mother's report as a source of information for their child's immunization status. Therefore, the potential of recall bias in our results cannot be ignored. Nonetheless, the mother's report is considered to be a valid measure of coverage in the absence of a health card, especially in developing countries.[42] The explanatory variables were selected based on previous studies and relied on the information available from the dataset. Therefore, there might be some other potential predictors that might be influenced by full immunization which was not captured in this study. Despite the limitations, the study results can be generalized at a country level because the study utilized data from the latest nationally representative household survey. Thus, our findings are still significant and relevant in drawing attention to the health policy makers in ensuring the benefit of vaccination for the betterment of child health.

CONCLUSION

Our results identified the presence of disparities for immunization coverage across regions and by types of vaccines in Bangladesh. Findings revealed that full immunization status was significantly associated with regional variation, the age of the children, maternal age, parental education, family size, woman autonomy for child healthcare, and wealth quintiles. Our study found that a large number of children from the Sylhet division, poor and larger family, and from lower parental education were not fully immunized. The study also identified that measles immunization coverage was the lowest among the eight recommended vaccines. Therefore, to achieve maximum success and prevent children from vaccine preventable diseases, it is mandatory to address the issues obstructing full vaccination. The findings of this study will serve to inform and support innovative approach for immunization programs, and the introduction of relevant policies,

including the regular monitoring and evaluation of immunization coverage particularly for low performing regions of Bangladesh and targeting various vaccines in order to allow the broader benefit of the immunization program to be achieved in all strata of society.

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Ethics approval This study did not require ethical approval as it used unidentifiable secondary DHS data set. According to the DHS, written informed consent was obtained from mothers/caretakers on behalf of the children enrolled in the survey. The DHS data are publicly accessible and were made available to us upon request by Measure DHS. No identifiable information was included in the dataset and no attempt was made to identify any individual interviewed in the survey.

Data sharing statement The electronic datasets analysed in this study are available for legitimate research purposes from the Measure DHS website.

References:

1. World Health Organization (WHO). *Protecting people from Vaccine Preventable Diseases: Strategic Plan (2010-2013)*. (2013).
2. Andre, F. E. *et al.* Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bull. World Health Organ.* **86**, 140–146 (2008).
3. WHO, UNICEF & World Bank. *State of the World's Vaccine and Immunization, 3rd ed.* (2009).
4. Jamil, K., Bhuiya, A., Streatfield, K. & Chakrabarty, N. The immunization programme in Bangladesh: impressive gains in coverage, but gaps remain. *Health Policy Plan.* **14**, 49–58 (1999).
5. Keja, K., Chan, C., Hayden, G. & Henderson, R. Expanded programme on immunization. *World Heal. Stat. Q.* **41**, 59–63 (1988).

6. Quaiyum, M. *et al.* Research report. Impact of national immunization days on polio-related knowledge and practice of urban women in Bangladesh. *Health Policy and Planning* **12**, 363–371 (1997).
7. Sarkar, P. K., Sarker, N. K., Doulah, S. & Bari, T. I. A. Expanded Programme on Immunization in Bangladesh : A Success Story. *Bangladesh J. Child Heal.* **39**, 93–98 (2015).
8. World Health Organization (WHO). *Polio-free certification: WHO South-East Asia*
9. Sk, M. I. K., Sk, M. F., Kurlikar, P. R. & Chourase, M. Status and determinants of child immunisation coverage in three South Asian countries , India , Bangladesh and Nepal : Evidence from the Demographic and Health Survey. *Sri Lanka J. Child Heal.* **47**, 56–63 (2018).
10. Expanded Program on Immunization (EPI). *Bangladesh EPI Coverage Evaluation Survey 2016*. (2017).
11. United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). *Levels & Trends in Child Mortality: Report 2017, Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation*. (2017).
12. Boulton, M. L., Carlson, B. F., Power, L. E. & Wagner, A. L. Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. *Int. J. Infect. Dis.* **69**, 35–40 (2018).
13. Liu, L. *et al.* Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: An updated systematic analysis. *Lancet* **385**, 430–440 (2015).
14. Rahman, M. & Obaida-Nasrin, S. Factors affecting acceptance of complete immunization coverage of children under five years in rural Bangladesh. *Salud Publica Mex.* **52**, 134–140 (2010).
15. Herliana, P. & Douiri, A. Determinants of immunisation coverage of children aged 12-59 months in Indonesia: A cross-sectional study. *BMJ Open* **7**, 1–14 (2017).
16. Oleribe, O., Kumar, V., Awosika-Olumo, A. & Taylor-Robinson, S. D. Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. *Pan Afr. Med. J.* **26**, 1–14 (2017).
17. Meleko, A., Geremew, M. & Birhanu, F. Assessment of Child Immunization Coverage and Associated Factors with Full Vaccination among Children Aged 12–23 Months at Mizan Aman Town, Bench Maji Zone, Southwest Ethiopia. *Int. J. Pediatr.* **2017**, 1–11 (2017).
18. Sheikh, N. *et al.* Coverage , Timelines , and Determinants of Incomplete Immunization in Bangladesh. *Trop. Med. Infect. Dis.* **3**, 1–14 (2018).
19. Uddin, M. J. *et al.* Child immunization coverage in urban slums of Bangladesh: impact of an intervention package. *Health Policy Plan.* **25**, 50–60 (2010).
20. Rahman, A. *et al.* Equity and determinants of routine child immunisation programme among tribal and non-tribal populations in rural Tangail subdistrict, Bangladesh: a cohort study. *BMJ Open* **8**,

e022634 (2018).

21. Adhikary, M., Haque, R. & Tanira, S. Determinants of child immunization under expanded programme on immunization (EPI) in a rural setting of Bangladesh. *J. Dhaka Med. Coll.* **22**, 201–206 (2013).
22. Nasrin Afzal, B. Z. Determinants and Status of Vaccination in Bangladesh. *Dhaka Univ.J.Sci.* **60**, 47–51 (2012).
23. Rutstein, S. O. & Rojas, G. *Guide to DHS statistics: Demographic and Health Surveys Methodology*. (2006).
24. National Institute of Population Research and Training (NIPORT), Mitra and Associates, and I. I. 2016. *Bangladesh Demographic and Health Survey 2014*. (2014).
25. Directorate General of Health Services (DGHS). EPI vaccine Schedule. *Ministry of Health and Family welfare* Available at: http://www.dghs.gov.bd/index.php/en/mis-docs/epi. (Accessed: 10th March 2019)
26. WHO. WHO South-East Asia:Expanded Programme on Immunization (EPI) REGIONAL FACT SHEET 2017. *World Heal. Organ.* **6**, 1–98 (2017).
27. Adams, A. M. *et al.* Bangladesh: Innovation for Universal Health Coverage 4: Explaining equity gains in child survival in Bangladesh: Scale, speed, and selectivity in health and development. *The Lancet* (2013). doi:10.1016/S0140-6736(13)62060-7
28. El Arifeen, S. *et al.* Community-based approaches and partnerships: Innovations in health-service delivery in Bangladesh. *The Lancet* (2013). doi:10.1016/S0140-6736(13)62149-2
29. Holipah, Maharani, A. & Kuroda, Y. Determinants of immunization status among 12- to 23-month-old children in Indonesia (2008-2013): A multilevel analysis. *BMC Public Health* **18**, 1–11 (2018).
30. Schoeps, A. *et al.* Socio-demographic determinants of timely adherence to BCG, Penta3, measles, and complete vaccination schedule in Burkina Faso. *Vaccine* (2013). doi:10.1016/j.vaccine.2013.10.063
31. Abadura, S. A., Lerebo, W. T., Kulkarni, U. & Mekonnen, Z. A. Individual and community level determinants of childhood full immunization in Ethiopia: A multilevel analysis Global health. *BMC Public Health* **15**, 1–10 (2015).
32. Danis, K., Georgakopoulou, T., Stavrou, T., Laggas, D. & Panagiotopoulos, T. Socioeconomic factors play a more important role in childhood vaccination coverage than parental perceptions: a cross-sectional study in Greece. *Vaccine* **28**, 1861–1869 (2010).
33. Oliveira, M. F. S. de, Martinez, E. Z. & Rocha, J. S. Y. Factors associated with vaccination coverage in children <5 years in Angola. *Rev. Saude Publica* **48**, 906–915 (2014).
34. Mitchell, S. *et al.* Equity and vaccine uptake: a cross-sectional study of measles vaccination in

Lasbela District, Pakistan. *BMC Int. Health Hum. Rights* (2009). doi:10.1186/1472-698X-9-S1-S7

35. Lanaspa, M. *et al.* The performance of the expanded programme on immunization in a rural area of Mozambique. *Acta Trop.* (2015). doi:10.1016/j.actatropica.2015.06.007
36. Shrivastwa, N., Gillespie, B. W., Kolenic, G. E., Lepkowski, J. M. & Boulton, M. L. Predictors of Vaccination in India for Children Aged 12-36 Months. *Am. J. Prev. Med.* (2015). doi:10.1016/j.amepre.2015.05.008
37. Fernandez, R., Rammohan, A. & Awofeso, N. Correlates of first dose of measles vaccination delivery and uptake in Indonesia. *Asian Pac. J. Trop. Med.* (2011). doi:10.1016/S1995-7645(11)60055-2
38. Clouston, S., Kidman, R. & Palermo, T. Social inequalities in vaccination uptake among children aged 0-59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. *Vaccine* (2014). doi:10.1016/j.vaccine.2014.04.030
39. Antai, D. Inequitable childhood immunization uptake in Nigeria: A multilevel analysis of individual and contextual determinants. *BMC Infect. Dis.* (2009). doi:10.1186/1471-2334-9-181
40. Uddin, M. J., Koehlmoos, T. P., Saha, N. C., Khan, I. A. & Shamsuzzaman. Child immunization coverage in rural hard-to-reach areas of Bangladesh. *Vaccine* **28**, 1221–1225 (2010).
41. Uddin, M. J. *et al.* Use of mobile phones for improving vaccination coverage among children living in rural hard-to-reach areas and urban streets of Bangladesh. *Vaccine* (2016). doi:10.1016/j.vaccine.2015.11.024
42. Langsten, R. & Hill, K. The accuracy of mothers' reports of child vaccination: evidence from rural Egypt. *Soc. Sci. Med.* (1998). doi:10.1016/S0277-9536(97)10049-1

Table 1. The Expanded Program on Immunizations (EPI) schedule in Bangladesh

Diseases	Name of vaccine	Recommended age
Childhood tuberculosis (TB)/poliomyelitis	BCG	At birth/0 day
Diphtheria/tetanus/pertussis/ Hepatitis B/Hib pneumonia and meningitis	Pentavalent 1	42 days
	Pentavalent 2	70 days
	Pentavalent 3	98 days
Poliomyelitis	OPV 1	42 days
	OPV 2	70 days
	OPV 3	98 days
Measles	Measles	273 days

Hib: Haemophilus influenzae type B, BCG: Bacille Calmette Guerin; OPV: Oral Polio Vaccine

Table 2: Baseline characteristics of study participants and their immunization coverage in Bangladesh, 2014, (n=6,230)

Characteristics of Sample	Frequency (%)	Fully immunized % (95% CI)
Immunization status		
Partially/Unimmunized	874 (14.03)	
Fully immunized	5,356 (85.97)	
Area of residence		
Urban	1,577 (25.32)	88.50 (86.83, 89.98)
Rural	4,653 (74.68)	85.11 (84.06, 86.10)
Division		
Rajshahi	642 (10.30)	86.16 (83.26, 88.62)
Barisal	352 (5.65)	84.89 (80.75, 88.27)
Chittagong	1,336 (21.45)	85.38 (83.38, 87.18)
Dhaka	2,187 (35.11)	88.81 (87.42, 90.07)
Khulna	468 (7.51)	89.01 (85.84, 91.55)
Rangpur	624 (10.01)	91.48 (89.01, 93.43)
Sylhet	622 (9.98)	69.81 (66.08, 73.30)
Sex		
Male	3,236 (51.94)	85.57 (84.31, 86.73)
Female	2,994 (48.06)	86.40 (85.13, 87.58)
Age category (in months)		
12 - 23	1,630 (26.17)	83.97 (82.10, 85.67)
24 - 35	1,560 (25.04)	86.68 (84.90, 88.28)
36 - 47	1,529 (24.55)	86.63 (84.83, 88.24)
48 - 59	1,510 (24.24)	86.72 (84.91, 88.34)
Birth order		
1	2,346 (37.66)	88.35 (86.99, 89.59)
2	1,880 (30.18)	87.66 (86.09, 89.07)
>=3	2,003 (32.16)	81.59 (79.83, 83.22)
Mother's age		
< 20 years	690 (11.07)	86.85 (84.12, 89.18)
20 - 34 years	5,011 (80.43)	85.97 (84.98, 86.91)
35 years and more	529 (8.50)	84.75 (81.43, 87.57)
Family size (members)		
Small (<4)	772 (12.39)	86.35 (83.74, 88.59)
Medium (4 - 6)	3,609 (57.93)	87.88 (86.77, 88.90)
Large (>6)	1,849 (29.68)	82.08 (80.26, 83.76)
Mother's education		
No education	1,053 (16.91)	76.77 (74.13, 79.23)

Primary	1,740 (27.93)	81.17 (79.27, 82.94)
Secondary	2,870 (46.07)	90.62 (89.50, 91.64)
Higher	566 (9.09)	94.22 (91.97, 95.87)
Father's education		
No education	1,683 (27.02)	78.64 (76.61, 80.53)
Primary	1,843 (29.58)	84.84 (83.13, 86.41)
Secondary	1,857 (29.81)	90.21 (88.77, 91.48)
Higher	847 (13.60)	93.69 (91.83, 95.14)
Mass media access		
Yes	2,546 (40.87)	90.62 (89.42, 91.69)
No	3,684 (59.13)	82.75 (81.50, 83.94)
Wealth index		
Poorest	1,438 (23.08)	76.13 (73.85, 78.26)
Poorer	1,160 (18.62)	85.32 (83.16, 87.24)
Middle	1,184 (19.01)	89.07 (87.17, 90.73)
Richer	1,260 (20.23)	88.10 (86.20, 89.78)
Richest	1,187 (19.05)	93.16 (91.58, 94.46)
Child's healthcare decision maker		
Herself	934 (15.25)	88.08 (85.84, 90.01)
Jointly with husband	3,577 (58.37)	87.94 (86.84, 88.97)
Husband alone	1,249 (20.38)	79.08 (76.73, 81.25)
By other	368 (6.00)	88.30 (84.59, 91.21)
Mother's healthcare decision maker		
Herself	764 (12.46)	89.23 (86.82, 91.24)
Jointly with husband	3,208 (52.33)	87.91 (86.74, 88.99)
Husband alone	1,797 (29.32)	81.78 (79.93, 83.50)
By other	361 (5.88)	86.23 (82.27, 89.42)

Table 3: Unadjusted and adjusted effects of factors that are associated with full immunization coverage

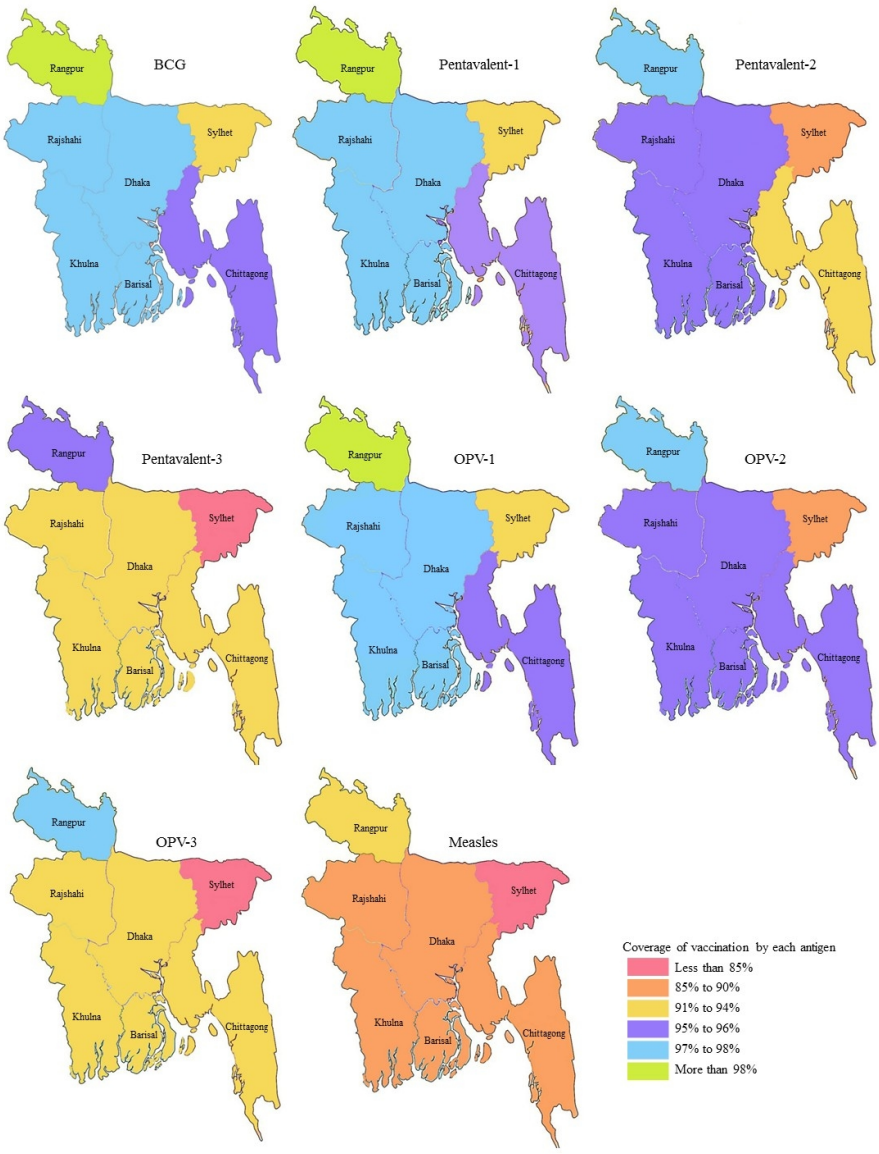
Characteristics	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Area of residence				
Urban	1.35 (1.13, 1.6)	**0.001**	0.83 (0.68, 1.03)	0.092
Rural	1.00		1.00	
Division				
Rajshahi	2.69 (2.03, 3.57)	**0.000**	1.96 (1.46, 2.64)	**0.000**
Barisal	2.43 (1.73, 3.41)	**0.000**	1.9 (1.33, 2.71)	**0.000**
Chittagong	2.53 (2.01, 3.18)	**0.000**	1.77 (1.39, 2.26)	**0.000**
Dhaka	3.43 (2.76, 4.26)	**0.000**	2.59 (2.05, 3.28)	**0.000**
Khulna	3.5 (2.5, 4.9)	**0.000**	2.33 (1.62, 3.33)	**0.000**
Rangpur	4.64 (3.34, 6.45)	**0.000**	3.46 (2.45, 4.88)	**0.000**
Sylhet	1.00		1.00	
Sex				
Male	0.93 (0.81, 1.08)	0.342	0.92 (0.79, 1.07)	0.294
Female	1.00		1.00	
Age categories (in months)				
12 - 23	1.00		1.00	
24 - 35	1.24 (1.02, 1.51)	**0.031**	1.26 (1.02, 1.56)	**0.033**
36 - 47	1.24 (1.01, 1.51)	**0.035**	1.22 (0.99, 1.52)	0.064
48 - 59	1.25 (1.02, 1.52)	**0.030**	1.32 (1.06, 1.64)	**0.013**
Birth order				
1	1.71 (1.45, 2.03)	**0.000**	1.16 (0.92, 1.46)	0.204
2	1.6 (1.34, 1.91)	**0.000**	1.18 (0.96, 1.45)	0.113
>=3	1.00		1.00	
Mothers age				
< 20 years	1.19 (0.86, 1.64)	0.295	0.75 (0.5, 1.12)	0.164
20 - 34 years	1.1 (0.86, 1.42)	0.443	0.71 (0.53, 0.95)	**0.021**
More than 35 years	1.00		1.00	
Family size (members)				
Small (<4)	1.38 (1.09, 1.75)	**0.008**	1.29 (0.97, 1.72)	0.074
Medium (4 - 6)	1.58 (1.36, 1.85)	**0.000**	1.56 (1.32, 1.86)	**0.000**
Large (>6)	1.00		1.00	
Mothers education				
No education	1.00		1.00	
Primary	1.3 (1.08, 1.57)	**0.005**	1.21 (0.98, 1.49)	0.076
Secondary	2.92 (2.42, 3.54)	**0.000**	1.85 (1.45, 2.35)	**0.000**
Higher	4.93 (3.37, 7.22)	**0.000**	1.96 (1.21, 3.17)	**0.006**
Fathers education				
No education	1.00		1.00	
Primary	1.52 (1.28, 1.81)	**0.000**	1.18 (0.97, 1.43)	0.099
Secondary	2.5 (2.07, 3.03)	**0.000**	1.35 (1.06, 1.71)	**0.014**
Higher	4.03 (2.98, 5.44)	**0.000**	1.55 (1.05, 2.29)	**0.026**
Wealth index				
Poorest	1.00		1.00	
Poorer	1.82 (1.49, 2.23)	**0.000**	1.41 (1.13, 1.75)	**0.002**
Middle	2.56 (2.05, 3.18)	**0.000**	1.78 (1.37, 2.3)	**0.000**
Richer	2.32 (1.88, 2.86)	**0.000**	1.38 (1.03, 1.84)	**0.030**
Richest	4.27 (3.31, 5.52)	**0.000**	2.2 (1.5, 3.21)	**0.000**
Access to mass media				
Yes	2.01 (1.72, 2.36)	**0.000**	1.15 (0.92, 1.43)	0.214
No	1.00		1.00	
Mothers healthcare decision maker				
Herself	1.00		1.00	
Jointly with husband	0.88 (0.68, 1.13)	0.312	0.89 (0.66, 1.2)	0.431

Husband alone	0.54 (0.42, 0.7)	**0.000**	0.77 (0.57, 1.06)	0.107
By other	0.76 (0.52, 1.1)	0.146	0.67 (0.42, 1.08)	0.098
Child healthcare decision maker				
Herself	1.00		1.00	
Jointly with husband	0.99 (0.79, 1.23)	0.910	1.06 (0.82, 1.39)	0.641
Husband alone	0.51 (0.4, 0.65)	**0.000**	0.69 (0.51, 0.92)	**0.012**
By other	1.02 (0.7, 1.49)	0.912	1.3 (0.81, 2.07)	0.277
Mean VIF			*3.07*	
LR chi²			*438.82*	
Prob > chi²			*0.000*	
Pseudo R²			*0.089*	
linear predicted value (_hat)			*0.000*	
linear predicted value squared (_hatsq)			*0.885*	
HL chi²(8)			*7.88*	
Prob > chi²			*0.4452*	

Abbreviations: OR, odds ratios; CI, confidence interval; LR, likelihood ratio; VIF, variance inflation factor; HL, Hosmer-Lemeshow

Figure 1: Coverage rate by individual vaccines (BCG, PCV, OPV, and MR) across administrative divisions in Bangladesh

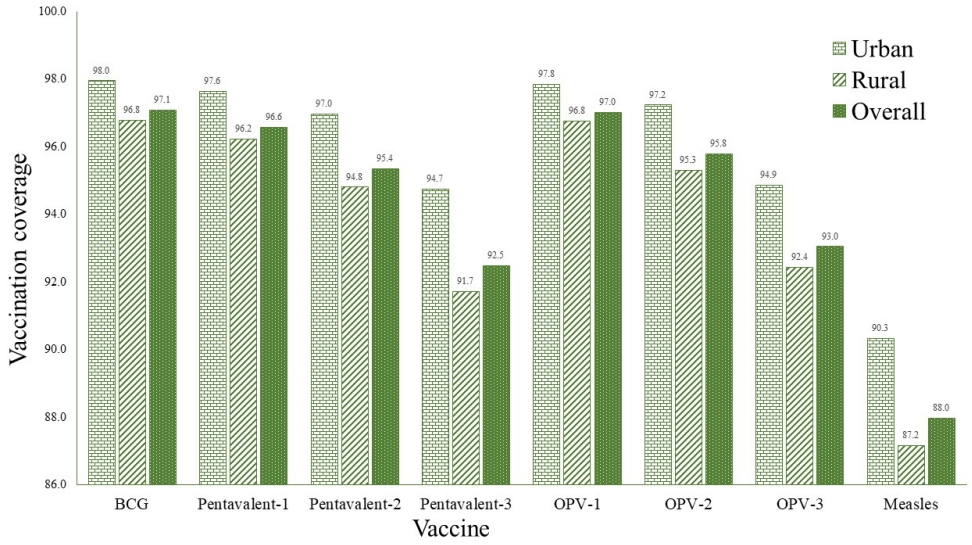
Figure 2: Coverage rate by individual vaccines across place of residence of respondents (urban vs. rural) in Bangladesh



Map of Bangladesh by administrative division

Coverage rate by individual vaccines (BCG, PCV, OPV, and MR) across administrative divisions in Bangladesh

292x387mm (96 x 96 DPI)



Coverage rate by individual vaccines across place of residence of respondents (urban vs. rural) in Bangladesh

338x190mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	*5*
Study size	10	Explain how the study size was arrived at	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	5
Outcome data	15*	Report numbers of outcome events or summary measures	6,7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6,7
		(*b*) Report category boundaries when continuous variables were categorized	6,7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8,9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Coverage and factors associated with full immunization among children aged 12 to 59 months in Bangladesh: insights from the nationwide cross-sectional demographic and health survey

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Title: Coverage and factors associated with full immunization among children aged 12 to 59 months in Bangladesh: insights from the nationwide cross-sectional demographic and health survey

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Abstract

Objective To estimate the coverage and factors associated with full immunization coverage among children aged 12 to 59 months in Bangladesh.

Study design The study is cross-sectional in design. Secondary dataset from Bangladesh Demographic and Health Survey (BDHS) was used for this analysis. Immunization status was categorized as 'fully immunized' if the children had received all the eight recommended vaccine doses otherwise 'partially/unimmunized'.

Settings Bangladesh.

Participant Children aged 12 to 59 months were the study participants. Participants were randomly selected through a two-stage stratified sampling design. A total of 6,230 children were eligible for the analysis.

Results About 86% of the children (5,356 out of 6,230) were fully immunized. Bacille Calmette Guerin (BCG) has the highest coverage rate (97.1%) followed by Oral Polio Vaccine (OPV) 1 (97%) and Pentavalent 1 (96.6%), where the coverage rate was lowest for measles vaccine (88%). Coverage was higher in urban areas (88.5%) when compared to rural ones (85.1%). Full immunization coverage was significantly higher among children who lived in the Rangpur division (AOR=3.46; CI: 2.45-4.88, *p<0.001*), were 48 to 59 months old (AOR=1.32; CI:1.06-1.64, *p=0.013*), lived in a medium size family (AOR=1.56; CI:1.32-1.86, *p<0.001*), had parents with a higher level of education (AOR=1.96; CI:1.21-3.17, *p=0.006* and AOR=1.55; CI:1.05-2.29, *p=0.026*) and belonged to the richest families (AOR=2.2; CI:1.5-3.21, *p<0.001*). The likelihood of being partially or unimmunized was higher among children who had the father as their sole healthcare decision maker (AOR=0.69; CI: 0.51-0.92, *p<0.012*).

Conclusions There were significant variations of child immunization coverage across socio-economic and demographic factors. These findings will inform innovative approaches for immunization programs, and the introduction of relevant policies, including regular monitoring and evaluation of immunization coverage - particularly for low performing regions, so that the broader benefit of immunization programs can be achieved in all strata of the society.

Strengths and limitations of this study

- Our study did a pioneer investigation of full immunization coverage across various regions in Bangladesh using the latest nationwide demography and health survey dataset
- Multivariable logistic regression models were constructed to assess the potential factors associated with full immunization coverage
- The study results can be generalized at the country level because of its large sample size and using the latest nationally representative demographic and health survey data of Bangladesh
- Due to the nature of the study, the possibility of recall bias with our results cannot be ignored.

BACKGROUND

Universal immunization program of children against vaccine-preventable diseases (VPD) has been recognized as one of the most cost-effective programs to diminish childhood mortalities and morbidities across the world.[1,2] Every year, vaccination against VPDs prevents debilitating illness and disability, saving millions of young lives globally.[3] Over the decades, remarkable improvements have been made toward the development of national immunization programs, with the Expanded Program on Immunization (EPI) being a major contribution to this success.[4] EPI was formally established in 1974, with the support of World Health Organization (WHO), with the goal of immunizing every child against six vaccine-preventable diseases (i.e., diphtheria, pertussis, tetanus, poliomyelitis, measles, and tuberculosis) by 1990.[5] The utmost priority was given to developing countries because of the higher prevalence and inadequate service delivery for immunization within these settings.[4] The government of Bangladesh had initiated the EPI with the support of UNICEF and WHO through various outreach activities from 1979, with the overall objective to immunize all children by 1990 to prevent the VPDs and to eradicate poliomyelitis.[5,6] Later, in 1995, National Immunization Day (NID) was initiated by EPI to sustain the polio-free status and also to increase the immunization coverage that was achieved through different operational activities.[6,7] The implementation of the EPI has already been shown to be a great success globally. This can be seen through the significant improvement in child immunization coverage and the eradication of poliomyelitis.[8] In the line of success, Bangladesh has experienced impressive improvements in increasing immunization coverage and a significant contribution to the reduction of childhood morbidity, mortality and also maintaining its polio-free status.[9,10] Despite the success in reducing the child mortality rate by two-thirds since 1990, Bangladesh recorded 0.1 million child deaths in 2016[11] and was among the top 10 countries that had the highest childhood mortality globally.[12] A recent study revealed that almost half of these deaths could be prevented through immunization alone.[3,13] Therefore, a greater focus on completion of all recommended EPI vaccines are needed to further achieve gains in decreasing childhood morbidities and mortalities.[7] Unquestionably, improving the utilization of routine immunization services, and easy access to all vaccines is the best option to improve the immunization coverage.

Although a number of studies have reported findings on child immunization, few of them have generated evidence about the socio-demographic factors associated with full vaccination among children aged 12 to 59 months.[14–16] Furthermore, available studies have either focused on specified geographical settings, age groups or ethnic groups rather than the nationwide setting and have not identified the determinants of individual vaccines separately.[15–22] This study thus sought to capture the full immunization status using the latest country representative Demographic and Health Survey (DHS) dataset. The DHS provides reliable information on individual-level immunization coverage, as well as a range of factors that might influence immunization practices. As such, the objective of this study was to estimate the extent of full

immunization coverage and to investigate the determinants of full immunization using the nationally representative data of Bangladesh. Analysis of a nationally representative dataset would thus allow for a generation of the current evidence of vaccination practices that could be useful for international comparison and will help in implementing the relevant immunization policies and priorities for the betterment of the child's health against vaccine-preventable diseases in Bangladesh.

METHODS

Study design and population

This study was based on a secondary analysis of the latest Bangladesh Demographic and Health Survey (DHS) 2014 dataset. The DHS is a nationally representative cross-sectional survey, which uses a two-stage stratified sampling design to cover the target population of the entire country. This survey used the sampling frame provided by the Bangladesh Bureau of Statistics. This survey was carried out for 6 months, from June 2014 to November 2014. The BDHS-2014 used three types of questionnaires: household questionnaire, woman's questionnaire, and community questionnaire. Through the women's questionnaire, up-to-date information on socio-demographic, maternal, and child health indications including individual-level vaccination coverage were collected. Participants of this study were children aged between 1 to 5 years. Childhood immunization history was collected for all surviving children over the last five years. Immunization data were collected mainly from the records on vaccine cards; if vaccine card was not available, mothers were asked to recall about the vaccination history of the respective child. Face-to-face interviews were conducted with reproductive-aged women (15-49 years) were conducted for the collection of data using the structured questionnaire.[23] Details about sampling technique, survey design, and quality control have been described elsewhere.[24] All the DHS data was publicly accessible and were made available upon request by the MEASURE DHS. Furthermore, approval was sought from and given by the MEASURE DHS program office in the use of this data set for this specific study. According to the DHS, written informed consent was obtained from all participants prior to the interviews.

Outcome variable

The outcome variable of the analysis was the children's immunization status and categorized as fully immunized and partially/unimmunized. Vaccination status was categorized as 'fully immunized' if the children had received doses of all the eight recommended vaccines; one dose of the vaccine against tuberculosis (BCG), three doses of pentavalent (DPT, Hib, and HepB), three doses of polio vaccine (OPV), and one dose of measles vaccines.[24] Children aged 12 to 59 months of age were included in this analysis to capture the vaccination status of the children. Children younger than 12 months of age were excluded as they were not old enough to receive the full schedule of the routine vaccines. The WHO recommended vaccination schedule for Bangladesh [25] is presented in table 1. Immunization histories for all vaccines were

coded as dummy responses, with 1 for fully immunized and 0 otherwise. In a small number of cases, the immunization cards were not available, and mothers responded with "don't know" while asked about their children's vaccination status on certain vaccines. In that cases, the vaccination status of children was considered as "not fully immunized" since such responses reflect a negative response regarding immunization.[15]

Explanatory variables

Explanatory variables were selected based on the published literature, prior knowledge, and availability of variables in the BDHS 2014 dataset. Area of residence, administrative division, sex and age of children, birth order, family size, parental education, mass media exposure, household wealth index and the mother's decision-making ability for both the children and their own healthcare matters were included as explanatory variables. In this analysis, the categorization of continuous variables was done in light of previous literature where the child's age was categorized into four groups at twelve-month intervals, and maternal age was categorized into three groups (less than 20 years, 20-34 years and more than 34 years). Self-reported parental (both mother and father) educational attainment was used and categorized as "no education," "primary," "secondary," and "higher." No education refers to there not having any formal education, with primary was defined as completing grade 5, secondary as completing grade 10, and higher was defined as attaining more than grade 10. Family size was determined by the number of family members who lived together in a household, and defined by the BDHS. Family size was categorized on the basis of other published literature and categorized as "small", "medium" and "large". A "Small" family size refers to the family consisting of less than 4 members, "medium" as 4 to 6 members and "large" if the family member exceeds 6 members. Mass media access was categorized as "Yes" if the family had access to televisions and radios and "No" otherwise. We utilized the predetermined wealth index category provided in the dataset generated from selected household assets using principal component analysis (PCA) and classified it into five groups, namely: "poorest," "poorer," "middle," "rich," and "richest." Moreover, both the decision-making ability of the mothers for both their children and personal healthcare were categorized into four groups as "herself," "jointly with husband," "husband alone" and "other."

Statistical analysis

The original dataset comprised of 8,092 children, aged 0 to 59 months of age. In the case of our analysis, 1,555 children were excluded as they were under the age of 12 months. Moreover, 307 cases of missing data were present, and these were cases where no information was provided (no responses, neither "yes", "no" nor "don't know") on vaccination information, and thus also excluded from the analysis. Finally, a total of 6,230 children were eligible and included in the analysis. A proper sampling weight was used in this analysis to make the sample more representative of the population at the national level. Descriptive

statistics, such as frequency with percentages were executed to represent the background characteristics of study participants, and a proportion with 95% confidence interval (CI) was used for presenting the coverage rate of fully vaccinated children. The association between each independent variable and the full vaccination uptake was investigated using a univariate analysis. Multivariable logistic regression that adjusted for all the selected independent variables was also constructed to determine the significant influencing factors for fully vaccination and results were presented in terms of adjusted odds ratio(s) (AOR) with a 95% confidence intervals (CI). Before the execution of a multivariate regression model, a bivariate analysis was conducted to trace out the significant factors for full immunization. Variables significant at p value ≤ 0.05 were included in the multivariate logistic regression analysis. Variance Inflation Factor (VIF) was calculated to detect any multicollinearity in the model. The low value of average VIF (3.07) confirms no notable multicollinearity among variables. Linktest command through Stata/SE 13.0 indicated that the constructed model was well specified where the Hosmer-Lemeshow test statistics of goodness-of-fit indicates the acceptance of the model. Data cleaning, validation, and all statistical analyses were performed using Stata /SE 13.0 (Stata Corporation, College Station, TX, USA).

Patient and public involvement

No patients were involved in developing the research question, outcome measure, and design of the study. We are unable to disseminate the results of the research directly to study participants

RESULTS

Descriptive statistics

Distribution of study participants across the socio-demographic variables is presented in table 2. The proportion of full vaccination was 86% (5,356 out of 6,230 children). Among the participants, 74.7% were from rural areas and 35.1% were from the Dhaka division. Participants were almost equally distributed by sex and age categories. Among the participants, 37.7% was the first-born child, and most of the children's families (57.9%) consisted of 4 to 6 members. Majority of the mothers (80.4%) were aged between 20 to 34 years. 46.1% of the mothers and 29.8% of fathers had secondary level education. Less than half of the mothers (40.9%) had access to mass media, e.g., radio and television. In addition, a majority of the mothers reported that they had the capacity for decision-making with regards to both their own as well as their children's healthcare.

Vaccination coverage rate among study participants

Full immunization coverage rate of study participants is also presented in table 2. Findings revealed that full immunization coverage was slightly higher in urban areas (88.5%) as compared to rural areas (85.1%)

and was found to be the highest in the Rangpur division (91.5%) followed by Khulna (89%), Dhaka (88.8%) and the lowest in Sylhet division (69.8%). The immunization coverage across individual vaccines are shown in Figure 1. Full immunization coverage was similar across sex and age categories of the children. However, first born child had slightly higher vaccine coverage rates (88.4%) than the other (87.7% for second and 81.6% for third or more birth order).

Full immunization coverage was highest among the children whose parents had higher educational attainment (94.2% and 93.7% for higher educated mother and father, respectively). Vaccine coverage rate was also higher among the children of mothers who have access to mass media. Full vaccination coverage was found to increase in accordance with a higher economic status of the children's family (73.9% for the poorest to 93.2% for the richest quintile). Full immunization coverage rate was higher among the children whose mother had her own healthcare decision-making ability, including that of her children's healthcare. The overall coverage rate of BCG vaccine was the highest (97.1%) followed by OPV-1 (97%), Pentavalent-1 (96.6%), OPV-2 (95.8%) and Pentavalent-2 (95.4%) where the coverage of measles was the lowest (88%) (Figure 2). Furthermore, the coverage of each vaccine by urban and rural areas is also presented in the following figure 2.

Factors associated with full immunization coverage

Table 3 shows factors associated with the full-immunization coverage among children aged 12 to 59 months in terms of both unadjusted and adjusted odds ratios. The analysis shows that several socio-demographic factors, like administrative divisions, age of children, family size, parental education, wealth index, and child healthcare decision makers were associated with the full-immunization status in both models. From the univariate analysis, we found that area of residence, childbirth order, access to mass media and mothers' healthcare decision maker were significant factors for fully-immunization. Urban children were significantly 1.35 times more likely to be fully-vaccinated than rural ones (CI: 1.13-1.60; *p=0.001*), and the 1st born child was 1.71 times more likely to be fully-vaccinated than the child of third or more birth order (CI: 1.45-2.03; *p<0.001*). We also observed that mothers of the children who had access to the mass media had higher odds than their counterparts (OR= 2.01; CI: 1.72-2.36; *p< 0.001*). Similarly, parental education and wealth status played a significant role for full immunization coverage among children. Findings revealed that children of higher educated mother were significantly 4.93 times (CI: 3.37-7.22, *p<0.001*) and children of higher educated father were 4.03 times (CI: 2.98-5.44, *p<0.001*) more likely to be fully immunized than children of uneducated mothers and fathers. Findings also revealed that children from the richest households were significantly 4.27 times (CI: 3.31-5.52, *p<0.001*) more likely to be fully immunized than the poorest.

In the adjusted model, the likelihood of being fully vaccinated was significantly lower in the Sylhet division than all other regions. We found that the number of full immunized children was significantly higher in Rangpur division (AOR: 3.46; CI: 2.45-4.88; *p< 0.001*) followed by the children from Dhaka (AOR: 2.59; CI: 2.05-3.28; *p< 0.001*), Khulna (AOR: 2.33; CI: 1.62-3.33; *p< 0.001*) and Rajshahi (AOR: 1.96; CI: 1.46-2.64; *p< 0.001*) division. The odds of full immunization differed across age groups of the children. For instance, children aged 48 to 59 months had the highest odds of being fully vaccinated (AOR=1.32; CI: 1.06 – 1.64; *p=0.013*) compared to children aged 12 to 23 months. Family size was also appeared to be a significant factor for full immunization as medium households (4 to 6 members) often fully immunized more than their counterpart (AOR=1.56; CI: 1.32–1.86, *p<0.001*). The findings also revealed that parental education was significantly associated with full-immunization. It was observed that the odds of being full immunization were increased as the educational attainment of parents increased; and that children from higher educated mother (AOR=1.96; CI: 1.21 – 3.17; *p=0.006*) and higher educated father (AOR=1.55; CI: 1.05 – 2.29; *p=0.026*) were more likely to be full vaccinated compared to those with uneducated parents. Children from the richest households had the highest odds of being fully immunized (AOR= 2.20; CI: 1.50 – 3.21; *p<0.001*) followed by the middle wealth quintile (AOR= 1.78; CI: 1.37–2.30; *p<0.001*). The lowest odds were found among the children whose health care decision was made solely by their father (AOR=0.69; CI: 0.51 – 0.92; *p=0.012*) compared to children with healthcare decisions that were made by the mothers.

DISCUSSION

The present study examined the extent of full immunization coverage and determinants of full-immunization status. We found that the overall full immunization coverage is impressive (86%) within South East Asia Region.[26] The underlying success is due to the nature of a pluralistic health system of Bangladesh, where the public, private sector, and non-governmental organizations actively participate to deliver healthcare services. In addition, the introduction of systematic outreach approaches helped to increase accessibility to routine immunization where community health workers are directly involved in delivering vaccines.[27] Further, community mobilization and public awareness related programs have also played a significant role in generating demand for vaccine uptake.[28]

Despite the success, full immunization coverage varies across the country. For instance, the full immunization coverage is highest in Rangpur while lowest coverage is observed in the Sylhet region. Our study showed that various factors, such as parental education particularly mothers' education, age of the children, family size, regional variation, and wealth quintiles played a significant role for full immunization coverage. The importance of parental education in improving child's health is universally recognized. Similar to earlier studies on childhood vaccination, we found that parental education appeared

to be a significant factor for childhood immunization.[15,29] This is due to their better knowledge and understanding of the recommended immunization schedules than non-educated parents.[30] Furthermore, educated parents are likely to be wealthier and have better access to health facilities and immunization services.[29] Like other studies in various settings, we observed that children of educated mothers were often fully immunized when compared to non-educated mothers.[15,29,31] It is well established that there is a positive relationship between level of education and public health awareness. Therefore, community-based behaviour changes programs, such as immunization announcement through radio, television and using local drama and public announcement through miking (loud speaker), should be approached to target uneducated mothers in order to provide a better understanding of the beneficial role of immunization so that they are encouraged to vaccinate their children in a timely fashion.

We observed that full immunization coverage was higher among elder children (e.g., 48 to 59 months of age) compared to the younger children (e.g., 12 to 23 months of age). Policy makers should provide more focus on continuous monitoring and promotional activities to increase the number of full immunization coverage of all strata.[15] Again, the size of the family appeared to be a significant factor of fully immunized children. Those who belonged to larger family size were more likely to be unimmunized. This is similar to the findings in other earlier studies conducted in Indonesia, Greece, and Angola, where it was also reported that children form larger family size were less likely to be fully immunized.[15,32,33] This might also reflect the socioeconomic status of the households as larger families consume more resources, which is troublesome for resource-poor families and would thus impact on their livelihoods. Therefore, policies should focus on awareness development, especially in targeting the larger family to increase the full immunization coverage. Wealth status of the household plays a significant role in the immunizing of their children. Our results are similar to many earlier studies which have shown that there is a significant positive relationship between wealth index and childhood immunization completion rates; the chance of having fully immunized children increases in accordance with the wealth index of household.[15,29,31] While the immunization services in Bangladesh are completely free of charge, the indirect cost of vaccination, such as income loss and transportation cost might be associated with the low demand for vaccination specially for poorest households.[34,35] Children from urban areas have been reported to have better immunization status compared to their rural counterparts. This result confirmed previous findings where similar association was also reported.[15,36] This is due to better health services available in urban areas compared to the rural.[37]

Our study observed that child healthcare decision making by mothers also contributed, playing a significant role in full immunization coverage, with the child more likely to be fully immunized if the mother was the decision maker. This might be due to more awareness of the mothers for their child's health than the fathers. Therefore, the mothers' autonomy is essential for their child's immunization.

However, an earlier study showed that if the parents jointly decided on healthcare decision, their children were often fully immunized.[15] Thus, there is a need to disseminate information about women autonomy in making health care decisions about their children to increase full immunization coverage. Based on the findings, community-based behaviour change program that target parents might be helpful for developing awareness for their childhood immunization. Like many low and middle-income countries, we also observed that geographical disparities may contribute to the full immunization coverage in Bangladesh.[15,38-40] Our study found that children who lived in Sylhet region were more often unimmunized when compared with other parts of the country. This is may be due to various supply side and demand side factors, such as the distance of health facilities and vaccination centres, fragile communication systems in some remote areas, a fear of the side effects of vaccines, religious conservatism, a low level of literacy, and even lack of awareness about the benefit of vaccination for their children.[40] Therefore, policy should target divisions with low immunization coverage with an innovative immunization approach that addressing both supply and demand side barriers. For instance, households which are located away from or have difficulty in accessing immunization services, especially in hilly areas might benefit from outreach program or mobile immunization strategies. Furthermore, the use of mobile phones may be important vehicles for tracking and improving immunization coverage in these rural, hard to reach areas of Bangladesh.[41]

Strengths and limitations

The study has several limitations. The study was based on secondary data where immunization cards and mother's report was considered as the source of information for their child's immunization status. Therefore, the potential of recall bias in our results cannot be ignored. Nonetheless, the mother's report is considered to be a valid measure of coverage in the absence of a health card, especially in developing countries.[42] The explanatory variables were selected based on previous studies and relied on the information available from the dataset. Therefore, there might be some other potential predictors that might be influenced by full immunization which were not captured in this study. Despite the limitations, the study results can be generalized at a country level because the study utilized data from the latest nationally representative household survey. Thus, our findings are still significant and relevant in drawing attention to the health policy makers in ensuring the benefit of vaccination for the betterment of child health.

CONCLUSION

Our results identified the presence of disparities for full immunization coverage across regions and by types of vaccines in Bangladesh. Findings revealed that full immunization status was significantly associated with regional variation, the age of the children, maternal age, parental education, family size,

woman autonomy for child healthcare, and wealth quintiles. Our study found that a large number of children from the Sylhet division, poor and larger family, and from lower parental education were not fully immunized. The study also identified that measles immunization coverage was the lowest among the eight recommended vaccines. Therefore, to achieve maximum success and prevent children from vaccine preventable diseases, it is mandatory to address the issues obstructing full vaccination. The findings of this study will serve to inform and support innovative approach for immunization programs, and the introduction of relevant policies, including the regular monitoring and evaluation of immunization coverage particularly for low performing regions of Bangladesh and targeting various vaccines in order to allow the broader benefit of the immunization program to be achieved in all strata of society.

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Ethics approval This study did not require ethical approval as it used unidentifiable secondary DHS data set. According to the DHS, written informed consent was obtained from mothers/caretakers on behalf of the children enrolled in the survey. The DHS data are publicly accessible and were made available to us upon request by Measure DHS. No identifiable information was included in the dataset and no attempt was made to identify any individual interviewed in the survey.

Data sharing statement The electronic datasets analysed in this study are available for legitimate research purposes from the Measure DHS website (https://dhsprogram.com/data/).

References:

1 World Health Organization (WHO). Protecting people from Vaccine Preventable Diseases: Strategic Plan (2010-2013). Geneva 27, Switzerland: 2013.

2 Andre FE, Booy R, Bock HL, *et al.* Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bull World Health Organ* 2008;**86**:140–6. doi:10.2471/BLT.07.040089

3 WHO, UNICEF, World Bank. State of the World's Vaccine and Immunization, 3rd ed. World

Health Organization (WHO), Geneva: 2009.

4 Jamil K, Bhuiya A, Streatfield K, *et al.* The immunization programme in Bangladesh: impressive gains in coverage, but gaps remain. *Health Policy Plan* 1999;**14**:49–58. doi:10.1093/heapol/14.1.49

5 Keja K, Chan C, Hayden G, *et al.* Expanded programme on immunization. *World Heal Stat Q* 1988;**41**:59–63.

6 Quaiyum M, Bahari MB, Al-Qazaz HK, *et al.* Research report. Impact of national immunization days on polio-related knowledge and practice of urban women in Bangladesh. Health Policy Plan. 1997;**12**:363–71.

7 Sarkar PK, Sarker NK, Doulah S, *et al.* Expanded Programme on Immunization in Bangladesh : A Success Story. *Bangladesh J Child Heal* 2015;**39**:93–8.

8 World Health Organization (WHO). Polio-free Certif. WHO South-East Asia.

9 Sk MIK, Sk MF, Kurlikar PR, *et al.* Status and determinants of child immunisation coverage in three South Asian countries , India , Bangladesh and Nepal : Evidence from the Demographic and Health Survey. *Sri Lanka J Child Heal* 2018;**47**:56–63.

10 Expanded Program on Immunization (EPI). Bangladesh EPI Coverage Evaluation Survey 2016. Dhaka, Bangladesh: 2017.

11 United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). Levels & Trends in Child Mortality: Report 2017, Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation. New York: 2017.

12 Boulton ML, Carlson BF, Power LE, *et al.* Socioeconomic factors associated with full childhood vaccination in Bangladesh, 2014. *Int J Infect Dis* 2018;**69**:35–40.

13 Liu L, Oza S, Hogan D, *et al.* Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: An updated systematic analysis. *Lancet* 2015;**385**:430–40. doi:10.1016/S0140-6736(14)61698-6

14 Rahman M, Obaida-Nasrin S. Factors affecting acceptance of complete immunization coverage of children under five years in rural Bangladesh. *Salud Publica Mex* 2010;**52**:134–40. doi:10.1590/S0036-36342010000200005

15 Herliana P, Douiri A. Determinants of immunisation coverage of children aged 12-59 months in Indonesia: A cross-sectional study. *BMJ Open* 2017;**7**:1–14. doi:10.1136/bmjopen-2016-015790

16 Oleribe O, Kumar V, Awosika-Olumo A, *et al.* Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. *Pan Afr Med J* 2017;**26**:1–14. doi:10.11604/pamj.2017.26.220.11453

17 Meleko A, Geremew M, Birhanu F. Assessment of Child Immunization Coverage and Associated Factors with Full Vaccination among Children Aged 12–23 Months at Mizan Aman Town, Bench

Maji Zone, Southwest Ethiopia. *Int J Pediatr* 2017;**2017**:1–11. doi:10.1155/2017/7976587

18 Sheikh N, Sultana M, Ali N, *et al.* Coverage , Timelines , and Determinants of Incomplete Immunization in Bangladesh. *Trop Med Infect Dis* 2018;**3**:1–14. doi:10.3390/tropicalmed3030072

19 Uddin MJ, Larson CP, Oliveras E, *et al.* Child immunization coverage in urban slums of Bangladesh: impact of an intervention package. *Health Policy Plan* 2010;**25**:50–60. doi:10.1093/heapol/czp041

20 Rahman A, Reza AAS, Bhuiyan BA, *et al.* Equity and determinants of routine child immunisation programme among tribal and non-tribal populations in rural Tangail subdistrict, Bangladesh: a cohort study. *BMJ Open* 2018;**8**:e022634. doi:10.1136/bmjopen-2018-022634

21 Adhikary M, Haque R, Tanira S. Determinants of child immunization under expanded programme on immunization (EPI) in a rural setting of Bangladesh. *J Dhaka Med Coll* 2013;**22**:201–6.

22 Nasrin Afzal BZ. Determinants and Status of Vaccination in Bangladesh. *Dhaka UnivJSci* 2012;**60**:47–51. doi:10.3329/dujs.v60i1.10336

23 Rutstein SO, Rojas G. Guide to DHS statistics: Demographic and Health Surveys Methodology. Calverton, Maryland: 2006.

24 National Institute of Population Research and Training (NIPORT), Mitra and Associates and II 2016. Bangladesh Demographic and Health Survey 2014. Dhaka, Bangladesh, and Rockville, Maryland, USA: NIPORT, Mitra and Associates, and ICF International.: 2014.

25 Directorate General of Health Services (DGHS). EPI vaccine Schedule. Minist. Heal. Fam. Welf. http://www.dghs.gov.bd/index.php/en/mis-docs/epi (accessed 10 Mar 2019).

26 WHO. WHO South-East Asia:Expanded Programme on Immunization (EPI) REGIONAL FACT SHEET 2017. *World Heal Organ* 2017;**6**:1–98.

27 Adams AM, Rabbani A, Ahmed S, *et al.* Bangladesh: Innovation for Universal Health Coverage 4: Explaining equity gains in child survival in Bangladesh: Scale, speed, and selectivity in health and development. Lancet. 2013. doi:10.1016/S0140-6736(13)62060-7

28 El Arifeen S, Christou A, Reichenbach L, *et al.* Community-based approaches and partnerships: Innovations in health-service delivery in Bangladesh. Lancet. 2013. doi:10.1016/S0140-6736(13)62149-2

29 Holipah, Maharani A, Kuroda Y. Determinants of immunization status among 12- to 23-month-old children in Indonesia (2008-2013): A multilevel analysis. *BMC Public Health* 2018;**18**:1–11. doi:10.1186/s12889-018-5193-3

30 Schoeps A, Ouédraogo N, Kagoné M, *et al.* Socio-demographic determinants of timely adherence to BCG, Penta3, measles, and complete vaccination schedule in Burkina Faso. *Vaccine* Published Online First: 2013. doi:10.1016/j.vaccine.2013.10.063

31 Abadura SA, Lerebo WT, Kulkarni U, *et al.* Individual and community level determinants of childhood full immunization in Ethiopia: A multilevel analysis Global health. *BMC Public Health* 2015;**15**:1–10. doi:10.1186/s12889-015-2315-z

32 Danis K, Georgakopoulou T, Stavrou T, *et al.* Socioeconomic factors play a more important role in childhood vaccination coverage than parental perceptions: a cross-sectional study in Greece. *Vaccine* 2010;**28**:1861–9. doi:10.1016/j.vaccine.2009.11.078

33 Oliveira MFS de, Martinez EZ, Rocha JSY. Factors associated with vaccination coverage in children <5 years in Angola. *Rev Saude Publica* 2014;**48**:906–15. doi:10.1590/S0034-8910.2014048005284

34 Mitchell S, Andersson N, Ansari N, *et al.* Equity and vaccine uptake: a cross-sectional study of measles vaccination in Lasbela District, Pakistan. *BMC Int Health Hum Rights* Published Online First: 2009. doi:10.1186/1472-698X-9-S1-S7

35 Lanaspa M, Balcells R, Sacoor C, *et al.* The performance of the expanded programme on immunization in a rural area of Mozambique. *Acta Trop* Published Online First: 2015. doi:10.1016/j.actatropica.2015.06.007

36 Shrivastwa N, Gillespie BW, Kolenic GE, *et al.* Predictors of Vaccination in India for Children Aged 12-36 Months. *Am J Prev Med* Published Online First: 2015. doi:10.1016/j.amepre.2015.05.008

37 Fernandez R, Rammohan A, Awofeso N. Correlates of first dose of measles vaccination delivery and uptake in Indonesia. *Asian Pac J Trop Med* Published Online First: 2011. doi:10.1016/S1995-7645(11)60055-2

38 Clouston S, Kidman R, Palermo T. Social inequalities in vaccination uptake among children aged 0-59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. *Vaccine* Published Online First: 2014. doi:10.1016/j.vaccine.2014.04.030

39 Antai D. Inequitable childhood immunization uptake in Nigeria: A multilevel analysis of individual and contextual determinants. *BMC Infect Dis* Published Online First: 2009. doi:10.1186/1471-2334-9-181

40 Uddin MJ, Koehlmoos TP, Saha NC, *et al.* Child immunization coverage in rural hard-to-reach areas of Bangladesh. *Vaccine* 2010;**28**:1221–5. doi:10.1016/j.vaccine.2009.11.028

41 Uddin MJ, Shamsuzzaman M, Horng L, *et al.* Use of mobile phones for improving vaccination coverage among children living in rural hard-to-reach areas and urban streets of Bangladesh. *Vaccine* Published Online First: 2016. doi:10.1016/j.vaccine.2015.11.024

42 Langsten R, Hill K. The accuracy of mothers' reports of child vaccination: evidence from rural Egypt. *Soc Sci Med* Published Online First: 1998. doi:10.1016/S0277-9536(97)10049-1

Table 1. The Expanded Program on Immunizations (EPI) schedule in Bangladesh

Diseases	Name of vaccine	Recommended age
Childhood tuberculosis (TB)	BCG	At birth/0 day
Diphtheria/tetanus/pertussis/ Hepatitis B/Hib pneumonia and meningitis	Pentavalent 1	42 days
	Pentavalent 2	70 days
	Pentavalent 3	98 days
Poliomyelitis	OPV 1	42 days
	OPV 2	70 days
	OPV 3	98 days
Measles	Measles	273 days

Hib: Haemophilus influenzae type B, BCG: Bacille Calmette Guerin; OPV: Oral Polio Vaccine

Table 2: Baseline characteristics of study participants and their immunization coverage in Bangladesh, 2014, (n=6,230)

Characteristics of Sample	Frequency (%)	Fully immunized % (95% CI)
Immunization status		
Partially/Unimmunized	874 (14.03)	
Fully immunized	5,356 (85.97)	
Area of residence		
Urban	1,577 (25.32)	88.50 (86.83, 89.98)
Rural	4,653 (74.68)	85.11 (84.06, 86.10)
Division		
Rajshahi	642 (10.30)	86.16 (83.26, 88.62)
Barisal	352 (5.65)	84.89 (80.75, 88.27)
Chittagong	1,336 (21.45)	85.38 (83.38, 87.18)
Dhaka	2,187 (35.11)	88.81 (87.42, 90.07)
Khulna	468 (7.51)	89.01 (85.84, 91.55)
Rangpur	624 (10.01)	91.48 (89.01, 93.43)
Sylhet	622 (9.98)	69.81 (66.08, 73.30)
Sex		
Male	3,236 (51.94)	85.57 (84.31, 86.73)
Female	2,994 (48.06)	86.40 (85.13, 87.58)
Age category (in months)		
12 – 23	1,630 (26.17)	83.97 (82.10, 85.67)
24 – 35	1,560 (25.04)	86.68 (84.90, 88.28)
36 – 47	1,529 (24.55)	86.63 (84.83, 88.24)
48 – 59	1,510 (24.24)	86.72 (84.91, 88.34)
Birth order		
1	2,346 (37.66)	88.35 (86.99, 89.59)
2	1,880 (30.18)	87.66 (86.09, 89.07)
>=3	2,003 (32.16)	81.59 (79.83, 83.22)
Mother's age		
< 20 years	690 (11.07)	86.85 (84.12, 89.18)
20 - 34 years	5,011 (80.43)	85.97 (84.98, 86.91)
35 years and more	529 (8.50)	84.75 (81.43, 87.57)
Family size (members)		
Small (<4)	772 (12.39)	86.35 (83.74, 88.59)
Medium (4 - 6)	3,609 (57.93)	87.88 (86.77, 88.90)
Large (>6)	1,849 (29.68)	82.08 (80.26, 83.76)
Mother's education		
No education	1,053 (16.91)	76.77 (74.13, 79.23)

Primary	1,740 (27.93)	81.17 (79.27, 82.94)
Secondary	2,870 (46.07)	90.62 (89.50, 91.64)
Higher	566 (9.09)	94.22 (91.97, 95.87)
Father's education		
No education	1,683 (27.02)	78.64 (76.61, 80.53)
Primary	1,843 (29.58)	84.84 (83.13, 86.41)
Secondary	1,857 (29.81)	90.21 (88.77, 91.48)
Higher	847 (13.60)	93.69 (91.83, 95.14)
Mass media access		
Yes	2,546 (40.87)	90.62 (89.42, 91.69)
No	3,684 (59.13)	82.75 (81.50, 83.94)
Wealth index		
Poorest	1,438 (23.08)	76.13 (73.85, 78.26)
Poorer	1,160 (18.62)	85.32 (83.16, 87.24)
Middle	1,184 (19.01)	89.07 (87.17, 90.73)
Richer	1,260 (20.23)	88.10 (86.20, 89.78)
Richest	1,187 (19.05)	93.16 (91.58, 94.46)
Child's healthcare decision maker		
Herself	934 (15.25)	88.08 (85.84, 90.01)
Jointly with husband	3,577 (58.37)	87.94 (86.84, 88.97)
Husband alone	1,249 (20.38)	79.08 (76.73, 81.25)
By other	368 (6.00)	88.30 (84.59, 91.21)
Mother's healthcare decision maker		
Herself	764 (12.46)	89.23 (86.82, 91.24)
Jointly with husband	3,208 (52.33)	87.91 (86.74, 88.99)
Husband alone	1,797 (29.32)	81.78 (79.93, 83.50)
By other	361 (5.88)	86.23 (82.27, 89.42)

Table 3: Unadjusted and adjusted effects of factors that are associated with full immunization coverage

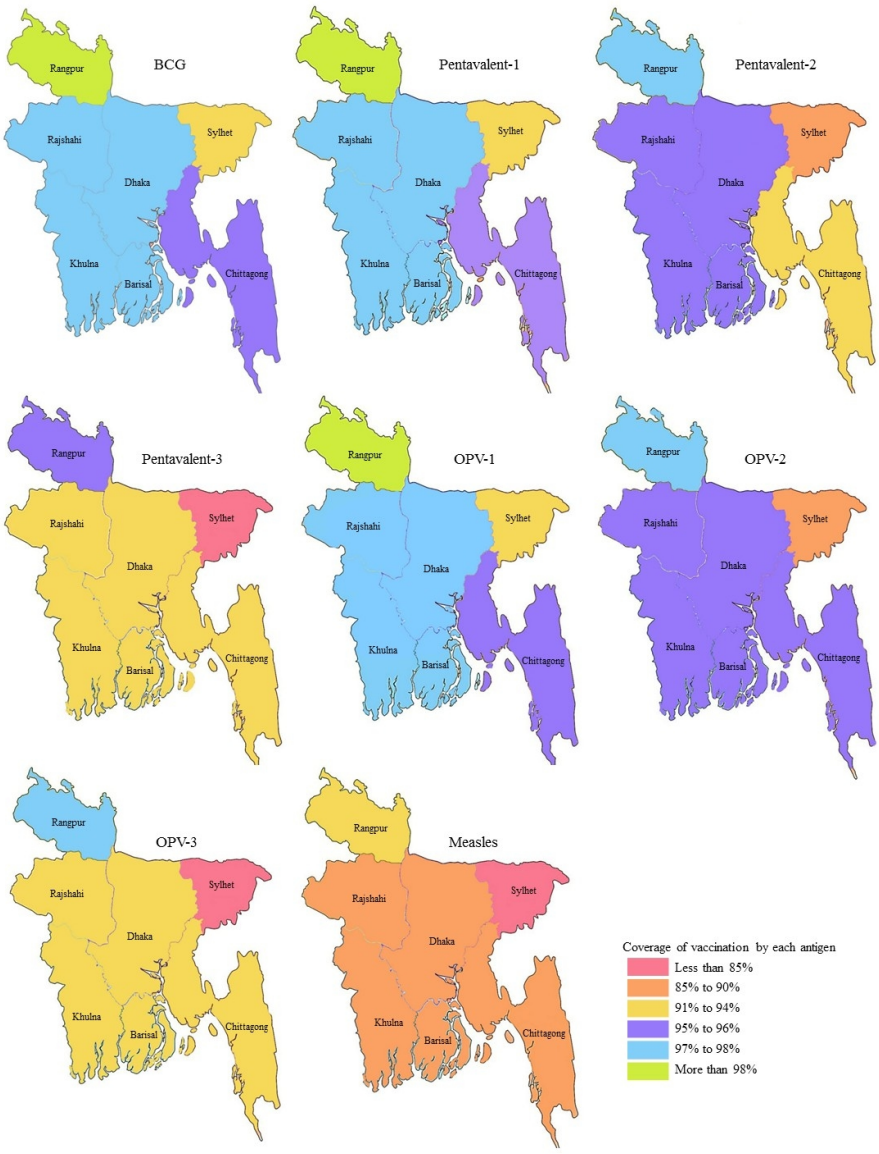
Characteristics	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Area of residence				
Urban	1.35 (1.13, 1.6)	**0.001**	0.83 (0.68, 1.03)	0.092
Rural	1.00		1.00	
Division				
Rajshahi	2.69 (2.03, 3.57)	**<0.001**	1.96 (1.46, 2.64)	**<0.001**
Barisal	2.43 (1.73, 3.41)	**<0.001**	1.9 (1.33, 2.71)	**<0.001**
Chittagong	2.53 (2.01, 3.18)	**<0.001**	1.77 (1.39, 2.26)	**<0.001**
Dhaka	3.43 (2.76, 4.26)	**<0.001**	2.59 (2.05, 3.28)	**<0.001**
Khulna	3.5 (2.5, 4.9)	**<0.001**	2.33 (1.62, 3.33)	**<0.001**
Rangpur	4.64 (3.34, 6.45)	**<0.001**	3.46 (2.45, 4.88)	**<0.001**
Sylhet	1.00		1.00	
Sex				
Male	0.93 (0.81, 1.08)	0.342	0.92 (0.79, 1.07)	0.294
Female	1.00		1.00	
Age categories (in months)				
12 - 23	1.00		1.00	
24 – 35	1.24 (1.02, 1.51)	**0.031**	1.26 (1.02, 1.56)	**0.033**
36 – 47	1.24 (1.01, 1.51)	**0.035**	1.22 (0.99, 1.52)	0.064
48 – 59	1.25 (1.02, 1.52)	**0.030**	1.32 (1.06, 1.64)	**0.013**
Birth order				
1	1.71 (1.45, 2.03)	**<0.001**	1.16 (0.92, 1.46)	0.204
2	1.6 (1.34, 1.91)	**<0.001**	1.18 (0.96, 1.45)	0.113
>=3	1.00		1.00	
Mothers age				
< 20 years	1.19 (0.86, 1.64)	0.295	0.75 (0.5, 1.12)	0.164
20 - 34 years	1.1 (0.86, 1.42)	0.443	0.71 (0.53, 0.95)	**0.021**
More than 35 years	1.00		1.00	
Family size (members)				
Small (<4)	1.38 (1.09, 1.75)	**0.008**	1.29 (0.97, 1.72)	0.074
Medium (4 - 6)	1.58 (1.36, 1.85)	**<0.001**	1.56 (1.32, 1.86)	**<0.001**
Large (>6)	1.00		1.00	
Mothers education				
No education	1.00		1.00	
Primary	1.3 (1.08, 1.57)	**0.005**	1.21 (0.98, 1.49)	0.076
Secondary	2.92 (2.42, 3.54)	**<0.001**	1.85 (1.45, 2.35)	**<0.001**
Higher	4.93 (3.37, 7.22)	**<0.001**	1.96 (1.21, 3.17)	**0.006**
Fathers education				
No education	1.00		1.00	
Primary	1.52 (1.28, 1.81)	**<0.001**	1.18 (0.97, 1.43)	0.099
Secondary	2.5 (2.07, 3.03)	**<0.001**	1.35 (1.06, 1.71)	**0.014**
Higher	4.03 (2.98, 5.44)	**<0.001**	1.55 (1.05, 2.29)	**0.026**
Wealth index				
Poorest	1.00		1.00	
Poorer	1.82 (1.49, 2.23)	**<0.001**	1.41 (1.13, 1.75)	**0.002**
Middle	2.56 (2.05, 3.18)	**<0.001**	1.78 (1.37, 2.3)	**<0.001**
Richer	2.32 (1.88, 2.86)	**<0.001**	1.38 (1.03, 1.84)	**0.030**
Richest	4.27 (3.31, 5.52)	**<0.001**	2.2 (1.5, 3.21)	**<0.001**
Access to mass media				
Yes	2.01 (1.72, 2.36)	**<0.001**	1.15 (0.92, 1.43)	0.214
No	1.00		1.00	
Mothers healthcare decision				

maker				
Herself	1.00		1.00	
Jointly with husband	0.88 (0.68, 1.13)	0.312	0.89 (0.66, 1.2)	0.431
Husband alone	0.54 (0.42, 0.7)	**<0.001**	0.77 (0.57, 1.06)	0.107
By other	0.76 (0.52, 1.1)	0.146	0.67 (0.42, 1.08)	0.098
Child healthcare decision maker				
Herself	1.00		1.00	
Jointly with husband	0.99 (0.79, 1.23)	0.910	1.06 (0.82, 1.39)	0.641
Husband alone	0.51 (0.4, 0.65)	**<0.001**	0.69 (0.51, 0.92)	**0.012**
By other	1.02 (0.7, 1.49)	0.912	1.3 (0.81, 2.07)	0.277
Mean VIF			*3.07*	
LR chi2			*438.82*	
Prob > chi2			*<0.001*	
Pseudo R2			*0.089*	
linear predicted value (_hat)			*<0.001*	
linear predicted value squared (_hatsq)			*0.885*	
HL chi2(8)			*7.88*	
Prob > chi2			*0.4452*	

Abbreviations: OR, odds ratios; CI, confidence interval; LR, likelihood ratio; VIF, variance inflation factor; HL, Hosmer-Lemeshow

Figure 1: Coverage rate by individual vaccines (BCG, Pentavalent, OPV, and Measles) across administrative divisions in Bangladesh (map obtained from open access source and edited according to study findings)

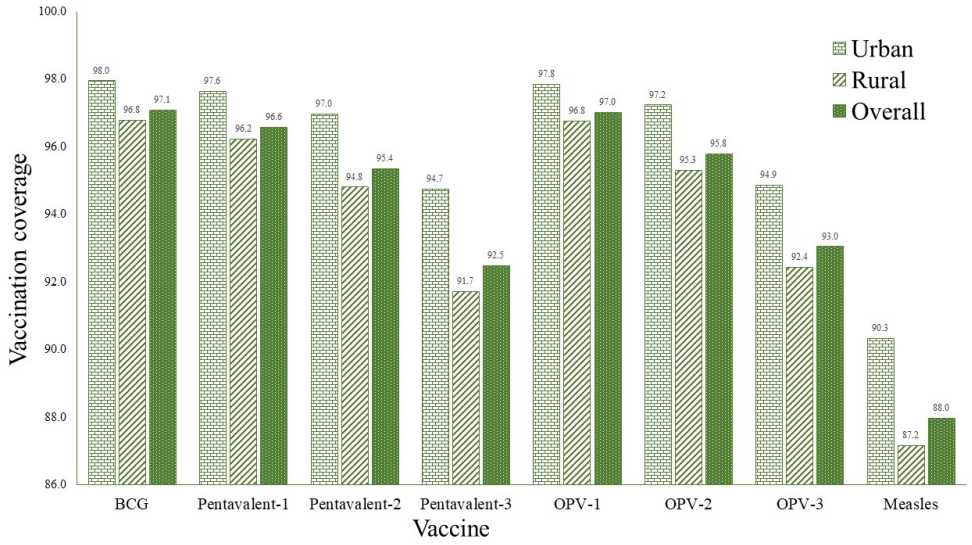
Figure 2: Coverage rate by individual vaccines across place of residence of respondents (urban vs. rural) in Bangladesh



Map of Bangladesh by administrative division

Coverage rate by individual vaccines (BCG, PCV, OPV, and MR) across administrative divisions in Bangladesh

292x387mm (96 x 96 DPI)



Coverage rate by individual vaccines across place of residence of respondents (urban vs. rural) in Bangladesh

338x190mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	*5*
Study size	10	Explain how the study size was arrived at	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	N/A
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	5
Outcome data	15*	Report numbers of outcome events or summary measures	6,7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6,7
		(*b*) Report category boundaries when continuous variables were categorized	6,7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	8,9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.