Factors associated with coverage gaps of Pentavalent vaccine doses among Bangladeshi children

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Date- 15th September 2021

The Thesis Entitled

"Factors associated with coverage gaps of Pentavalent vaccine doses among Bangladeshi children"

Is submitted to the Department of Public Health and Pharmacy, Independent University of Bangladesh for the partial fulfillment of the requirements of the degree of Master of Public (MPH)

Date: 15th September 2021

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Acknowledgement

I am grateful to the Almighty who has given me the strength, attitude, confidence, and skill to complete the study. This study is done as a thesis work of my Masters of Public Health (MPH) degree. It is of immense pleasure and pride to express my sincerest gratitude and deepest regards to Prof. Mahbub Latif, Ph.D. Institute of Statistical Research and Training (ISRT) University of Dhaka, Bangladesh, for his inspiration, cooperation, kind help, and guidance from beginning to end of this study.

With pleasure, I express my thanks to Dr. Nafisa Huq, Assistant Professor, and Course Coordinator, SPPH, IUB, for her whole hearted support and encouragement throughout the MPH course. My heartiest regards, profound and deepest appreciation to course coordinator Dr. S. M. Raysul Haque, Assistant Professor, Department of Public Health, SPPH, IUB, and Dr. Shabareen Tisha, Senior Lecturer, Department of Public Health, SPPH, IUB, for graceful support and encouragement. Thanks to Dr. JMA Hannan, Honorable Dean & Professor, SPPH, IUB, for his all cooperation.

I would also like to express my thanks to my classmates of MPH program in IUB for their encouragement and support. I additionally thank my parents for the persistent consolation, support and consideration.

Dated: 15th September 2021 Shuchita Rahman

Student Id- 19341514

Abbreviation

IUB - Independent University of Bangladesh

EPI - Expanded Program on Immunization

WHO - World Health Organization

DPT - diphtheria-pertussis-tetanus

Penta - Pentavalent

VPD - Vaccine Preventable Disease

SIA - Supplementary Immunization Activities

ANC - Antenatal Care

PNC - Postnatal Care

Hib - Haemophilus Influenzae type b

OR - Odds Ratios

CI - Confidence Intervals

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Abstract

Background: Achieving immunization through vaccination is an integral part of strengthening a country's health system, and childhood vaccination has played a pivotal role in improving the health care of a population. One of the transformative vaccination programs which played a significant role in the war against diphtheria, tetanus, hepatitis, pertussis, and Hib diseases is the pentavalent combination DTP-HB-HIB in the Expanded Program on Immunization (EPI) vaccination program.

Objective: This study conducted to determine the factors associated with the coverage gap of pentavalent vaccines among Bangladeshi children. The study was aimed to build awareness in removing barriers, and improving coverage and equity of pentavalent vaccination in children of Bangladesh.

Methods: A nationally representative survey data obtained from the Bangladesh Demographic and Health Survey 2017-18 (BDHS-2017) was used for this study. Multivariable logistic regression models were used to analyze a sample of 5049 children to examine the influence of socio-demographic and other related variables on vaccination. Effects of children and women-related variables on whether three-dose of pentavalent vaccination schedule was completed or not were also examined.

Results: First child is more (about 65%) likely to complete three dose of pentavalent vaccine compared to children of other birth orders. A secondary educated mother has 1.8 times higher odds of being fully vaccinated her child compares to that of a mother with no education (OR=1.780, $p<0.001$), and working mothers are 1.7 times more likely to administer the vaccine to their children than the non-working mother (OR=1.750; $p<0.001$). And mothers exposed to media outlets are more likely to give their children all three doses than those who were not exposed (OR=1.260, $p<0.008$).

Conclusion: Pentavalent vaccination coverage among children is greatly influenced by the mother's demographic and behavioral pattern, so awareness should be emphasized on educating mothers about the vaccination program.

Chapter-I

Introduction

Immunization is an effective method for preventing childhood diseases and supports some conditions enduring life. Vaccination played a pivotal role in the war against disease, reduced the incidence, and controlled and contained the outbreak of many more (Sreedhar *et al.,* 2014). The practice of vaccine administration is central to successful childhood immunization programs. The global burden of Haemophilus influenza type B - Hib disease is substantial but vaccine preventable. Expanded use of Hib vaccine could reduce childhood pneumonia and meningitis and decrease mortality. Hib vaccines were rapidly introduced in North America and Western Europe, but slowly in developing countries because of its high cost, concerns about the program, sustainability, limited vaccine supply, and uncertainty about the Hib disease burden. Hib Vaccination prevents Haemophilus influenza type B diseases, which include Pneumonia, Meningitis, Bacteremia, Epiglottitis, Septic Arthritis, etc. (Bavdekar *et al.*, 2019a). In all developed and developing countries where Hib vaccine has been introduced has nearly eliminated Hib disease (Verma *et al.*, 2013). Five antigens diphtheria, pertussis, tetanus, and hepatitis B and Haemophilus influenza type b are available as pentavalent combination DTP-HB-Hib vaccine, and used in the national immunization programmes of many developing countries (Bavdekar *et al.*, 2019b). In Bangladesh, in 2006, the pentavalent vaccine was introduced in the Expanded Program on Immunization (EPI).

Globally since 1980, significant progress in up-to-date vaccination coverage has been made to prevent 2 to 3 million deaths estimated yearly from Vaccine-Preventable Diseases (VPDs). Despite this overwhelming success, an estimated 1.5 million children still die every year, mainly in developing countries due to VPD. Thus, a child should be vaccinated within the recommended age and intervals to achieve maximal protection from VPDs (Tamirat and Sisay, 2019). The

Expanded Program on Immunization (EPI) was initiated in 1974 as a global agreement to collaborate nations as a priority program. The goal was to expand immunization services and coverage by following World Health Organization (WHO) recommended international guidelines (Vincent *et al.*, 2012). In 1979, the government of Bangladesh initiated EPI against six preventable diseases (Tuberculosis, Diphtheria, Pertussis, Tetanus, Polio, and Measles). Efforts intensified after 1985 when Bangladesh committed itself to reach universal child immunization by 1990. Like other countries, Hib disease occurred continuously before being introduced Hib vaccines were broadly introduced in Bangladesh (Sarker *et al.*, 2019).

This pentavalent vaccine has largely supplanted other pediatric combination vaccines (DTP/IPV-HepB-Hib), especially in middle- and low-income countries. By 2013, 100% of the DTP-containing vaccines were procured by UNICEF, for which pentavalent vaccines accounted for a considerable proportion of the world's children (Berhane *et al.*, 2014). There are three doses of pentavalent vaccine, known as Penta 1, 2, and 3. The generic name for this vaccine is Diphtheria, Tetanus, Pertussis (whole cell), Hepatitis B (rDNA), and Haemophilus influenza type B conjugate vaccine (absorbed) or DTP-HepB-Hib. Combination vaccines consisting of a single injection, contains two or more antigens against multiple diseases. It presents a practical approach to improving vaccine coverage, timeliness of administration, and compliance. (Lakew *et al.*, 2015). It is necessary to prioritize and monitor the immunization program efficiently. This will help us to reduce delayed and incomplete vaccination and ensure the benefits of immunization. (Sheikh *et al.*, 2018)

WHO recommends vaccinating children all recommended vaccines before their first birthday and recording the vaccinations history on a vaccination card issued to the parent (Malik, 2014). It was also recommended that each dose of vaccine should be given according to schedule that depends on age and any delay in the schedule is undesired. The status of vaccination coverage

given to the community depends on service factors and public understanding and trust in the immunization process. The vaccination coverage status of a community depends on awareness and trust in service and the process (Cooper *et al.*, 2008).

Accordingly, scheduled Pentavalent 1–3 and Measles vaccine doses are given at six weeks, ten weeks, 14 weeks, and nine months of age, respectively. The minimum interval will be four-weeks, which might require less antibody response on sub-optimal stereo conversion rate (Lakew *et al.*, 2015). Delayed or an altered sequence of vaccinations, which causes non-specific effects of vaccines with negative consequences on childhood morbidity and mortality. Moreover, delayed vaccination is found to be a risk factor for Pertussis, Measles, and invasive Haemophilus Influenzae type B diseases. At the same time, infants and children in their early life are most vulnerable and exposed to vaccine-preventable conditions. Therefore reduce the risk of having those diseases from unvaccinated children due to herd immunity (Lakew *et al.*, 2015).

In many countries, strategies under the government health policy focused on improving child health such as Vaccination (Tamirat *et al.*, 2019). Worldwide, studies showed that only a small proportion of children received all recommended vaccine doses on time, even with high coverage. Researchers observed a substantial delay in timely vaccination receipt in Sub-Sahara African countries, and maintaining recommended vaccination schedule is schedules very scarce. There is also limited information on the scope of age-appropriate vaccination and its associated factors for pentavalent (Lakew *et al.*, 2015).

Maternal education and child health are strongly related. Household income, employment status, wealth condition, residence, etc., are also essential. Socio-demographic factors influence vaccination coverage significantly, especially in vaccination uptake(Forshaw *et al.*, 2017) Effect of mother-related factors increases the likelihood of child vaccination practice, e.g. mothers with secondary education are better informed about immunization, and their children are more likely

to be vaccinated to those mothers with primary education (Marefiaw *et al.*, 2019). Mothers' education allows more significant exposure to the mass media, keeping mothers better informed about the health issues (Baker *et al.*, 2007). Immunization compliance increased with the mothers' with higher financial condition are credible to immunize their children than mothers with relatively poor economic condition (Mukungwa, 2015). Immunization compliance is also higher for mothers who previously utilized antenatal care services during pregnancy and delivered in health care facilities (Al-lela *et al.*, 2014). Family's economic status is also relevant with child vaccination rate as well as mothers' empowerment to make decisions and implement children's health care which plays a vital role (Subhani *et al.*, 2015).

In a study on "Child immunization coverage in urban slums of Bangladesh" in 2010 revealed that the mothers working out of their homes had solid financial power, so they got the right to participate in family decisions. Working mothers are intense to get their children vaccinated compared to non-working mothers (Uddin *et al.*, 2010). A significant relationship between child immunization and birth order was found to be significant (Valadez and Wel, 1992). Positive and meaningful relationship between mother's age and child immunization was found in a study conducted in Nigeria (Babaloa, 2009). Older mothers were more sensible, so most of their children got vaccinated (Ibnouf *et al.* 2014).

The coverage gap which was found in different vaccination doses but in the same schedule had valuable factors. Some socio-demographic factors which are significantly associated with immunization practice. These factors have a high impact on coverage gap, which is also an issue in public health. Vital reasons for dropping vaccines are postpone for afterward, a child being sick (for this reason not being bring to the center for immunization), unaware of the importance of vaccination, place of immunization being far, no faith in vaccination, unaware of the need to return for 2nd and 3rd dose, a mother being too busy, fear of side effects, wrong ideas about

immunization, lack of public understanding, and trust in the immunization process etc (Atkinson and Cheyne, 1994).

To this end, the current thesis seeks to conduct a study to estimate effects of socio-demographic factors on incomplete Pentavalent vaccines, i.e. whether three-dose are completed or not. Specific objectives are to observe the significance of socio-demographic characteristics and identify the other potential determinants for vaccination uptake in Bangladesh. The study hypothesizes that women's education, working status, and empowerment factors are significantly associated with the gaps in pentavalent vaccine doses.

Chapter-II

Materials and Methods

2.1 Bangladesh Demographic and Health Survey 2017

This thesis is based on secondary data from the standard Demographic and Health Survey (DHS) collected nationally in Bangladesh 2017-18. The survey was conducted in four phases by Mitra and Associates under NIPORT (National Institute of Population Research and Training) of the Ministry of Health and Family Welfare with financial support USAID. Bangladesh Demographic and Health Survey (BDHS) 2017-18 is the eights in a series of DHS undertaken in Bangladesh. The BDHS is a vital source of records on socio-economic status, demographic information, marriage, sexual activity, fertility information, contraceptive use, fertility preference and regulation, Women empowerment, and health-seeking-related information. The inclusion criterion for the study was married at the time of survey, age between 15 and 49 years and had their most recent births within the 3 years preceding the survey.

BDHS-2017 is a cross-sectional survey that is nationally representative. The survey used a two-stage stratified sampling design, and data collection was done over the duration. Six months, from June 2017 to November 2017. A total of 20,376 ever-married women age 15-49 were selected, and with a 98.4% response rate, a total of 20,127 interviews were successfully conducted. Further explanations about sampling design and other related issues of the 2017-18 BDHS are accessible elsewhere. Ethical Clearance included in BDHS2017, no other procedure needed to use this secondary dataset.

Three types of questionnaires were used in BDHS 2017. which are household questionnaire (division, area of residence, socioeconomic status, drinking water source, type of fuel for cooking, type of toilet facility), woman's questionnaire (woman's age, marital status, educational

level, currently working, read newspaper or magazine, watching TV, listing Radio, healthcare facilities, ANC, cesarean section, child's age, birth order, sex, ever breastfed, nutritional status, vaccination status, women empowerment index questions: decision making on health and family issues, and community questionnaire. The women's questionnaire collected socio-demographic, maternal, and child indicators including individual-level vaccination coverage. The study participants were the mother with at least a child aged between 1 and 5 years. History of vaccinations of their children has been collected for all surviving children over the last five years. Data on vaccination are obtained from the records on vaccine cards; if the vaccine card was not available, mothers had asked to recall the vaccination history of the respective child. Face-to-face interviews were conducted with selected women to collect data using structured questionnaires.

2.2 Outcome and explanatory Variables

The outcome variable of the analysis is to assess the coverage gap between all the three doses of pentavalent vaccine received by the children. A child was said to be fully vaccinated with no coverage gap, if they have taken all the three doses of the pentavalent vaccine according to the schedule. Coverage gap is said to be present if a child did not received all the three doses in the scheduled time prescribed by the healthcare center.

In the analysis, the vaccination status of children 12–59 months old was included. In a few cases, the immunization cards were not available, and mothers responded 'don't know while asking about their children's vaccination status on certain vaccines. In those cases, vaccination status is considered as 'not fully vaccinated.

Explanatory variables selected for this study are based on the published literature, prior knowledge, and availability of variables in the dataset BDHS 2017. The residence, geographical administrative division, children's sex and age, birth order of children, family size, parent's

education, mass media exposure, household wealth index, and the mother's decision-making ability for both the children and their healthcare matters included explanatory variables. In the analysis, categorization of continuous variables has been done in light of previous literature.

2.3 Statistical Analysis

Data scrutinizing, cleaning and inconsistency checking was done through the execution of range and influential/outlier value identification. All the identified influential missing observations were excluded from the data set. Finally, a total of 5049 children are taken as the sample observation. The associations between socio-demographic factors and the gap of three doses of pentavalent vaccination assessed by using Multivariate logistic regression, with estimates of odds ratios (OR) and 95% confidence intervals (CI) for under-vaccinated compared to fully vaccinated Children. Data management and analysis were performed using Statistical package R (version 3.6.2)

Chapter- III

Analysis of Pentavalent Vaccination Gap

The analysis has two parts, the first part contains the exploratory analysis of variables related to vaccine incompliance and the second part is based on fitting a logistic regression model.

3.1 Exploratory Analysis

The sample of 5049 children consisted of information about children 12–24 months of age at the survey time. Descriptive statistics associated with variables related to children mother and household are described in Tables 1, 2, and 3.

The child's age was categorized into four groups at 12-month intervals; maternal age was categorized into four groups. Parents' educational attainment was categorized into four groups: no education, primary, secondary, and higher education). Family size determined the number of family members who lived together in a household. Mass media access is categorized as 'yes' if the family had access to televisions and radios and 'no' otherwise. The predetermined wealth index category in the dataset was generated from selected household assets using principal component analysis, which was classified in five groups ('poorest', 'poorer', 'middle', 'rich' and 'richest'). Furthermore, the decision-making ability of the mothers for both their children and personal healthcare were placed in two categories: ‘herself' and 'husband.'

Table1: Descriptive Statistics of Children-related Variable

Variables	Frequency	Percentage (%)
Pentavalent Vaccination		
Vaccinated	4050	80.2
Year of birth		
2014	94	1.9
2015	1538	30.5
2016	1653	32.7
2017	1690	33.5
2018	74	1.5
Birth Order		
1	1945	38.5
2	1630	32.3
3	862	17.1
4+	612	12.1
Sex of Child		
Girl	2394	47.5
Age of Child		
0-12	1784	35.3
12-24	1644	32.6
24-36	1621	32.1
Age in year (Mean and SD)	0.96	0.82 (SD)
Place of Delivery		
Home	2510	49.7

In Table 1, summary statistics of both dependent and children- related variables, showing that only 19.8% of children were not vaccinated completely. Among the selected 5049 children, 47.5% were girls, and about 50% were delivered at home. About 38.5% of selected children were the first birth, and only about 12% were of birth order four or more. The average age of the children is less than 12 months, and proportions of children of age group 0-12, 12-24, and 24-36 months are quite similar.

Table 2: Descriptive Statistics of Mother-related Variable

Variables	Frequency	Percentage (%)
Mothers Age-(categorical)		
15-19	856	16.8
20-24	1810	35.4
25-29	1321	25.9
30-34	758	14.8
35+	304	6.0
Mothers Age (In Years)	24.93(Mean)	5.53(SD)
Mothers Education		
No Education	324	6.4
Primary	1386	27.5
Secondary	2407	47.8
Higher	919	18.2
Husband Education		
No education	691	13.7
Primary	1699	33.7
Secondary	1660	33.0
Higher	986	19.6
Religion		
Muslim	4636	91.8
Mother's Working status		
Working	3191	63.20
Women empowerment Index		
Respondent	1367	27.1
Husband	3682	72.9
ANC		
Less than 4	2529	51.6
4+	2369	48.4
Cesarean section delivery		
Yes	1706	33.4

Table 2, shows the descriptive statistics of the mother-related variable which shows that almost half of the selected mothers have completed secondary education (47%) and 6.4%, 28% 18% of then had no formal education , primary education, and higher education respectively. About 33.7% of husbands has a primary level of education while 33% had at least secondary level of education out of 5049 mothers 35.9% had their first child within the age of 20-24 years, and the mean age of the mothers was 25. In the case of religion 91.8% are Muslims. The working mother group consists of 63.2% of the total respondents, and 73% of the mothers have considered their husband as the sole decision-maker for their healthcare. The proportion of respondents taking ANC four or more times is 51.6%, and that of the respondents given birth by caesarean section is 33.4%.

Table 3: Descriptive Statistics of Household-related Variables

Variables	Frequency	Percentage (%)
Place of Residence		
Urban	1726	34.2
Rural	3323	65.8
Media Exposed		
Yes	3212	63.8
Wealth Index		
Poorest	1086	21.57
Poorer	1028	20.36
Middle	908	17.98
Richer	996	19.73
Richest	1028	20.36
Administrative Division		
Barisal	531	10.5
Chittagong	855	16.9
Dhaka	740	14.7
Khulna	513	10.2
Mymensingh	605	12.0
Rajshahi	524	10.4
Rangpur	562	11.1
Sylhet	719	14.2
Family Size	6.16(Mean)	2.71(SD)

Table 3, showing summary statistics of independent house hold related variables, respondents are from 8 administrative divisions, and most of them are from the Chittagong division (16.8%), followed by Dhaka (14.7%) and Sylhet (14.2%) divisions. Among the respondents, 65.8% reside in a rural area, while 34.2% reside in urban area. Respondents in exposure with media are 63.8%, while 36.2% are not in direction with media. In the case of the wealth index, we can see all the groups have almost similar distribution while Poorest has the maximum 21.6% respondents and middle class consists the lowest 17.9%. The mean of family members is 6.

3.3 Regression models

A multivariable logistic regression model was considered for assessing the coverage gap of pentavalent vaccination. Here dependent variable is compiling three-dose of Pentavalent vaccine, and the independent variables are, childes sex, birth order, place of delivery, mothers education, her husband's education, wealth index, working status, age, child birth order, religion, residence, divisional administration. place of delivery, ANC4+, cesarean section delivery etc. are considered. Estimates of model parameters and corresponding p-values, and 95% confidence intervals are shown in three different Tables (4, 5, and 6).

Table 4: Estimates of Model Parameters and Corresponding p-values, Odds Ratios, and 95% Confidence Intervals for Children-related Variables Considered in the Logistic Regression Model.

Variables	Estimate	OR	P-value	95% CL of OR	
				Lower	Upper
Sex of children					
Male					
Female	-0.0467	0.954	0.528	0.825	1.103
Birth Order					
First Birth					
2	-0.430	0.650	< 0.001	0.533	0.792
3	-0.786	0.456	<0.001	0.346	0.598
4+	-1.170	0.309	<0.001	0.218	0.437
Place of Delivery					
Hospital					
Home	-0.042	0.959	0.703	0.772	1.185

From Table 4, it is seen that sex of child has no significant effect, the birth order of the child is statistically significant with the Pentavalent vaccination schedule ($p<0.001$). As the birth order increases, odds of compiling three-dose vaccination significantly decreases, e.g. for a child of second birth, the odds decreases about 35% compared to that of a child of first birth, decreases of the same odds is about 55% and 70% for a child of birth order 3 and more, respectively compared to a child of the first birth. Gender of the child and place of delivery did not have any association with completing three doses of vaccine.

Table 5: Estimation of women Empowerment Index and Other Women Variable from Regression model

Variables	Estimate	OR	P-value	95% CL of OR	
				Lower	Upper
Mothers Age	0.085	1.090	< 0.001	1.066	1.112
Maternal Education					
No Education					
Primary	0.244	1.320	0.069	0.975	2.434
Secondary	0.549	1.780	<0.001	1.296	0.890
Higher	0.248	1.310	0.170	0.888	1.926
Husband's Education					
No Education					
Primary	-0.008	0.991	0.941	0.784	1.248
Secondary	0.026	1.030	0.839	0.794	1.323
Higher	-0.109	0.897	0.506	0.649	1.236
Women Empowerment in health care					
Respondent					
Husband	-0.047	0.954	0.151	0.894	1.768
ANC visits					
less than 4					
4+	0.208	1.230	0.013	1.048	1.447
Caesarean section					
No					
Yes	-0.081	0.921	0.482	0.732	1.156
Mother Currently Working					
Not working					
Working	0.559	1.750	<0.001	1.479	2.072

From Table 5, it is observed that Mother's education has an impact on the compiled three-dose of Pentavalent vaccination. A child of a secondary educated mother has 1.8 times higher odds of being fully vaccinated than a child of a mother with no education (OR=1.780; $p<0.001$), and working mothers are 1.7 times more likely to administer the vaccine to their children than the non-working mothers (OR=1.750, $p<0.001$). Additionally, Antenatal care (ANC) during pregnancy the mother who had more than four times (4+) visits had a significant association with the vaccine uptake; the odds of the child getting vaccinated is 1.23 times more in mothers receiving ANC than those who were devoid of it (OR=1.230, P-value=0.013). Husbands' education level and husband decision-making in the mother's healthcare did not play a significant role in pentavalent vaccine administration ($p>0.05$).

Table 6: Estimation of Household Variable from Regression Model

Variables	Estimate	OR	P-value	95% CL of OR	
				Lower	Upper
Media Exposure					
Non Exposed					
Exposed	0.234	1.260	0.008	1.061	1.503
Place of Residence					
Urban					
Rural	0.081	1.080	0.355	0.912	1.287
Administrative					
Division					
Barisal					
Chittagong	0.003	0.996	0.979	0.746	1.325
Dhaka	-0.022	0.978	0.886	0.721	1.322
Khulna	-0.201	0.818	0.223	0.592	1.130
Mymensingh	128	0.880	0.405	0.651	1.187
Rajshahi	0.059	1.060	0.721	0.765	1.475
Rangpur	0.011	1.010	0.942	0.733	1.397
Sylhet	-0.267	0.765	0.698	0.572	1.020
Wealth Index					
Poor					
Poorer	0.036	1.040	0.753	0.936	1.782
Middle	-0.127	0.881	0.314	0.688	1.127
Richer	0.025	1.034	0.849	0.786	1.339
Richest	0.255	1.269	0.120	0.936	1.782

It is seen from Table 6 that the women in urban areas are 1.08 times more likely to complete the full dose schedule of pentavalent vaccine than the ones residing in rural areas. (OR=0.355, CL= 0.912, 1.287). Similarly, the odds of completing the three doses of pentavalent vaccine tend to get higher as the wealth index changes from poorest to richest. (OR = 0.881, 1.034, and 1.269). Mothers exposed to media with the frequency of access to radio, television, and newspaper combined are more likely to give their children all three doses than those not exposed to media outlets (OR=1.260, CL=1.061,1.503).

Chapter-IV

Discussion

Vaccinations are a vital element of the UN- SDGs, which contain end preventable deaths of young children, reducing under-five mortality, and ensure admission to vaccines for all (UN *SDG*,2017). A nationally representative sample from the most recent BDHS 2017 found relatively elevated vaccination reporting in Bangladeshi children 1–2 years of age and significant `disparities. Vaccination coverage was found relatively low for those children whose mothers have no education, are not working, are lower in wealth index, do not have media exposure, and do not participate in healthcare decision-making. These result can helps to guide immunization programming to apply more resources to routine immunization services for specific socio-demographic groups or decide whom and where to target SIAs (Supplementary Immunization Activities) to improve coverage (Kagoné *et al.*, 2017). These are also addressed in the SDGs

This study analyzes a data set obtained from BDHS-2017 with a total of 5049 children. In tabular form, a descriptive summary of vaccinated status was exposed to the rest of the child's characteristics related to vaccination, mother's characteristics, and household factors variables. For the multivariable logistic regression model, analyses were adjusted with the significant variables. Significant risk factors of pentavalent vaccination gap among Bangladeshi children were associated with age, mother's education, working status, socio-economic status, area of residence, media exposure, and received maternal care at pregnancy (ANC). Previously, an investigation on vaccination in the United States found that maternal education was a significant predictor of childhood vaccination coverage (Jain *et al.*, no 2015). In another study in India was to examine the association of maternal autonomy with preventive and curative child health care utilization were a particular association of Mothers autonomy (in decision making, access to

finance and resources, and freedom of movement) with child's primary immunization and seeking treatments for acute respiratory infection of children (Malhotra *et al.*, 2012).

This study found that the first child is more (about 65%) likely to complete three doses of pentavalent vaccine than children of other birth orders. It seems that Mothers are more sincere in completing the entire course of pentavalent vaccine for their 1st child compared to her 2nd, 3rd or more children. A child's birth order is inversely related to vaccination status and presents a nonlinear exposure-response relationship, and an independent risk factor for under immunization, associated with childhood vaccination status beyond economic, social, and demographic parental characteristics (Natalie *et al.*, 2012).

A mother who has education for secondary level is more aware (1.8 times) of completing the vaccination to her child than a mother who doesn't have any education. The role of mothers' education determined the possibility that children receive vaccination on time. As the education level increases, considerable improvements are seen in pentavalent vaccination uptake coverage. So, Mothers' education is likely to play an essential role in the practical progress of childhood immunization (Kibreab *et al*, 2020). In this study, the education level of a father was found less effective than mothers' education in vaccination uptake of children. It is acknowledged that removing the hindrances on maternal education in nations could be an effective strategy for significant progress in pentavalent vaccination uptake. Education is essential to adopt things those effects are not visible immediately, and vaccination is one of them (Streatfield *et al,* 1990).

Moreover, the odds pentavalent vaccination uptake among children of working mothers was 1.7 times higher than other mothers. It seems Working mothers are more likely to administer the vaccine to their children than non-working mothers. Impact of mothers working has shown in a study that unemployed mothers had less probability of immunizing their children. They had.588

less likelihood to partially vaccinate their children compared to the employed mothers of the country. It was recommended the male and females should give equal chances of employment in the country (Subhani *et al.,* 2015). In addition, complete childhood vaccination is positively associated with exposure to media for vaccine uptake (Boulton *et al.*, 2018). Similarly, this study has found that Mothers exposed to media outlets are more likely to give their children all three doses than those not exposed. Children of mothers of age 30 or less are more likely to recive Vaccination compared to the other children.

Moreover, Antenatal care (ANC) during pregnancy, the mother who had more than four times (4+) visits had a significant association with the vaccine uptake; the odds of the child getting vaccinated is 1.23 times more in mothers receiving ANC than those who were devoid of it. It has been found in national guidelines and SOPs (Standard Operating Procedure) that a mother should attend more than four times ANC visits at maternity clinics, and four times PNC after delivery, they got immunization information along with maternal care and family planning there (Heim *et al*, 2019). Other socio-demographic and household factors like residence, delivery, and decision-making on health care do not show a significant association with pentavalent vaccine uptake.

About the strengths and limitations of this study, the robust database from the DHS is the main strength and it ensured a sample representative of the entire country. The data were obtained from previously validated questionnaires. However, the cross-sectional nature of the DHS complicates the determination of causality and is a limitation of the study. Some information is based on parental recall, and individuals of different demographic groups may remember information about their child's vaccination status differently.

In conclusion, this study found that pentavalent vaccination coverage in Bangladesh was the significant rate in the WHO Southeast Asia Region for several antigens, and coverage increased rapidly over the 18 years 2006–2021 in EPI, still showing disparities. Though the coverage gap

has reduced over the year, the gap is undesired in the same vaccination schedule. While this is encouraging and may not be surprising given Bangladesh's rapidly growing economy, significant disparities in coverage by wealth status and healthcare access remain. Geographical and demographic differences in vaccination may portend difficulties in eliminating preventable diseases within Bangladesh.

We need to emphasize mothers' educational levels and working status to enhance their knowledge and support children's development financially. The more the mothers are educationally qualified, the more they can do a qualified job and improve their socio-economic status. Thus, the effect of non-working mothers with no education living in low-income families in other urban areas was higher than others. The use of a combined vaccine protecting against six childhood diseases has an even more significant impact where remoteness and healthcare access stands in the way of vaccination, and children receiving at their eligible age was a finding that deserves further study.

Recommendation

Future success in increasing all childhood vaccination coverage will require improvements in healthcare access to reach the poor and underserved populations. The success of vaccination programs would also benefit from mothers having greater autonomy in making healthcare decisions about their children and themselves. Some recommendation based on the study for full coverage of pentavalent vaccine uptake, are-

- Mothers/caregivers should ensure equitable access to vaccination for all of their children.
- Awareness among the mothers who are not educated needs to be increased consistently on a targeted basis.
- Non-working mothers need more motivation and follow-up (through IPC sessions/health workers) to get the vaccination for their children in a timely manner.
- Emphasis on the importance of timely vaccination during seeking ANC4 and PNC visits by the health care provider.
- To sustain and improve vaccination coverage gains necessary to link future analytic approaches, strategies, and planning for higher-level health-system strengthening.

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Annex

R script

```
library (tidyverse)
library (labelled)
# Spenta_dat <- haven::read_spss(file = "BDKR7RFL.SAV")
#view(Spenta_dat)
load("Spenta_dat.Rdata")
#Spenta_dat <- Spenta_dat %>%
  filter(!(is.na(H3) & is.na(H5) & is.na(H7))) %>%
  filter(!(H3 == 8 & H5 == 8 & H7 == 8)) %>%
  select(CASEID, H3,H5,H7,B2,B4,B8,BORD,V012,V013,V024,V025,V106, V130,
V136,V157,V158,V159,V190,V701,V714, M15,M17, M14,V743A) %>%   mutate(
     V013 = to_factor(V013),
     V024 = to_factor(V024),
     V025 = to_factor(V025),
     V106 = to_factor(V106),
     V190 = to_factor(V190),
     V701 = to_factor(V701),
     V701 = fct_recode(V701, NULL = "Don't know"),
     V714 = to_factor(V714),
     B4 = to_factor(B4),
     H31 = if_else(H3 == 0, 0, 1),
     H51 = if_else(H5 == 0, 0, 1),
     H71 = if_else(H7 == 0, 0, 1),
     yall = if_else(H3 > 0 & H5 > 0 & H7 > 0, 1, 0),
     Decission = if_else (V743A <= 2, 1,0),
     Place_delivary = if_else(M15 == 11, "Respondent's home", "Hospital & Others"),
     Place_delivary = factor(Place_delivary),
     media = if_else(V157 == 0 & V158 == 0 & V159 == 0, 0, 1),
     islam = if_else(V130 == 1, "Islam", "Others"),
     M14 = if_else ( M14 <4, 0, 1),  border = if_else(BORD > 3, "3+", as.character(BORD)))
     save(Spenta_dat, file = "Spenta_dat.Rdata")
#Spenta_dat %>% count(Decission)
Spenta_dat %>% count(M14)
Spenta_dat %>% count(M17)
Spenta_dat %>% count(B2)
library (broom)
#Model - child sex+birth order_ place of delivary+mothers age+ mothers edu+Husband
_edu +Currently working+religion+media+ adminstrative division+place of residence +
wealth_index
mod2 <- glm(yall ~ B4 + border + Place_delivary + V012 +V106 + V701 + V714 + islam +
media + V025 + V024 + V190 + V743A + M14 + M17,   family = binomial("logit"), data =
Spenta_dat)
broom:: tidy(mod2)%>% mutate (OR = exp(estimate)) %>%  select (term, estimate,
p.value, OR )%>%  print(n = 50)
exp(confint(mod2))
summary(mod2)
```

Questionnaire

SECTION 5A. CHILD IMMUNIZATION (LAST BIRTH)

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
501A	CHECK 215 IN THE BIRTH HISTORY: ANY BIRTHS IN 2014 OR LATER? ONE OR MORE BIRTHS IN 2014 OR LATER ☐ NO BIRTHS IN 2014 OR LATER ☐ → 601		
502A	RECORD THE NAME AND BIRTH HISTORY NUMBER FROM 212 OF THE LAST CHILD BORN IN 2014 OR LATER. NAME OF LAST BIRTH _____ BIRTH HISTORY NUMBER . . . . . ☐☐		
503A	CHECK 216 FOR CHILD: LIVING ☐ DEAD ☐ → 501B		
504A	Do you have a card or other document where (NAME)'s vaccinations are written down?	YES, HAS ONLY A CARD . . . . . 1 → 507A YES, HAS ONLY ANOTHER DOCUMENT . . . . 2 YES, HAS CARD AND OTHER DOCUMENT . . . . 3 → 507A NO, NO CARD AND NO OTHER DOCUMENT . . 4	
505A	Did you ever have a vaccination card for (NAME)?	YES . . . . . 1 NO 2	
506A	CHECK 504A: CODE '2' CIRCLED ☐ CODE '4' CIRCLED ☐ → 511A		
507A	May I see the card or other document where (NAME)'s vaccinations are written down?	YES, ONLY CARD SEEN . . . . . 1 YES, ONLY OTHER DOCUMENT SEE . . . . . 2 YES, CARD AND OTHER DOCUMENT SEEN . . 3 NO CARD AND NO OTHER DOCUMENT SEE . . 4 → 511A	

SECTION 5B. CHILD IMMUNIZATION (NEXT-TO-LAST BIRTH)

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
501B	CHECK 215 IN THE BIRTH HISTORY: ANY BIRTHS IN 2014 OR LATER? MORE BIRTHS IN 2014 OR LATER ☐ NO BIRTHS IN 2014 OR LATER ☐ → 501		
502B	RECORD THE NAME AND BIRTH HISTORY NUMBER FROM 212 OF THE LAST CHILD BORN IN 2014 OR LATER. NAME OF NEXT-TO-LAST BIRTH _____ BIRTH HISTORY NUMBER . . . . . ☐☐		
503B	CHECK 216 FOR CHILD: LIVING ☐ DEAD ☐ → 526B		
504B	Do you have a card or other document where (NAME)'s vaccinations are written down?	YES, HAS ONLY A CARD . . . . . 1 → 507B YES, HAS ONLY AN OTHER DOCUMENT . . . . 2 YES, HAS CARD AND OTHER DOCUMENT . . . . 3 → 507B NO, NO CARD AND NO OTHER DOCUMENT . . 4	
505B	Did you ever have a vaccination card for (NAME)?	YES . . . . . 1 NO 2	
506B	CHECK 504B: CODE '2' CIRCLED ☐ CODE '4' CIRCLED ☐ → 511B		
507B	May I see the card or other document where (NAME)'s vaccinations are written down?	YES, ONLY CARD SEEN . . . . . 1 YES, ONLY OTHER DOCUMENT SEE . . . . . 2 YES, CARD AND OTHER DOCUMENT SEEN . . 3 NO CARD AND NO OTHER DOCUMENT SEE . . 4 → 511B	

SECTION 5A. CHILD IMMUNIZATION (LAST BIRTH)

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	NAME OF LAST BIRTH _____	BIRTH HISTORY NUMBE	
508A	COPY DATES FROM THE CARD. WRITE '44' IN 'DAY' COLUMN IF CARD SHOWS THAT A DOSE WAS GIVEN, BUT NO DATE IS		

	DAY		MONTH		YEAR			
BCG								
PENTA 1								
PENTA 2								
PENTA 3								
OPV/POLIO 1								
OPV/POLIO 2								
OPV/POLIO 3								
PCV/PNEUMOCOCCAL 1								
PCV/PNEUMOCOCCAL 2								
PCV/PNEUMOCOCCAL 3								
IPV								
fIPV 6 WEEKS								
fIPV 14 WEEKS								
MR AT 9 MONTHS								
MR AT 15 MONTHS								
VITAMIN A (MOST RECENT)								

509A	CHECK 508A: 'BCG' TO 'MR AT 15 MONTHS', ALL RECORDED? NO ☐ YES ☐ → 525A		
510A	In addition to what is recorded on (this document/these documents), did (NAME) receive any other vaccinations, including vaccinations received in campaigns or immunization days or child health days? RECORD 'YES' ONLY IF THE RESPONDENT MENTIONS AT LEAST ONE OF THE VACCINATIONS IN 508A THAT ARE NOT RECORDED AS HAVING BEEN GIVEN.	YES . . . . . 1 (PROBE FOR VACCINATIONS AND WRITE '66' IN THE CORRESPONDING DAY COLUMN IN 508A THEN WRITE '00' IN THE CORRESPONDING DAY COLUMN FOR ALL (THEN SKIP TO 525A) NO . . . . . 2 DON'T KNOW . . . . . 8 (WRITE '00' IN THE CORRESPONDING DAY COLUMN FOR ALL VACCINATIONS NOT (THEN SKIP TO 525A)	

SECTION 5A. CHILD IMMUNIZATION (LAST BIRTH)

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	NAME OF LAST BIRTH _____	BIRTH HISTORY NUMBE	
511A	Did (NAME) ever receive any vaccinations to prevent (NAME) from getting diseases, including vaccinations received in campaigns or immunization days or child health days?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 525A
512A	Has (NAME) ever received a BCG vaccination against tuberculosis, that is, an injection in the left upper arm or shoulder that usually causes a	YES ..... 1 NO ..... 2 DON'T KNOW 8	
514A	Has (NAME) ever received a pentavalent vaccination, that is, an injection given in the thigh at the same time as polio drops and PCV?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 516A
515A	How many times did (NAME) receive the pentavalent vaccine?	NUMBER OF TIMES	
516A	Has (NAME) ever received oral polio vaccine, that is, about two drops in the mouth to prevent polio?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 519A
517A	Did (NAME) receive the first oral polio vaccine in the first two weeks after birth or later?	FIRST TWO WEEKS ..... 1 LATER 2	
518A	How many times did (NAME) receive the oral polio vaccine?	NUMBER OF TIMES	
519A	Has (NAME) ever received a pneumococcal vaccination, that is, an injection in the thigh to prevent pneumonia?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 521A
520A	How many times did (NAME) receive pneumococcal vaccination?	NUMBER OF TIMES	
521A	Has (NAME) ever received an IPV vaccination, that is, an injection in the thigh to prevent polio?	YES ..... 1 NO ..... 2 DON'T KNOW 8	
523A	Has (NAME) ever received a measles-rubella vaccination, that is, an injection into the muscles of the left thigh to prevent measles?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 525A
524A	How many times did (NAME) receive the measles-rubella vaccine?	NUMBER OF TIMES	
525A	Did (NAME) receive any polio vaccine from the National Immunization Days (NIDs)?	YES ..... 1 NO ..... 2 DON'T KNOW 8	→ 527A
526A	At which national immunization day campaigns did (NAME) receive vaccinations?	CAMPAIGN 1: NID (JAN 2014) ..... 1 CAMPAIGN 2: NID (FEB 2014) 2	
527A	Did (NAME) receive any measles-rubella vaccine from the National Measles-Rubella Campaign?	YES ..... 1 NO ..... 2 DON'T KNOW 8	
528A	CONTINUE WITH 501B.		