Determinants of hepatitis B vaccination coverage in children aged 12-23 months: evidence from the Multiple Indicator Cluster Survey

Husham O. Elzein,[1] Elryah I. Ali,[1] Mohammed Suleiman Zaroog,[2] Eltigani O.M. Omer,[2] Kamal Elbssir Mohammed Ali,[2] Eltayeb I.O. Elmahi,[2] Sara H.M. Hamad,[3] Zakariya M.S. Mohammed[4,5]

[1]Department of Medical Laboratory Technology, College of Applied Medical Sciences, Northern Border University, Arar, Saudi Arabia; [2]Department of Community Health, College of Applied Medical Sciences, Northern Border University, Arar, Saudi Arabia; [3]Central Bureau of Statistics, Khartoum, Sudan; [4]Center for Scientific Research and Entrepreneurship, Northern Border University, Arar, Saudi Arabia; [5]Department of Mathematics, College of Science, Northern Border University, Arar, Saudi Arabia

Correspondence: Husham O. Elzein, Department of Medical Laboratory Technology, College of Applied Medical Sciences, Northern Border University, Arar, Saudi Arabia.
E-mail: husham.osman@nbu.edu.sa

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Informed consent: the survey's goal and procedure are fully understood by participants, who voluntarily consent to participate without coercion or duress.

Patient consent for publication: the participants understand that the material may be published in a journal and agree to provide consent for publication to MICS.

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ABSTRACT

Hepatitis B is a prevalent disease, especially in children. Numerous factors influence its vaccination rate. Therefore, this study aims to assess different socio-economic factors associated with hepatitis B vaccination among children in Sudan. Data from the nationwide Sudan Multiple Indicator Cluster Survey 2014 were utilized. The dataset comprises the hepatitis B immunization status and child, parental, and household characteristics of 2,672 children aged 12 to 23 months. Univariable and multivariable survey logistic regression analyses were conducted to identify determinants of hepatitis B immunization, and unadjusted and adjusted odds ratios (AORs) were reported along with 95% confidence intervals. A p-value of less than 0.05 was considered statistically significant. IBM SPSS was used to facilitate data analysis. The national hepatitis B vaccination rate in Sudan was 73.9%. Urban regions had a statistically greater rate of immunization than the average; 81.8% of children were registered, according to the survey. The findings showed that 87.2% of households had an educated mother; married mothers were more than mothers who were single or had never married. The result revealed that 87% of mothers gave birth in the private sector. According to the antenatal visits, 81% of mothers had four or more prenatal visits. The logistic regression analysis for socio-demographic and household characteristics revealed that the odds of immunization are significantly higher for registered children (AOR: 1.69), with the highest likelihood of immunization among mothers aged 35-39 (AOR: 2.48). The study reported that the chance of hepatitis B immunization was highest among women who had four or more antenatal visits (AOR: 1.95). Additionally, the likelihood of receiving a vaccination was higher for all wealth levels than for the poorest (AOR: 4.97). Furthermore, compared to a public or private health institution, the odds of immunization are much lower when the delivery takes place at home (AOR: 0.67). The study highlighted the importance of socio-economic factors in determining hepatitis B vaccination among children in Sudan. Educated mothers, registered children, and the place of delivery have significantly impacted the immunization against the hepatitis B virus. However, marital status, polygyny, and the wealth index quintile were found to be the main barriers to HBV vaccine coverage.

Introduction

Definition and description of the hepatitis B virus

Hepatitis is a severe hepatic disorder caused by specific infectious viruses and noninfectious agents. The World Health Organization (WHO) current prevalence revealed that 254 million people would be diagnosed with chronic hepatitis B in 2022, with 1.2 million new infections occurring each year, resulting in an expected 1.1 million deaths.

The prevalence of the hepatitis B virus

The report also revealed that in Africa, approximately 65 million people were affected by hepatitis B.[1,2] Hepatitis can be caused by one of five viral strains: A, B, C, D, or E.[3,4] However, hepatitis B virus (HBV) is highly contagious and potentially fatal. It can lead to acute or chronic conditions such as cirrhosis and hepatocellular carcinoma, and is considered the sixth leading cause of death worldwide. Fortunately, it can be prevented with a vaccination.[5-7] HBV can spread by blood and other bodily fluids, such as seminal fluid, vaginal fluids, nasopharyngeal excretions, and saliva. It can also be transmitted through injections during birth or pregnancy.[8,9] Some previous studies conducted in Indonesia and Oman have found that hepatitis B inside a household significantly increases the likelihood of intrafamilial transmission.[10,11] Prior research also reported that more than 80% of people with chronic HBV infection are unaware of their condition, which prevents them from receiving necessary medical support, therapy, and actions intended to reduce the risk of further transmission.[12]

Factors influencing the vaccination

Vaccination is a highly effective and low-cost public health intervention. From 1990 to 2017, deaths from vaccine-preventable diseases in children under 5 decreased from 5.1 to 1.8 million annually.[13] In 2016, the WHO approved vaccination as the most effective approach to prevent and eliminate HBV. They set a goal to eliminate HBV infection as a public health issue globally by 2030, aiming to reduce its incidence by 90% and its mortality by 65%.[14] The monovalent HBV vaccine birth dose should be administered immediately after birth, within the first 24 hours of life; this dose should be followed by two or three additional doses of combined vaccine (either pentavalent or hexavalent) scheduled at 6-10 and 14 weeks or 8-12 and 16 weeks. The vaccine is 98% to 100% effective and safe in preventing transmission of hepatitis B from mother to child.[2,15] The vaccine has significantly reduced global hepatitis B infection rates and can potentially lower chronic infection rates.[16,17] Therefore, the WHO and other international guidelines advocate comprehensive HBV screening for pregnant women and the immunization of all non-immune newborns and adolescents.[18-20]

Situation in Sudan

Despite efforts to boost baby immunization adoption in Sudan over the last decade, the country still has a high prevalence of hepatitis B.[21] Children aged 12-23 months have a higher risk of contracting hepatitis B because the infection can be transmitted from mother to child (vertical transmission) or through close contact with infected individuals (horizontal transmission) in the first few months of life.[22,23] Studies found that the prevalence of hepatitis B antigen is low in children vaccinated within the first 24 months of life, especially if they received the birth dose.[24,25] Several factors can influence the rate of HBV vaccination. These factors include family-related attributes, such as residence, maternal age, education, and other relevant factors, including household attitudes and knowledge about vaccination programs. It is essential to recognize the significance of vaccinations in preventing diseases.[26]

Study aim

To the best of our knowledge, there are no previous reports assessing the factors associated with HBV vaccination in Sudan. Therefore, the primary aim of the current study is to investigate these factors among Sudanese children aged 12 to 23 months.

Materials and Methods

Study design and setting

This research employs a cross-sectional design, utilizing secondary data collected retrospectively from the 2014 Sudan Multiple Indicator Cluster Survey (MICS). The current survey is the most recent comprehensive nationwide survey carried out by UNICEF and the Central Bureau of Statistics, covering all 18 states of Sudan. The survey used a two-stage sampling method: first, selecting census enumeration areas, and then, within each selected area, choosing households for interviews. This approach produced robust, reliable, comprehensive, and nationally representative data on children, women, and housing characteristics, which is also internationally comparable. Detailed information about the survey and the general report is available in MICS 2014.[27] The data is accessible for research purposes upon request from UNICEF.[28]

Ethical issues

The present study utilizes data from the 2014 MICS, which, after being registered for research purposes, is anonymized and made publicly available through the MICS portal (http://mics.unicef.org/surveys). When the data were first obtained, participants provided informed consent, and ethical approval was granted, ensuring that no additional clearance was required for using the resulting dataset.

Data and variables

The total number of children aged 12 to 23 months was 2672. The dependent (outcome) variable is receiving the third dose of Pentavalent, including DPT, hepatitis B, and Haemophilus influenzae type b antigen, categorized as "Yes" or "No". "Yes" indicates that the child received the third dose of Pentavalent, while "No" indicates that the child did not. Potential variables that could influence immunization with the third dose of Pentavalent include mother's age and educational level, marital status, polygyny, place of delivery, number of antenatal visits, household head's academic level, area of residence, state, child's sex, birth order,

ever been breastfed, civil registration, and household wealth index which is defined as a combined indicator of a household's overall standard of life, access to improved sources of drinking water and improved sanitation.

Statistical analysis

Two types of analysis were performed: descriptive statistics and analytical statistics. The descriptive part enables us to describe the sample characteristics and estimate the prevalence of receiving the third dose of Pentavalent across different categories of explanatory variables. The analytical part includes statistical tests and regression. The Chi-square test was used to test potential associations between the dependent and explanatory variables. Survey logistics regression was used to determine factors associated with receiving the third dose of Pentavalent. The regression was applied in two steps. Initially, the explanatory variables were introduced into the model individually to calculate the unadjusted odds ratios (UORs), which determined which variables should be included in the multivariable logistic regression. Variables with p-values below 0.25 were considered for inclusion in the multivariable model, where adjusted odds ratios (AOR) were calculated.[29] Unlike standard logistic regression, survey logistic regression adjusts for the complex survey design by accounting for sample weights, clustering, and strata.

Results

The demographic data, selected sample characteristics, and hepatitis B immunization coverage

Tables 1 and 2 summarize the characteristics of the study population. Among the 2672 children in the study, who were between the ages of 12 and 23 months, 50% were male, 72.8% resided in rural areas, 34.3% were 4-6 birth or-

Table 1. The demographic and selected sample characteristics.

Variables	Frequency (n)	Percent (%)
Area		
Urban	726	27.2
Rural	1946	72.8
Sex		
Male	1337	50.0
Female	1335	50.0
Birth order		
1	431	16.5
2-3	808	30.9
4-6	897	34.3
7+	480	18.4
Birth registration		
Not registered	822	30.8
Registered	1850	69.2
Child ever been breastfed		
Yes	2607	97.6
No	50	1.9
DK	1	0.0
Missing	15	0.5
Age of mother		
15-19	141	5.3
20-24	514	19.5
25-29	737	27.9
30-34	586	22.2
35-39	457	17.3
40-44	153	5.8
45-49	52	2.0
Marital status		
Currently married	2593	98.2
Formerly married	36	1.4
Never married	9	0.3
Missing	1	0.1
Polygyny		
No	2082	80.3
Yes	511	19.7
Place of delivery		
Public sector health facility	740	28.7
Private sector health facility	36	1.4
Home	1786	69.3
Other	3	0.1
Missing/DK	13	0.5
Number of antenatal visits		
No antenatal care visits	501	19.4
One visit	111	4.3
Two visits	202	7.8
Three visits	358	13.9
4 or more visits	1381	53.6
Missing/DK	25	1.0
Mother's education		
None	1049	39.3
Primary	929	34.8
Secondary	481	18.0
Higher	211	7.9
Missing/DK	1	0.0
Education of household head		
None	1058	39.6
Primary	878	32.9
Secondary	532	19.9
Higher	188	7.1
Missing/DK	16	0.6
Improved sources of drinking water		
Unimproved water	909	34.0
Improved water	1762	66.0
Improved sanitation		
Unimproved sanitation	1931	72.3
Improved sanitation	741	27.7
Wealth index quintile		
Poorest	536	20.1
Second	591	22.1
Middle	560	21.0
Fourth	553	20.7
Richest	432	16.2

ders, 97.6% had ever been breastfed, 69.2% had their births registered, 66% used improved drinking water, and 27.7% had improved sanitation. Regarding mothers'/caregivers' characteristics, 39.3% of mothers or caregivers had no formal education, 27.9% of them were 25-29 years old, 98.2% of them were currently married, 80.3% of them living with a husband without polygamy, 69.3% of them gave birth at home, and 53.6% of them had four or more antenatal visits.

As presented in Figure 1, the national level of hepatitis B immunization coverage in Sudan is 73.9%, with the highest coverage in Blue Nile State (96.1%) followed by Gezira (91.4%), and the lowest coverage in South Darfur (42.9%), followed by West Kordofan followed by (46.5%). Table 2 presents statistically significant variations in immunization prevalence according to exploratory variables. The prevalence was higher in urban areas (82.1% *vs*. 70.8% in rural areas), most affluent households (88.7%), registered children (81.8%), higher educated household head (87.2%), mothers with secondary education (85.9%) and higher education (82.9%), mothers of 35-39 years of age (80.4%), currently married mothers (74.4%), mothers not in polygamy marriage (77.1%), mothers giving birth in the private sector (88.3%), mothers visiting four or more antenatal visits (81.3%), households with improved water sources (77.6%), and households with improved sanitation (83.5%).

The analysis of the significant association between study variables

Table 3 shows the results of the logistic regression analysis, which contains both unadjusted prevalence odds ratios obtained from a univariate logistic regression with one predictor and adjusted prevalence odds ratios obtained from multivariable logistic regression. Birth order, marital status, and ever-been breastfed variables have p>0.25 in univariate logistic regression, so they were omitted from the final model.

Area and child registration

The unadjusted logistic regression results show that the likelihood of immunization is significantly higher in urban [UOR: 1.89; 95% confidence interval (CI):1.43-2.52] compared to rural, registered children (UOR: 3.54; 95% CI: 2.73-4.58) compared to unregistered children.

Mother demographic characteristics

In comparison to mothers aged 15-19, children of mothers aged 20-24 (UOR: 1.66; 95% CI: 1.06-2.61) and 35-39 (UOR: 2.29; 95% CI: 1.38-3.79) and those not in polygamy marriage (UOR: 1.94; 95% CI: 1.50-2.50) were compared to those in polygamy marriage. For antenatal visits, the odds of immunization are significantly higher in all numbers of antenatal visits compared to no antenatal care visits, and it is the highest in four or more visits (UOR: 3.42; 95% CI: 2.45-4.77). Regarding mothers' education, all educational levels have higher odds of coverage compared to no education, with the highest odds in secondary education (UOR: 3.54; 95% CI: 2.43-5.17).

Socioeconomic impact on immunization coverage

The likelihood of immunization was almost eight times higher for the wealthiest households compared to the poorest

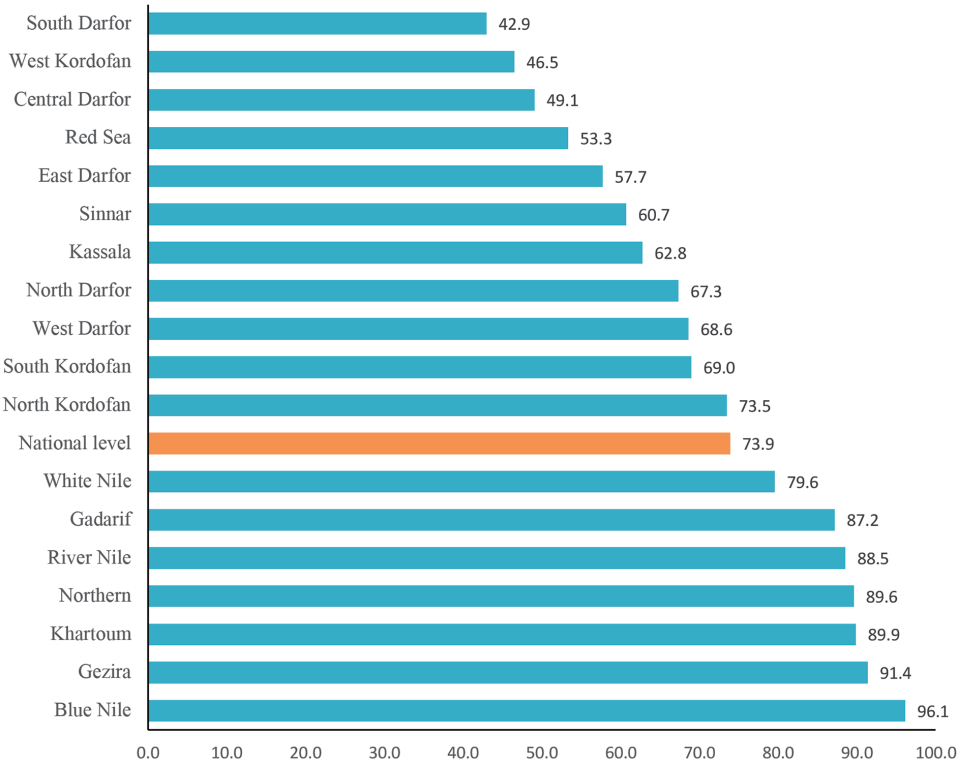

Figure 1. Hepatitis B immunization coverage at the national level and per state.

(UOR: 7.74; 95% CI: 4.72-12.70). Also, the odds of immunization are significantly higher between children who have access to improved sources of water (UOR: 1.75; 95% CI: 1.31-2.32) compared to those who do not, and for those who have access to improved sanitation (UOR: 2.14; 95% CI: 1.49-3.09) compared to those who do not. The odds of immunization are significantly lower when the place of delivery is home (UOR: 0.36; 95% CI: 0.27-0.49) compared to public and private health sector facilities. After adjusting for socio-demographic and household characteristics, the results show that the odds of immunization are significantly higher in registered children (AOR: 1.69; 95% CI: 1.26-2.27). Compared to women in the 15-19 age range, mothers in the 20-24, 25-29, 35-39, and 40-44 age ranges had the highest probability of receiving vaccinations (AOR: 2.48; 95% CI: 1.43-4.32). Additionally, the odds of hepatitis B immunization were highest among women who received antenatal care visits 2, 3, 4, or more, compared to those with no antenatal care visits, and were highest for women with four or more antenatal visits (AOR: 1.95; 95% CI: 1.39-2.74). Regarding the wealth index, the likelihood of immunization was higher at all wealth levels compared to the poorest, and it was highest for the richest (AOR: 4.97; 95% CI: 2.08-11.85). Also, the odds of immunization are significantly lower when the place of delivery is home (AOR: 0.67; 95% CI: 0.47-0.95) compared to public or private sector health facilities.

Discussion

The study highlights a significant improvement in HBV vaccination coverage in Sudan, about a 20% increase from 2006 to 2014 for the complete three-dose series, demonstrating progress in expanding immunization services. However, disparities persist, particularly by region and socioeconomic status, indicating areas that need focused intervention. The national hepatitis B immunization coverage in Sudan was 73.9%, lower than in several West African countries, such as Senegal (93%), The Gambia (88%), Burkina Faso (91%),

Table 2. The demographic and selected sample characteristics distributed by Hepatitis B immunization coverage.

Variables	Hepatitis B immunization coverage (%)	p
Area		<0.000
Urban	82.1	
Rural	70.8	
Sex		0.121
Male	72.6	
Female	75.2	
Birth order		0.088
1	74.5	
2-3	75.4	
4-6	75.1	
7+	69.5	
Birth registration		<0.000
Not registered	56.0	
Registered	81.8	
Child ever been breastfed		0.145
Yes	74.1	
No	82.5	
Age of mother		0.001
15-19	64.3	
20-24	74.9	
25-29	72.4	
30-34	73.1	
35-39	80.4	
40-44	76.0	
45-49	61.5	
Marital status		0.002
Currently married	74.4	
Formerly married	52.8	
Never married	41.1	
Polygyny		<0.000
No	77.1	
Yes	63.5	
Place of delivery		<0.000
Public sector health facility	86.2	
Private sector health facility	88.3	
Home	69.3	
Number of antenatal visits		<0.000
No antenatal care visits	56.0	
One visit	70.7	
Two visits	73.2	
Three visits	75.7	
4 or more visits	81.3	
Mother's education		<0.000
None	63.2	
Primary	77.6	
Secondary	85.9	
Higher	82.9	
Education of household head		<0.000
None	65.4	
Primary	75.8	
Secondary	83.0	
Higher	87.2	
Improved sources of drinking water		<0.000
Unimproved water	66.5	
Improved water	77.6	
Improved sanitation		<0.000
Unimproved sanitation	70.2	
Improved sanitation	83.5	
Wealth index quintile		<0.000
Poorest	50.3	
Second	63.2	
Middle	83.1	
Fourth	86.7	
Richest	88.7	

and Mali (77%). However, Sudan's national coverage for hepatitis immunization was higher compared to Sierra Leone, Liberia, and Guinea, as they reported 70.3%, 64.7%, and 40%, respectively.[30]

In 2021, the WHO reported that only 14 out of 47 countries in the African region had integrated the HBV birth dose vaccine into their national programs, with only 1 in 5 newborns in the region receiving it. The birth dosage was just established in Sudan in 2021; hence, it was not one of these 14 nations.[31-33] In countries where the HBV birth dose is implemented, barriers such as high costs, home births, limited access to skilled birth attendants, and low awareness of HBV

Table 3. The logistic regression analysis results for the association investigation.

Variable	Unadjusted prevalence odds ratio	Adjusted prevalence odds ratio
Area		
Rural	1.00	1.00
Urban	1.89* (1.43,2.52)	0.77 (0.53,1.14)
Child sex		
Male	1.00	1.00
Female	1.15 (0.94,1.41)	1.14 (0.90,1.44)
Birth registration		
Not registered	1.00	1.00
Registered	3.54* (2.73,4.58)	1.69* (1.26,2.27)
Mother age		
15-19	1.00	1.00
20-24	1.66* (1.06,2.61)	1.88* (1.09,3.25)
25-29	1.46 (0.94,2.26)	1.68* (1.03,2.72)
30-34	1.51 (0.96,2.38)	1.49 (0.89,2.48)
35-39	2.29* (1.38,3.79)	2.48* (1.43,4.32)
40-44	1.76 (0.96,3.24)	2.26* (1.19,4.30)
45-49	0.89 (0.39,2.05)	1.05 (0.38,2.91)
Polygyny		
Yes	1.00	1.00
No	1.94* (1.50,2.50)	1.24 (0.95,1.63)
Place of delivery		
Public sector health facility	1.00	1.00
Private sector health facility	1.20 (0.29,4.96)	0.98 (0.24,3.96)
Home	0.36* (0.27,0.49)	0.67* (0.47,0.95)
Number of antenatal visits		
No antenatal care visits	1.00	1.00
One visit	1.90* (1.08,3.32)	1.41 (0.82,2.43)
Two visits	2.15* (1.35,3.40)	1.77* (1.09,2.86)
Three visits	2.44* (1.52,3.94)	1.81* (1.13,2.91)
4 or more visits	3.42* (2.45,4.77)	1.95* (1.39,2.74)
Mother education		
None	1.00	1.00
Primary	2.02* (1.52,2.68)	1.05 (0.77,1.43)
Secondary	3.54* (2.43,5.17)	0.91 (0.57,1.43)
Higher	2.83* (1.57,5.08)	0.51 (0.22,1.17)
Education of household head		
None	1.00	1.00
Primary	1.66* (1.23,2.22)	1.03 (0.77,1.38)
Secondary	2.59* (1.87,3.59)	0.96 (0.62,1.50)
Higher	3.59* (2.13,6.06)	1.33 (0.74,2.40)
Improved sources of drinking water		
Unimproved	1.00	1.00
Improved	1.75* (1.31,2.32)	1.05 (0.78,1.43)
Improved sanitation		
Unimproved	1.00	1.00
Improved	2.14* (1.49,3.09)	0.90 (0.54,1.48)
Wealth index		
Poorest	1.00	1.00
Second	1.70* (1.19,2.43)	1.51* (1.05,2.16)
Middle	4.86* (3.32,7.11)	4.46* (2.19,6.84)
Fourth	6.46* (4.31,9.68)	4.12* (2.32,7.32)
Richest	7.74* (4.72,12.70)	4.97* (2.08,11.85)

*Significant at less than 0.05.

among healthcare workers and parents remain significant obstacles to successful vaccination efforts. Significant vaccination barriers exist during at-home births, primarily due to communication gaps between community members and healthcare facilities. Community health workers can bridge these fissures, improving vaccine awareness and knowledge in a community.[34]

Our study offers valuable insights into the prevalence and sociodemographic and healthcare factors associated with childhood HBV vaccination coverage across 18 states in Sudan. Significant disparities were observed across regions; South and Central Sudan reported higher coverage compared to Kordofan and Darfur states. Vaccination rates were 12% higher in urban areas compared to rural areas, and children from higher socioeconomic classes showed higher vaccination coverage. Furthermore, maternal characteristics, including older age, marital status, absence of polygamy, home births in the private sector, antenatal care visits, and improved household water and sanitation, were associated with higher vaccination coverage rates. Logistic regression analysis revealed that children from wealthier households were nearly five times more likely to be vaccinated than those from poorer households, and maternal education significantly increased the likelihood of vaccination. In the few sub-Saharan African countries where the HBV birth dose has been implemented, impact assessments have identified barriers such as implementation costs, a high percentage of births occurring outside healthcare facilities (*e.g.*, home births), limited access to skilled birth attendants, and insufficient HBV awareness among health workers and parents as key challenges to the successful administration of the vaccination.[33,35,36] The result revealed that in Sudan, the place of delivery was very highly significant ($p \leq 0.00$), impacting the coverage of HBV vaccination. However, the coverage range was found to be from 86.2 to 88.3 at health services, whether public or private, whereas at-home delivery was observed as one of the barriers to HBV vaccine coverage, with a rate of 69.3 in this study (Table 1). The logistic regression analysis, as presented in Table 2, confirmed the same result. The odds of immunization were significantly lower when the place of delivery was home (UOR: 0.36; 95% CI: 0.27-0.49) compared to public and private health sector facilities (Table 2).

These findings are consistent with other studies, such as one conducted in Uganda, which reported an HBV vaccination uptake of 41.9% and identified barriers to vaccine access. Similar trends were observed in West Africa, with countries such as Nigeria (14.2%) and Ethiopia (4%) exhibiting lower vaccination rates, while Ghana demonstrated higher coverage at 53.4%. These disparities reflect variations in healthcare access, economic conditions, and cultural beliefs across different regions.

As highlighted in Table 1, of the 1850 registered children, approximately 1,513 (81.8%) received the third dose of the Pentavalent vaccination, while only 56% (460 children) of the non-registered children (822 children) received this vaccination. The differences between the two study groups regarding vaccination for their children are highly significant ($p \leq 0.00$). This finding is from a previous study that showed a significant difference between registered and floating children ($p \leq 0.001$) regarding vaccination, and this variation was attributed to the disadvantage of floating people in accessing public health services.[37] Despite the secondary level of mother education showing a higher percentage of children's immunization, this result indicated that the increase in the education level of both mother and household head was proportional to children's immunization. Along with this educational level, the mother's age also significantly affected childhood vaccination, as the age range of 35-39 years showed the highest children's immunization rate. This result aligns with previous studies that have reported the effects of maternal age and education on childhood vaccination rates.[36-41] Unlike polygamous families, children living in single-woman households in this study showed a higher immunization rate. Similar findings were reported in earlier research by Ijarotimi *et al.* in 2018, which examined Nigerian children. The immunization rate among children born at home was very low in the current study; however, an increase in immunization rates among children delivered in private or public health facilities had been previously reported.[40] The study also indicated that the rate of children's vaccination was increasing with the increase in antenatal visit times. This study is similar to other studies conducted in Ethiopia, which have shown that various factors, including antenatal care visits, influence vaccination coverage.[38] According to different previous studies, the study showed that the wealth index had a significant effect on the childhood vaccination rate, as the children of the richest wealth quintile were vaccinated more than those of the poorest ones.[39,40]

After adjusting for socio-demographic and household characteristics, as presented in Table 2, the results indicate that registered children had significantly higher odds of being immunized (AOR: 1.69; 95% CI: 1.26-2.27) compared to non-registered children. Additionally, mothers aged 20-24, 25-29, 35-39, and 40-44 had higher odds of immunizing their children compared to mothers aged 15-19, with the highest likelihood of immunization observed in the 35-39 age group (AOR: 2.48; 95% CI: 1.43-4.32). Similar findings were reported by Etana and Deressa,[42] who noted an equal proportion of children of both sexes completing the immunization card (17% *vs*. 18%). Children from wealthier households were more likely to be fully immunized compared to those from lower-income households, with many children from upper socioeconomic classes receiving full immunization, as shown by Malkar *et al.*[42]

The findings of this study have significant implications for public health policies aimed at increasing HBV vaccination coverage in Sudan. Targeted interventions, such as enhancing maternal education, promoting birth registration, and improving access to healthcare, particularly in rural areas, are essential to addressing the disparities identified in this study. Additionally, increasing the number of antenatal visits and encouraging institutional deliveries could improve vaccination coverage. The WHO's goal of reducing HBV incidence by 90% by 2030 necessitates focused efforts to overcome the socio-economic and logistical barriers to vaccination in Sudan. Addressing these barriers, particularly in underserved rural populations, is critical to achieving this goal.

Table 1 also revealed that the coverage of the third dose of Pentavalent in the urban population (82.1%) was higher compared to the rural population (70.8%). However, there was a significant difference ($p \leq 0.00$) between the two groups in the study in their response to receiving the third Pentavalent vaccination for their children. This result suggests that urban populations are more likely to vaccinate

their children compared to rural ones. Lower vaccination rates in rural areas compared to urban areas have been reported in many studies.[36-41] A previous study suggested people in urban areas have an advantage in access to immunization services in comparison to their counterparts.[43] On the other hand, as shown in the results of this study, several factors were found to influence the rate of the third Pentavalent vaccination of Sudanese children. The most important were birth registration, mother's age, polygamy, place of delivery, number of antenatal visits, mother's education, education of household head, and wealth index.

Strengths and limitations of the study

One of the strengths of this study is the use of nationally representative data, which allows for the generalization of the findings to the entire population of Sudanese children aged 12 to 23 months. Additionally, the use of ro-bust statistical methods, including multivariable logistic regression, enabled the identification of key factors associated with vaccination uptake. However, several limitations should be acknowledged. The study relied on secondary data, which may be subject to recall bias, particularly concerning vaccination history and maternal characteristics. Moreover, the cross-sectional nature of the study precludes the assessment of causal relationships between the identified factors and vaccination coverage.

Recommendations

Future research should consider longitudinal studies to monitor trends in hepatitis B vaccination coverage over time, particularly in the context of ongoing public health interventions. Additionally, qualitative studies could provide deeper insights into household attitudes and beliefs regarding vaccination, particularly in rural and underserved populations. Such research could help inform the design of more culturally sensitive and effective vaccination programs. Public health policies should focus on expanding maternal education programs, improving healthcare access in rural areas, and increasing antenatal care utilization to ensure that all children in Sudan have equitable access to life-saving vaccines.

The study highlighted the importance of socio-economic factors in determining hepatitis B vaccination among children in Sudan. The education level of mothers, the registration of children, and the place of delivery have significantly impacted vaccination against HBV. However, marital status, polygyny, and the wealth index quintile were found to be the main barriers to HBV vaccine coverage.

Conclusions

This study found that disparities in vaccination coverage, particularly between urban and rural areas and across different socioeconomic groups, are crucial for improving child health outcomes and achieving global HBV reduction targets. The study also revealed that the vaccination coverage was proportionally associated with the educational attainment of the mothers. The place of delivery, whether at home or in a hospital, was highly significant, impacting the coverage of HBV vaccination. The logistic regression analysis confirmed the same result. The registered children reported higher coverage of the third dosage of the Pentavalent vaccination compared to non-registered children. Moreover, marital status, polygyny, low mothers' education, and poor wealth index are the main barriers to HBV vaccine coverage.

References

1. Dalal M. Uganda elevates health for all with free hepatitis testing, treatment, and vaccines. 2023. Available from: https://www.afro.who.int/countries/uganda/news/uganda-elevates-health-all-free-hepatitis-testing-treatment-and-vaccines.
2. WHO. Global hepatitis report 2024: action for access in low-and middle-income countries. 2024. Available from: https://www.who.int/publications/i/item/9789240091672.
3. Nguyen VT, Law MG, Dore GJ. An enormous hepatitis B virus-related liver disease burden projected in Vietnam by 2025. Liver Int 2008;28:525-31.
4. Castaneda D, Gonzalez AJ, Alomari M, et al. From hepatitis A to E: a critical review of viral hepatitis. World J Gastroenterol 2021;27:1691-715.
5. WHO. Global hepatitis report, 2017. Available from: https://www.who.int/publications/i/item/9789241565455.
6. Cui F, Blach S, Mingiedi CM, et al. Global reporting of progress towards elimination of hepatitis B and hepatitis C. Lancet Gastroenterol Hepatol 2023;8:332-42.
7. Sahu T, Pande B, Verma HK, et al. Infection and potential challenge of childhood mortality in sickle cell disease: a comprehensive review of the literature from a global perspective. Thalass Rep 2023;13:206-29.
8. WHO. WHO guidelines on hepatitis B and C testing. 2017. Available from: https://www.who.int/publications/i/item/9789241549981.
9. Al-Busafi SA, Al-Harthi R, Al-Naamani K, et al. Risk factors for hepatitis B virus transmission in Oman. Oman Med J 2021 Jul;36:e287.
10. Gunardi H, Iskandar MY, Turyadi, et al. Hepatitis B virus infection in children of HBV-related chronic liver disease patients: a study of intra-familial HBV transmission. Hepatol Int 2017;11:96-104.
11. Stanaway JD, Flaxman AD, Naghavi M, et al. The global burden of viral hepatitis from 1990 to 2013: findings from the Global Burden of Disease Study 2013. Lancet 2016;388:1081-8.
12. Dekker T, Hefele L, Neven A, et al. Factors associated with hepatitis B vaccination in Laos: findings from the multiple indicator cluster surveys in 2011/12 and 2017. Lancet Reg Health West Pac 2024;46:101059.
13. WHO. Global health sector strategy on viral hepatitis 2016-2021. Available from: https://iris.who.int/bitstream/handle/10665/246177/WHO-HIV-2016.06-eng.pdf.
14. García FJ, Ortega MJ, Aldeán JÁ, Garcés-Sánchez M, et al. Immunisation schedule of the Pediatric Spanish Association: 2021 recommendations. An Pediatr 2021;94:58.e1-e10.
15. Zanetti AR, Van Damme P, Shouval D. The global impact of vaccination against hepatitis B: a historical overview. Vaccine 2008;26:6266-73.
16. WHO. Hepatitis B position paper. 2017. Available from: http://www.who.int/immunization/policy/position_papers/hepatitis_b/en/.

17. WHO. Guidelines for the prevention, care, and treatment of persons with chronic hepatitis B infection. 2015. Available from: https://www.who.int/publications/i/item/9789241549059.
18. Terrault NA, Lok ASF, McMahon BJ, et al. Update on prevention, diagnosis, and treatment of chronic hepatitis B: AASLD 2018 hepatitis B guidance. Hepatology 2018;67:1560-99.
19. Mudawi HM, Smith HM, Rahoud SA, et al. Prevalence of hepatitis B virus infection in the Gezira state of central Sudan. Saudi J Gastroenterol 2007;13:81-3.
20. Ansari A, Vincent JP, Moorhouse L, et al. Risk of early horizontal transmission of hepatitis B virus in children of uninfected mothers in sub-Saharan Africa: a systematic review and meta-analysis. Lancet Glob Health 2023;11:e715-28.
21. Indolfi G, Easterbrook P, Dusheiko G, et al. Hepatitis B virus infection in children and adolescents. Lancet Gastroenterol Hepatol 2019;4:466-76.
22. Shimakawa Y, Veillon P, Birguel J, et al. Residual risk of mother-to-child transmission of hepatitis B virus infection despite timely birth-dose vaccination in Cameroon (ANRS 12303): a single-centre, longitudinal observational study. Lancet Glob Health 2022;10:e521-9.
23. Ekouevi DK, Larrouy L, Gbeasor-Komlanvi FA, et al. Prevalence of hepatitis B among childbearing women and infant born to HBV-positive mothers in Togo. BMC Infect Dis 2020;20:839.
24. Luhm KR, Cardoso MR, Waldman EA. Vaccination coverage among children under two years of age based on electronic immunization registry in Southern Brazil. Rev Saúde Publica 2010 10;45:90-8.
25. Ferreira VLDR, Waldman EA, Rodrigues LC, et al. Assessment of vaccination coverage of children in a medium-sized Brazilian city using electronic immunization registry. Cad Saude Publica 2018;34:e00184317.
26. Central Bureau of Statistics US. Multiple Indicator Cluster Survey 2014 of Sudan, Final Report. 2016. Available from: https://www.unicef.org/sudan/media/1146/file/Multiple-Indicator-Cluster-Survey-Report-2014%20.pdf.
27. UNICEF. Multiple Indicator Cluster Survey Programme. Available from: http://mics.unicef.org/.
28. Hosmer DW Jr, Lemeshow S, Sturdivant RX. Applied logistic regression. New York, NY, USA: Wiley; 2013.
29. WHO. Hepatitis B vaccination coverage. 2023. Available from: https://immunizationdata.who.int/global/wiise-detail-page/hepatitis-b-vaccination-coverage.
30. Statistics Sierra Leone- Stats SL and ICF. Sierra Leone demographic and health survey 2019. Available from: https://dhsprogram.com/pubs/pdf/FR365/FR365.pdf.
31. Institut National de la Statistique and ICF. Papua New Guinea demographic and health survey 2016-18. Available from: https://www.dhsprogram.com/pubs/pdf/FR364/FR364.pdf.
32. Coalition for Global Hepatitis Elimination. Introduction of hepatitis B birth dose vaccination in Africa: a toolkit for national immunization technical advisory groups. 2022. Available from: https://www.globalhep.org/sites/default/files/content/page/files/2022-12/HepB-BD%20NITAG%20toolkit%20final%20version_12-16-22_0-FINAL.pdf.
33. Boisson A, Goel V, Yotebieng M, et al. Implementation approaches for introducing and overcoming barriers to hepatitis B birth-dose vaccine in sub-Saharan Africa. Glob Health Sci Pract 2022;10:e2100277.
34. Oster NV, Williams EC, Unger JM, et al. Hepatitis B birth dose: first shot at timely early childhood vaccination. Am J Prev Med 2019;57:e117-24.
35. Oku A, Oyo-Ita A, Glenton C, et al. Factors affecting the implementation of childhood vaccination communication strategies in Nigeria: a qualitative study. BMC Public Health 2017;17:200.
36. Forshaw J, Gerver SM, Gill M, et al. The global effect of maternal education on complete childhood vaccination: a systematic review and meta-analysis. BMC Infect Dis 2017;17:801.
37. Gebreyesus A, Tesfay K. Effect of maternal education on completing childhood vaccination in Ethiopia: systematic review and meta-analysis. Sci Rep 2024;14:17453.
38. Kibreab F, Lewycka S, Tewelde A. Impact of mother's education on full immunization of children aged 12–23 months in Eritrea: population and health survey 2010 data analysis. BMC Public Health 2020;20:267.
39. Khan MT, Zaheer S, Shafique K. Maternal education, empowerment, economic status and child polio vaccination uptake in Pakistan: a population based cross sectional study. BMJ Open 2017;7:e013853.
40. Supiatun MLS, Aâ€™yuni ZQ, Marhana IA, Husada D. Correlations between maternal age, education, and knowledge on the compliance of COVID-19 vaccine uptake in children aged 6-11 years. J Maternal Child Health 2022;7:720-8.
41. Etana B, Deressa W. Factors associated with complete immunization coverage in children aged 12–23 months in Ambo Woreda, Central Ethiopia. BMC Public Health 2012;12:566.
42. Malkar VR, Khadilakar H, Lakde RN, et al. Assessment of sociodemographic factors affecting immunization status of children in age group of 12-23 months in a rural area. Indian Medical Gazette 2013;164-9.
43. Ijarotimi IT, Fatiregun AA, Adebiyi OA, et al. Urban-rural differences in immunisation status and associated demographic factors among children 12-59 months in a southwestern state, Nigeria. PLoS One 2018;13:e0206086.