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Factors Associated with Chlorhexidine Use for Umbilical Cord Care in Rural Bangladesh: Secondary Analysis of BDHS 2022.

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Abstract

Background

Chlorhexidine (CHX) is an effective antiseptic recommended for umbilical cord care to prevent neonatal infections and mortality in low-resource settings. However, its use remains limited in rural Bangladesh. This study aimed to identify factors associated with CHX use for umbilical cord care among rural births in Bangladesh.

Method

A cross-sectional secondary analysis was conducted using Bangladesh Demographic and Health Survey (BDHS) 2022. The study sample consisted of 1340 rural live births with complete data on

CHX use and key covariates. CHX use was defined by maternal report of CHX applied to the umbilical cord after birth. Chi-square tests were used to assess associations with maternal, household and healthcare characteristics. The analysis included survey weights, clustering, and stratification.

Outcome

Only 14% of mothers reported applying CHX to the umbilical cord, while 86% did not. CHX use was significantly associated with maternal education ($p = 0.029$), household wealth ($p = 0.030$), husband's education ($p = 0.007$), place of delivery ($p < 0.001$), skilled birth attendance ($p < 0.001$), newspaper exposure ($p = 0.011$), and television exposure ($p = 0.016$). CHX use was higher among mothers with secondary or higher education, those delivering in health facilities, and those attended by skilled birth attendants. Among deliveries attended by skilled birth attendants, 66% involved CHX use compared with 34% without skilled attendance.

Conclusion.

Use of CHX for umbilical cord care still very low among rural births in Bangladesh. Maternal education, household socio-economic characteristics, place of delivery and skilled birth attendance are significant factors associated with CHX uptake. Strengthening availability of CHX, training of health workers, counseling during antenatal and postnatal care and community-based interventions may be useful to improve equitable adoption of recommended cord-care practices.

Keywords: Chlorhexidine, CHX, Umbilical Cord Care, Neonatal Infections, Health Equity, Bangladesh, Rural Health

Background

In traditional times, 1 of four million neonatal deaths is attributed to infections, as well as a half a million maternal deaths worldwide, especially among underdeveloped and low resource settings (McClure et al., 2007). Worldwide, it is estimated 1.3-3.9 million cases of neonatal sepsis per year and 400,000-700, 000 deaths (Cassini et al., 2019). That indicates some progress - but the statistics are still terrifying. Even though the trend is decreasing worldwide, Africa and Southeast Asia bear most of the burden (Mu et al., 2025) Moreover, inappropriate umbilical cord care still contributes considerably to infection statistics. The umbilical cord can serve as a gateway for bacteria and poor handling may result in serious infections such as sepsis (Lawn et al. It has been indicated that poor hygienic cord care practices have led to the development of severe sequelae such sepsis and excess mortality which caused a need for early interventions in improving hygienic practices to prevent infections and enhance healthier outcomes (Rahman et al., 2017).

Chlorhexidine digluconate (CHX) is a recommended antiseptic that is effective for prevention of infection and commonly recommended by healthcare providers for umbilical cord care (Wei et al., 2021). Trials have demonstrated that routine application of chlorhexidine to the umbilical cord and stump can minimise prenatal cord infections by 32–75%, which in turn, is strongly correlated with a ~24% reduction in early neonatal death (McClure et al., 2007). Additionally, in a meta-analysis conducted by Imdad et al. (2013) demonstrate the overwhelming advantages of using 7.1% CHX on the umbilical cord, as it decreases infection and mortality among neonates at a substantial level, particularly in regions where rates of neonatal death are high. Considering these evidence, WHO recommends 7.1% chlorhexidine for umbilical cord care in settings with high neonatal mortality rates due to infection. This advice has implications for the need to standardize cord care practices in order to improve neonatal health (WHO, 2014).

As per Bangladesh Demographic and Health Survey (BDHS) done by National Institute of Population Research and Training (NIPORT), Medical Education and Family Welfare Division, Ministry of Health and Family Welfare, neonatal mortality affects 26 per 1,000 live births in Bangladesh cases are predominantly caused due to infections (NIPORT and ICF, 2023; UNICEF, 2021). The picture is worse in rural areas, where challenges to providing an adequate level of umbilical cord care are leading the country toward having highest infant mortality rates in the world (World Bank, 2022). Rural traditional practices may not be authorized and no or unhygienic materials such as cow dung, ash on the umbilical cord stump have been in practice India and that is linked with high risk of infection (Lawn et al., 2014). According to the study of Rahman et al. (2017), there is an urgent to improve hygiene practices in care of the umbilical cord given that most carers do not know how to apply them correctly, which has a direct effect on the rate of sepsis (Blencowe et al., 2011). In fact, studies show that many mothers particularly in rural settings deliver at home where there is no trained medical personnel and the risk of inadequate care of the cord is high (Opanga et al., 2022).

Despite the proven efficacy of chlorhexidine in preventing neonatal umbilical infections, and its addition to guidelines on newborn care in Bangladesh, there is variations of use among communities including rural areas. Existing analyses used older survey rounds or programmatic evaluations and thus little is known about contemporary drivers of chlorhexidine utilization in rural births. At the community level, cord care exposures are commonly determined by traditional practices and family advice, and home delivery without skilled attendance is widespread, limiting potential for counselling and proper use. Capacity of health systems, such as mixed messages during antenatal and postnatal care and lack of access to skilled providers, also restricts uptake. Material and methods Description of data The most recent nationally representative BDHS 2022 data (NIPORT and ICF, 2023) was used to study chlorhexidine use among rural neonates with respect to various maternal, household and delivery-related characteristics. In doing so, it adds to the evidence of how social position and access to care continue to influence who reaps the benefits of this straightforward but life-saving intervention.

Methodology

This study was a cross-sectional analysis using secondary data from the Bangladesh Demographic and Health Survey (BDHS) 2022. The study included rural areas of Bangladesh that were geographically divided into the eight administrative divisions, which were accounted for in the BDHS 2022. The BDHS is a nationally representative household-based survey, which collects data on population health, maternal and child health, and use of healthcare services throughout the country. Only rural areas were considered in the current analysis, because we wanted to examine the patterns of chlorhexidine use for umbilical cord application where home delivery and traditional neonatal behaviors predominate.

The data used in this study was derived from the BDHS 2022 implemented by National Institute of Population Research and Training (NIPORT) under Ministry of Health and Family Welfare with technical assistance from the DHS program. Information was recorded using standardized household and women's questionnaires which were conducted by trained interviewers in the BDHS 2022. This survey used a two-stage stratified cluster sampling method. In the first stage, household enumeration areas were chosen on the basis of probability proportional to size, and then households were systematically sampled in subsequent stages. We used sampling weights, which were provided for by the dataset, to adjust for clustering in the sample and ensure national representation.

The study was based on women living in rural areas who have had a live birth during the survey's reference period. For the current analysis, observations with any missing data outcomes or key covariates were dropped. Following inclusion/exclusion criteria, the complete analytic sample of rural live births was 1,340.

The main outcome variable was the use of CHX on the umbilical cord at any time following birth as reported by the mother, and secondary explanatory variables were individual-, household-, environment-related covariates. This variable was dichotomised (yes/no). Covariate selection selected from literature, their association with neonatal care practices, and availability within the BDHS variables. These determinants were grouped as individual, household and health service factors. Variables for the individual level consisted of maternal age, maternal education, parity, employment (mother not employed or mother employed), and child sex. Factors at household level were wealth quintile, type of family and husband's education. Health care factors: place of delivery, the skilled attendance at birth and mass media exposure (newspaper, radio, TV) were also included.

Cleaning of the data and statistical analyses were performed using R. All estimates were weighted, as the survey was based on a complex sampling design. Demographic characteristics of the study population were characterised using descriptive statistics. Bivariate associations of chlorhexidine application with explanatory variables were assessed using chi-square tests. Variables with a p-value of less than 0.05 in the bivariate analysis were entered into a multivariable binary logistic

regression to generate adjusted odds ratios (AORs) and their 95% confidence intervals. $P < 0.05$ was considered statistically significant. Statistical analyses were performed using R (version 4.3) adjusting for sampling weights, clusters and the stratified nature of BDHS survey design.

We conducted our study using publicly available, de-identified secondary dataset of the Bangladesh Demographic and Health Survey (BDHS) 2022. In the original survey, written consent was given by all included subjects. Because the present study was conducted with secondary data, it did not require additional informed consent.

Result

A summary of the characteristics of all 1,340 participants is presented in Table 1. Of these, 86% (1,076) were not applying CHX to the umbilical stump and only 14% (n=175) reported doing so. Seventy-six percent of mothers were aged 20–34 years, whereas the percentage who were younger than 20 years or aged 35-49 years was lower (15% and 8.6%, respectively). Education levels varied among mothers. Over half (54%) had secondary level education and 5.7% had no formal education. The majority (68%) of the participants resided in a nuclear family, and approximately one third (31%) were from the lowest wealth quintile.

Table 1: Descriptive Statistics of the Study Population (Rural Bangladesh, BDHS 2022)

Characteristic	**N = 1,340**[1]
Age	
<20	207 (15%)
20–34	1,018 (76%)
35–49	115 (8.6%)
Highest educational level	
No education	77 (5.7%)
Primary	376 (28%)
Secondary	726 (54%)
Higher	161 (12%)
Sex of child	
Male	675 (50%)
Female	665 (50%)
Parity	
1	472 (35%)
1–2	429 (32%)
3 or more	439 (33%)
employment_status	
Employed	21 (2.2%)
Unemployed	941 (98%)
Division	
Barishal	186 (14%)
Chattogram	235 (18%)

Characteristic	**N = 1,340**[1]
Dhaka	126 (9.4%)
Khulna	142 (11%)
Mymensingh	195 (15%)
Rajshahi	124 (9.3%)
Rangpur	155 (12%)
Sylhet	177 (13%)
family_type	
Extended Family(>6)	435 (32%)
Nuclear Family(<=6)	905 (68%)
Wealth index combined	
Poorest	416 (31%)
Poorer	346 (26%)
Middle	263 (20%)
Richer	206 (15%)
Richest	109 (8.1%)
Covered by health insurance	
No.	1,338 (100%)
Yes.	2 (0.1%)
Husband/partner's education level	
No education	228 (17%)
Primary	486 (37%)
Secondary	429 (32%)

Characteristic	**N = 1,340**[1]
Higher	182 (14%)
Don't know	3 (0.2%)
Household head's employment status	
Employed	557 (96%)
Unemployed	24 (4.1%)
Delivery Place	
Home	748 (56%)
Ngo	17 (1.3%)
Other	4 (0.3%)
Private	396 (30%)
Public	175 (13%)
Was chlorhexidine applied to the cord at any time	
No	1,076 (86%)
Yes	175 (14%)
Don't know	0 (0%)
SBA	
Not SBA	663 (49%)
SBA	677 (51%)
Frequency of reading newspaper or magazine	
Not at all	1,267 (95%)

Characteristic	**N = 1,340**[1]
Less than once a week	55 (4.1%)
At least once a week	18 (1.3%)
Almost every day	0 (0%)
Frequency of listening to radio	
Not at all	1,312 (98%)
Less than once a week	21 (1.6%)
At least once a week	7 (0.5%)
Almost every day	0 (0%)
Frequency of watching television	
Not at all	771 (58%)
Less than once a week	98 (7.3%)
At least once a week	471 (35%)
Almost every day	0 (0%)
Use of internet	
Never	1,008 (75%)
Yes, last 12 months	317 (24%)
Yes, before last 12 months	15 (1.1%)
Yes, can't establish when	0 (0%)
Owns a mobile telephone	
No.	509 (38%)
Yes.	831 (62%)

[1] n (%)

Healthcare utilization patterns showed that more than half of the deliveries occurred at home (56%). A smaller proportion of deliveries took place in private facilities (30%) and public hospitals (13%). Skilled birth attendants (SBA) were present in 51% of deliveries, while 49% were assisted by unskilled providers. Almost all participants (99.9%) did not have health insurance.

Table 2: Bivariate Analysis of Factors Associated with Chlorhexidine Application for Umbilical Cord Care

	Umbilical Cord Care by Chlorhexidine (CHX)		
Characteristic	**No** N = 1,076[1]	**Yes** N = 175[1]	**p-value**[2]
Age			0.4
<20	163 (15%)	31 (18%)	
20–34	821 (76%)	125 (71%)	
35–49	92 (8.6%)	19 (11%)	
Highest educational level			0.029
No education	66 (6.1%)	9 (5.1%)	
Primary	327 (30%)	35 (20%)	
Secondary	567 (53%)	107 (61%)	
Higher	116 (11%)	24 (14%)	
Sex of child			>0.9
Male	542 (50%)	87 (50%)	
Female	534 (50%)	88 (50%)	
Parity			0.085
1	363 (34%)	74 (42%)	
1–2	341 (32%)	50 (29%)	
3 or more	372 (35%)	51 (29%)	
Employment Status			>0.9
Employed	18 (2.4%)	3 (2.3%)	
Unemployed	742 (98%)	130 (98%)	
Division			0.077
Barishal	154 (14%)	23 (13%)	
Chattogram	194 (18%)	30 (17%)	
Dhaka	93 (8.6%)	20 (11%)	
Khulna	109 (10%)	16 (9.1%)	
Mymensingh	148 (14%)	31 (18%)	
Rajshahi	96 (8.9%)	25 (14%)	
Rangpur	130 (12%)	13 (7.4%)	
Sylhet	152 (14%)	17 (9.7%)	
Family Type			>0.9
Extended Family(>6)	346 (32%)	56 (32%)	

	Umbilical Cord Care by Chlorhexidine (CHX)		
Characteristic	**No** N = 1,076[1]	**Yes** N = 175[1]	**p-value**[2]
Nuclear Family(<=6)	730 (68%)	119 (68%)	
Wealth index combined			0.030
Poorest	349 (32%)	43 (25%)	
Poorer	281 (26%)	39 (22%)	
Middle	209 (19%)	37 (21%)	
Richer	153 (14%)	38 (22%)	
Richest	84 (7.8%)	18 (10%)	
Covered by health insurance			>0.9
No	1,075 (100%)	175 (100%)	
Yes	1 (<0.1%)	0 (0%)	
Husband/partner's education level			0.007
No education	196 (18%)	25 (14%)	
Primary	405 (38%)	48 (28%)	
Secondary	324 (30%)	75 (43%)	
Higher	138 (13%)	25 (14%)	
Don't know	3 (0.3%)	0 (0%)	
Household Employment Status			>0.9
Employed	457 (96%)	68 (96%)	
Unemployed	19 (4.0%)	3 (4.2%)	
Delivery Place			<0.001
Home	674 (63%)	63 (36%)	
NGO	14 (1.3%)	2 (1.1%)	
Other	4 (0.4%)	0 (0%)	
Private	259 (24%)	83 (47%)	
Public	125 (12%)	27 (15%)	
Skilled Birth Attendant (SBA)			<0.001
Not SBA	594 (55%)	59 (34%)	
SBA	482 (45%)	116 (66%)	
Frequency of reading newspaper or magazine			0.011

	Umbilical Cord Care by Chlorhexidine (CHX)		
Characteristic	**No** N = 1,076[1]	**Yes** N = 175[1]	**p-value**[2]
Not at all	1,027 (95%)	158 (90%)	
Less than once a week	39 (3.6%)	12 (6.9%)	
At least once a week	10 (0.9%)	5 (2.9%)	
Almost every day	0 (0%)	0 (0%)	
Frequency of listening to radio			0.2
Not at all	1,055 (98%)	168 (96%)	
Less than once a week	16 (1.5%)	5 (2.9%)	
At least once a week	5 (0.5%)	2 (1.1%)	
Almost every day	0 (0%)	0 (0%)	
Frequency of watching television			0.016
Not at all	647 (60%)	85 (49%)	
Less than once a week	75 (7.0%)	16 (9.1%)	
At least once a week	354 (33%)	74 (42%)	
Almost every day	0 (0%)	0 (0%)	
Use of internet			0.3
Never	815 (76%)	131 (75%)	
Yes, last 12 months	247 (23%)	44 (25%)	
Yes, before last 12 months	14 (1.3%)	0 (0%)	
Yes, can't establish when	0 (0%)	0 (0%)	
Owns a mobile telephone			0.086
No.	421 (39%)	56 (32%)	
Yes.	655 (61%)	119 (68%)	

The bivariate analysis (Table 2) examined factors associated with CHX application. Maternal education showed a significant association (p = 0.029). Mothers with secondary or higher education were more likely to use CHX compared to those with no formal education. Wealth also played an important role (p = 0.030). CHX use was lower among wealthier households. Among the richest group, 10% applied CHX, while in the poorest group, 25% did so. Husband's education

level also showed a significant relationship ($p = 0.007$). Women whose husbands had secondary or higher education had a greater likelihood of using CHX.

The place of delivery was strongly linked to CHX use ($p < 0.001$). Mothers who delivered in health institutions (private facilities (47%) and public hospitals (15%)) had higher CHX application rates compared to those who gave birth at home (36%). The presence of a skilled birth attendant also influenced CHX use ($p < 0.001$). CHX application was more common in deliveries assisted by skilled providers (66%) than in those handled by unskilled personnel (34%).

Media exposure was another key factor. Mothers who read newspapers at least once a week ($p = 0.011$) were more likely to use CHX than those who did not. Television exposure also played a role ($p = 0.016$). Women who watched television frequently had higher CHX use. However, some factors were not significantly associated with CHX application. These included the child's sex ($p > 0.9$), employment status ($p > 0.9$), family type ($p > 0.9$), and mobile phone ownership ($p = 0.086$).

Figure 1: Factors influencing Chlorhexidine use in Bangladesh

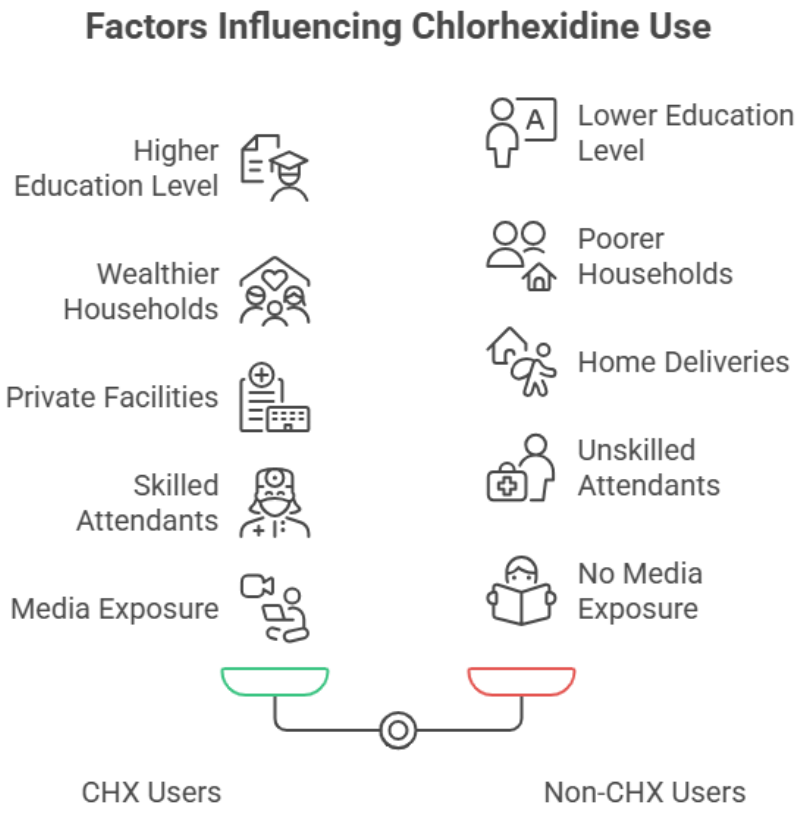


Figure 1: Factors influencing CHX use

Overall, the findings indicate that maternal education, household wealth, place of delivery, and skilled birth attendance are significantly associated with chlorhexidine use in Bangladesh. Nevertheless, the persistently low level of CHX application, observed in only 14% of rural births, suggests that individual socioeconomic characteristics alone do not fully explain the limited uptake of this intervention. Structural constraints, including inconsistent availability of chlorhexidine at community and facility levels, gaps in health worker training, and limited integration of CHX promotion within routine maternal and newborn health services, are likely to play an important role. Addressing these systemic barriers alongside socioeconomic disparities is essential for improving equitable access to recommended cord care practices, particularly in rural and low-income settings where home births remain common.

Discussion:

This study offers nationally-relevant insights into the factors that contribute to applying chlorhexidine (CHX) for possible use in nasal passages and/or direct application in rural Bangladesh and shows lingering inequities in coverage of this effective neonatal health intervention. Though there is robust evidence globally that CHX substantially decreases omphalitis, neonatal sepsis and neonatal mortality in low-resource settings, the coverage of CHX in rural Bangladesh has been minimal. In pooled analyses of community-based trials, chlorhexidine cord care has consistently been reported to markedly reduce neonatal mortality in areas with high infection-attributable mortality (Mullany et al., 2006; Mullany et al., 2009; Imdad et al., 2013). It is also worth noticing that previous multi-countries studies underlined the acceptability and efficiency of CHX as a low-cost, scalable intervention in resource-constraint settings (McClure et al., 2007).

The present study suggests that maternal education, household wealth, place of delivery and skilled birth attendance are the major determinants of the use of CHX. These relationships indicate that having access to information and exposure to the formal health sector may determine whether neonates are being kept free from infection through recommended cord management practices. Families whose mothers delivered at health care facilities or were attended by skilled birth attendants are more likely to be counselled and provided necessary items for hygienic newborn care, including CHX usables. This is consistent with global evidence which indicates that facility delivery and skilled attendance of birth increased the practice of optimum newborn care (World Health Organization, 2013).

Nevertheless, the findings that CHX had been accessed by only a minority of respondents suggest that individual-level socioeconomic factors are not sufficient to explain its widespread underutilisation. Structural and health system obstacles are likely to be critical. International guidance from the WHO highlights that successful delivery of chlorhexidine cord care will rely on ensuring a reliable supply, proper training for health workers and incorporating CHX promotion into routine postnatal/newborn care at household level (World Health Organization, 2013; World

Health Organization, 2014). In rural areas, where home births are still common, weak supply chains, limited reach of trained providers and inadequate follow-up during the postnatal period may affect potential for scale up.

The persistent usage of unsafe traditional products ie, ash and cow dung for umbilical cord care reported in previous national and international literature mirrors longstanding cultural practices and breakdowns in health communication. Dealing with such behaviors necessitates culturally appropriate programmes beyond the mere provision of information. The WHO has advocated integration of interpersonal counseling during antenatal and postnatal home visits with community-based behavior change strategies to increase best practices for safe newborn care (World Health Organization, 2014). Offering CHX counseling as part of the routine maternal and child health visits at antenatal care, facility-based delivery, or postnatal care or through community outreaches provides a feasible avenue for increasing coverage.

In terms of equity, it found that children born into poorer households, less literate mothers and families resorting to home delivery are also less likely to receive a low cost, user-friendly life saving intervention. This phenomenon mirrors general inequalities in neonatal health worldwide, where preventable deaths are more frequent among the socially and economically disadvantaged counterparts (UNICEF, 2021). As a result, the strengthening of health system readiness and the enhancement of last-mile delivery of essential newborn supplies as well as supporting frontline health workers are crucial to addressing disparities in neonatal outcomes.

This study has several limitations. First, the cross-sectional nature of the study does not allow causal inference between explanatory factors and CHX use. Second, data on chlorhexidine use were self-reported by mothers and may be recall biased. Third, the analysis was unable to directly measure supply-side factors such as facility level availability of CHX or quality of provider counseling which could impact uptake. Despite these limitations, the use of nationally representative survey data enhances the external validity of the results to rural Bangladesh.

In general, the findings emphasize that a multi-faceted approach is required to scale-up chlorhexidine cord care on both sides of the system. Without intentional link integrating promotion of CHX into established maternal and newborn health services, and without addressing the structural constraints that underlie delivery, it is unlikely that these benefits from an efficacious intervention will be equitably distributed to populations at greatest risk for infection- or neonatal-related morbidity and mortality.

Conclusion:

This paper presents nationally applicable evidence of factors affecting chlorhexidine application for umbilical cord care in rural Bangladesh, and highlights persistent inequities regarding the geographic isolation of a proven, low-cost intervention for neonatal health. However, CHX

coverage is unacceptably low, and few rural newborns receive appropriate cord care despite strong global and national recommendations. Correlates of CHX application were maternal education, household wealth, place of delivery and skilled birth attendance highlighting the influence of socioeconomic position as well as access to healthcare on neonatal care practices.

Nonetheless, given the poor population-level coverage of CHX, factors at an individual level may not readily explain disparities. Structural challenges, such as the lack of chlorhexidine at the community level, inadequate training and support for front-line workers and TBA providers, and poor CHX integration with routine MCH services are likely to limit effective scale-up. Breaking down these barriers calls for innovations at each level of the health system, including strengthening supply chains, institutionalizing CHX counseling in antenatal and postnatal care services, and using community-based platforms to reach households where home births are still prevalent.

Scaling-up more equitable access to chlorhexidine for cord care would have a large impact on preventable neonatal infections and deaths in rural Bangladesh. The incorporation of CHX promotion into the ongoing maternal and child health programming, in conjunction with culturally tailored behavior change strategies and capacity building for healthcare workers would contribute to filling the existing gaps to reach a more equitable distribution of the benefits of this life-saving approach.

Strengths and Limitations

Strengths:

This study used nationally representative BDHS 2022 data, providing broad generalizability to rural Bangladesh. The analysis incorporated survey weights, clustering, and stratification to account for the complex survey design. The study also examined CHX use across multiple maternal, household, and healthcare-related factors, providing a comprehensive assessment of potential determinants.

Limitations:

First, the cross-sectional design prevents establishing causal relationships between the identified factors and CHX use. Second, CHX use was self-reported by mothers and may therefore be subject to recall or reporting bias. Third, the analysis could not directly assess supply-side factors, such as CHX availability, health-worker counselling, training, or quality of service delivery, which may influence its use. Finally, observations with missing information on the outcome or key covariates were excluded, which may have introduced selection bias.

Declarations

Ethics approval and consent to participate

This study used publicly available, de-identified secondary data from the Bangladesh Demographic and Health Survey (BDHS) 2022. No primary data collection involving human participants was conducted. The original BDHS obtained informed consent from all participants. As this analysis involves only anonymized secondary data, no additional ethics approval or consent was required.

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Availability of Data and Materials

The dataset analyzed during the current study is publicly available from the DHS Program repository upon registration and approval of a data request (https://dhsprogram.com/data/available-datasets.cfm). Restrictions apply to the availability of these data, which were used under license for the current study, and are not publicly available without permission from the DHS Program.

Authors' Contributions:

NI: Conceptualization, methodology, formal analysis, writing – original draft

FAB: Writing original draft, writing, review and editing.

MMP: Conceptualization, supervision, writing – review and editing.

SNBK: Review and editing.

MSI: Writing, review and editing and submission

All authors read and approved the final manuscript.

Consent for Publication

Not applicable. This manuscript does not contain any individual person's details, images, or videos. All clinical data are presented in an anonymized, aggregated format to guarantee patient privacy and confidentiality.

Competing Interests

The authors declare that they have no competing interests.

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