**Assessing Contributory Factors of Diarrhea among Under-Five Children in Bangladesh: A Comprehensive Analysis of Three Waves of Nationally Represent Data**

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**Author Contributions**

MNH, MNS, MFA, SM, MABC, and MJU conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, supervision, validation, visualization, roles/writing - original draft, writing - review and editing.

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**Conflicts of interest**

No potential conflict of interest was reported by the authors.

**Ethical consent**

Our study was wholly based on an analysis of existing public domain health survey datasets obtained from the MICS 2006, 2012 and 2019 which is freely available online with all personal identifying information removed. The MICS procedures were reviewed and approved by the Bangladesh Bureau of Statistics (BBS) and UNICEF. Informed consent was obtained from participants while interviewing them. Because this study involved the analysis of secondary data thus, it did not require the ethical approval of the respective institution.

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**Abstract**

Diarrhea remains a significant cause of child mortality in Bangladesh. One-third of all child deaths in this country are caused by diarrhea. Yet there is limited understanding of the disease's trends and associated factors. This study aimed to investigate the changing patterns and contributory factors of diarrheal diseases among children 0-5 years by analyzing three distinct survey years, 2006, 2012, and 2019.

In this study, using the data from the Multiple Indicator Cluster Survey (MICS), a total of 31,566, 23,402, and 24,686 children under five were included from, 2012, and 2019, respectively. Logistic regressions were applied to analyze the changes in factors influencing childhood diarrhea.

The results revealed a decline in diarrhea prevalence from MICS 2006 (7.1%) to MICS 2012 (3.9%). However, there was an unfortunate increase to 6.9% in MICS 2019. Notably, children aged 12-23 months exhibited consistently 2.22 times (adjusted odds ratio (AOR) = 2.22, 95% confidence interval (CI: 1.86 – 2.65), 5.24 times (CI: 2.51 – 10.95) and 3.36 times (CI: 2.67 – 4.22) higher likelihood of experiencing diarrhea compared to the older age group (48-59 months) in MICS 2006, 2012 and 2019, respectively. The mother's educational background also played a role, in MICS 2006, 2012, and 2019, children whose mothers had no or incomplete primary education had 1.48 (CI: 1.18 - 1.86), 1.07 (CI: 0.76 - 1.50), and 1.34 (CI: 1.06 – 1.69) times higher chances of diarrhea compared to children of mothers with secondary complete or higher education.

Furthermore, underweight status, geographical division, household wealth status, and toilet facility type and its shared status emerged as contributing factors of diarrhea among children aged 0-5 years. The findings underscore the importance of child nutrition, basic hygiene practices, and special care during the rainy season to mitigate the under-five mortality rate associated with diarrhea.

**Keywords:** Children, Nutrition, Childhood diseases, Diarrhea, Trend, Determinant, Bangladesh.

**Introduction**

Diarrhea is an influential cause of under-five child mortality globally. According to the World Health Organization (WHO), every year, there are approximately 1.7 billion cases of diarrheal disease among children worldwide and diarrhea claims the lives of about 443,832 children under the age of 5, along with an additional 50,851 children aged 5 to 9 (WHO, 2024). In 2010, about 7.6 million Children aged below five years died worldwide and about 21,000 of them died every day (Woldu, Bitew, & Gizaw, 2016). Each year in developing countries, almost 2 million people die of diarrhea, a significant number of whom are children aged between 0-5 years (Zeleke & Alemu, 2014). The diarrhea-related mortality rate is high in developing countries and deaths from diarrhea is rare in developed countries (Podewils, Mintz, Nataro, & Parashar, 2004; Zeleke & Alemu, 2014). Due to high mortality rates in developing countries, the loss of human lives is the main concern for those countries while the developed countries focus on reducing the economic cost associated with the cases of diarrhea (Pinzón-Rondón, Zárate-Ardila, Hoyos-Martínez, Ruiz-Sternberg, & Vélez-van-Meerbeke, 2015). It was responsible for 9% of 5.8 million child deaths globally and 6% of 0.119 million child deaths in Bangladesh in 2015 (T. Alam et al., 2017).

Among the South Asian countries, the percentage of deaths due to diarrhea among children under five was high for Pakistan (8%), followed by India (7%) and Bangladesh (7%) and low for Maldives (1%) and Sri Lanka (1%) in 2019 (“Diarrhoea,” 2022). In a developing country like Bangladesh, most children suffer from diarrheal diseases which ultimately lead them to death (Shah, Yousafzai, Lakhani, Chotani, & Nowshad, 2003). Each year, in Bangladesh, every child suffers three to five times on an average from diarrheal attacks (M. J. Alam, 2007). Most of the deaths due to diarrhea occur in rural areas (Shah et al., 2003). A previous study showed that diarrhea is the reason behind about 33% of total child deaths in Bangladesh (M. R. Islam, Hossain, Khan, & Ali, 2015). On average, diarrhea happens more than 4 times per year to a rural child, which results in 2,30,000 child deaths (M. R. Islam et al., 2015). According to 2007 Bangladesh Demographic and Health Survey (BDHS) data, most sufferers are 6-23 months old children and boys are more at risk of this disease compared to girls (Begum, Ahmed, & Sen, 2011).

Being a developing country, Bangladesh has several resource constraints, such as the high density of population (3,277 people per meter squares (“Bangladesh Population (2022) - Worldometer,” 2022)), poverty, lack of awareness, food deficiency, malnutrition, etc. Moreover, in Bangladesh, approximately 2.5 million people suffer from basic sanitation issues, and about one million people are unable to have potable water (M. R. Islam et al., 2015). Previous studies in Bangladesh showed that age, sex, geographic location, drinking from unprotected water supply, sanitation, hygiene, and household economic status can cause diarrhea among children between 0-5 years (M. R. Islam et al., 2015; Rahman & Hossain, 2022).

Young children in Bangladesh generally experience a variety of common illnesses like fever, cough, short/difficult breathing, diarrhea, etc (Hasan et al., 2020; Md. Aminul Islam et al., 2022). Previous studies on diarrhea found several risk factors which were rainy season (R. L. Guerrant et al., 1983; Kosek et al., 2008; Mølbak, Jensen, lngholt, & Aaby, 1997), partial breastfeeding and early weaning (R. L. Guerrant et al., 1983; Maponga et al., 2013; Mølbak et al., 1997; VanDerslice, Popkin, & Briscoe, 1994), lower education level of mother (Dargent-Molina, James, Strogatz, & Savitz, 1994; Kosek et al., 2008; Mølbak et al., 1997), outdoor drinking water source like river, outdoor faucet (Ghosh et al., 1997; Kosek et al., 2008; Maponga et al., 2013; Mølbak et al., 1997; Tornheim, Morland, Landrigan, & Cifuentes, 2009), distance of drinking water source (Maponga et al., 2013), unprotected water storage container (D’Souza, 1997; Ghosh et al., 1997; Kosek et al., 2008; Maponga et al., 2013), not treating drinking water (Maponga et al., 2013; Tornheim et al., 2009), larger household size (Blake et al., 1993), lower household income (Blake et al., 1993; Genser, Strina, Teles, Prado, & Barreto, 2006), having dirt/wood/bark as floor material (Kosek et al., 2008), not having antenatal care during pregnancy (Genser et al., 2006), unimproved sanitation system (D’Souza, 1997; Genser et al., 2006; Sobel et al., 2004), wastewater to septic tank/street (Tornheim et al., 2009), disposal of child faces indiscriminately (Ghosh et al., 1997; Majorin, Torondel, Ka Seen Chan, & Clasen, 2019), no hand washing facility (Maponga et al., 2013), and unhealthy home environment (garbage and flies near home) (Maponga et al., 2013). It was identified that boys and younger children had a higher risk of having diarrhea (Mølbak et al., 1997; Quick et al., 1999). To reduce child morbidity and mortality, the prevention of diarrhea is indispensable.

Based on the Multiple Indicator Cluster Surveys (MICS) from 2006, 2012-13, and 2019, the prevalence of diarrhea among under-five children was reported at 7.1%, 3.9%, and 6.9%, respectively (MICS, 2006, 2014, 2019). Additionally, the BDHS from 2014, 2017-18, and 2022 indicated rates of 5.7%, 4.7%, and 4.8% (BDHS, 2014, 2019, 2022). Despite various interventions and innovations aimed at reducing childhood diarrhea, the burden of the disease appears to be increasing in recent years in Bangladesh. According to the information that we have, no study was conducted using the Multiple Indicator Cluster Survey (MICS) data of Bangladesh to portray the changes in factors influencing diarrhea over time. Additionally, we sought to understand the reasons behind the recent increase in diarrhea cases, despite improvements in various health indicators. We also intended to investigate the relationship between diarrhea and important features such as drinking water source, health of children, household economic status, and household environment. Overall, we aimed to analyze the prevalence of diarrhea and identify the factors contributing to diarrheal diseases among children aged 0-5 years in Bangladesh from 2006 to 2019, in order to understand the recent increase in this serious health issue.

**Methods**

We followed the STROBE guideline for better observational cross-sectional study reporting in epidemiology (Table S1).

**Data**

We used secondary data of year 2006, 2012-13 and 2019 of MICS of Bangladesh. Bangladesh Bureau of Statistics (BBS) and Ministry of Planning have been conducting MICS since 1993. As it was a part of global MICS program, BBS worked with United Nations Children’s Forum (UNICEF) which supported this survey by providing technical and financial support. This survey report has circumstantial information and investigation on children and women of Bangladesh for disease, health condition, household facilities, educational status, knowledge and practices related to disease prevention, access to media and technology, which is named *“Progotir Pathey”* (“Surveys - UNICEF MICS,” 2023).

The sampling procedure was two-stage stratified cluster sampling covering urban and rural areas of Bangladesh where enumeration areas (EAs) were selected at first stage and households with each selected EAs were selected at second stage. In the survey of 2006, the sample included 68,247 households, among which 67,540 had people to be interviewed. Among them, 62, 463 households were successfully completed the survey with response rate of 92.5 percent. In total, 31,566 children under age 5 were completed the questionnaire among 34,710 children identified from interviewed households with response rate of 90.9 percent. In the survey of 2012-2013, the sample covered 55,120 households from which 52,711 households had people to attend the interview and out of these, 51,895 were completely interviewed with response rate of 98.5 percent. In total 23,402 children under age five were selected in the sample but completed data found from 20,903 children given a response rate of 89.3 percent among visited households. The sample of 2019 survey selected 64,400 households and people were inhabited in 61,602 households of them. Among those, 61,242 household completed the survey with response rate of 99.4 percent. 24,686 children under age five were included in household survey and among them completed information of 23,099 children were found with response rate of 93.6 percent [**Figure 1**]. The sample size estimation and sample allocation are available in detail in the final reports of each survey (“Surveys - UNICEF MICS,” 2023).

**Questionnaires**

The MICS tools (“Tools - UNICEF MICS,” 2023) of round MICS3 were used in the survey of 2006, MICS5 in 2012-2013 and MICS6 in 2019 for Bangladesh. The round MICS3 had three questionnaires: i) household questionnaire which included information of the characteristics of household, ii) questionnaire for individual women which covered information of every woman aged 15-49 years in each household, and iii) questionnaire for children under five which covered each children’s overall information. The round MICS5 used four sets of questionnaire and along with the three questionnaires of MICS3 round, another questionnaire was for testing water quality which used to find out the arsenic and E. coli content in potable water of household. The round MICS6 used five questionnaires and the addition in this round was collecting information of one randomly selected child from 5-17 years age group from each household. All questionnaires were interpreted into Bangla.

**Outcome and possible covariates**

**Outcome variable**

In this study, we assessed diarrhea among children aged 0-5 years based on whether they experienced diarrhea in the two weeks prior to the survey. The responses were provided by mothers or caretakers. We defined the binary outcome variable “Diarrhea,” which has two categories: “Yes” for children who had diarrhea and “No” for those who did not in the two weeks before the survey.

**Covariates**

Characteristics of children such as age, sex, child supervision, nutritional status (stunned, wasted, underweight, overweight), community characteristics e.g. place of residence, division, parental characteristics e.g. mother’s education and age, household characteristics e.g. wealth index, religion, sex of household head, type of toilet facility and its shared status, salt iodization, access to mass media, household size, possession of livestock, drinking water source and type, water treatment were considered as covariates in the analysis. The covariates were selected for the analysis based on the available information in the MICS dataset and the findings of previous studies (Blake et al., 1993; Dargent-Molina et al., 1994; D’Souza, 1997; Genser et al., 2006; Ghosh et al., 1997; R. L. Guerrant et al., 1983; M. R. Islam et al., 2015; Kosek et al., 2008; Majorin et al., 2019; Maponga et al., 2013; Mølbak et al., 1997; Quick et al., 1999; Rahman & Hossain, 2022; Sobel et al., 2004; Tornheim et al., 2009; VanDerslice et al., 1994).

***Child characteristics***

We categorized children's ages into six groups: 0-11 months, 12-23 months, 24-35 months, 36-47 months, and 48-59 months. Additionally, we classified child sex as male or female, and assessed inadequate supervision, underweight, stunting, wasting, and overweight as binary variables (yes or no). A child had inadequate supervision if the child was not with any adult for more than one hour at least once during the last week. Stunting, wasting, underweight, and overweight were used as the measurements of nutritional status and height-for-age, weight-for-age and weight-for-height z-scores were used to calculate these measures (“The WHO Child Growth Standards,” 2023). The z-scores measure the distance of a measurement from its mean point in terms of standard deviation. A child was considered underweight if the weight for age z-score was less than or equal to -2 and overweight if the weight for height z-score was greater than or equal to 2. A child was stunned if the height for age z-score was less than or equal to -2 and wasted if the weight for height z-score was less than or equal to -2 (“WHO Child Growth Standards,” 2008).

***Community characteristics***

Flushed to the piped sewer system, septic tank, pit latrine, and open drain, ventilated improved pit latrine, pit latrine with and without slab were categorized as improved toilet facility and hanging toilet/latrine, bucket, composite toilet, and no facility/bush/field were categorized as an unimproved toilet facility (“Surveys - UNICEF MICS,” 2023). Salt iodization was considered “Yes” if the salt tested result showed 0 to 15 ppm or above 15 ppm and otherwise “No”. Having access to mass media indicated that a household at least accessed newspapers/TV/radio less than once a week. Piped into dwelling, to yard and neighbor, public tap, tube well, dug well (protected), protected spring, rainwater, bottled and sachet water were considered as improved water source and dug well (unprotected), unprotected spring, tanker truck, cart with small tank, water selling plant, surface water (river, dam, lake, pond, canal) and other were considered as unimproved water source. Drinking water was considered treated if any process among boiling, adding bleach/chlorine, straining through cloth, or using any kind of water filter was done (“Surveys - UNICEF MICS,” 2023).

**Data analysis**

Stata Statistical software for data science version 17.0 was used for data analysis. We applied univariate and multivariable logistic regressions to assess the association between diarrhea and the selected covariates at 5% significance level for each dataset. The final model output was represented in a forest-plot.

The procedure of choosing best model was step-wise logistic regression, and it included the factors found relevant and important to explain the behavior of the outcome variable from literature review. The measures of sensitivity and specificity from the Receiver Operating Characteristic (ROC) curve, were used to assess the optimal model. The models performed better, according to the higher area under curve of the ROC. A bigger area under the curve than the 0.50 on the ROC curve indicates that the model discriminates between the two groups (Cook & Rajbhandari, 2018). We also employ information criteria, e.g., the Akaike information criterion (AIC (Akaike, 1974)) and Bayesian information criterion (BIC (Schwarz, 1978)) as a goodness-of-fit measure for the final multivariable logistic model.

We used Stata command (Svyset) of the survey data reference manual to accounting for the complex survey settings of the datasets (“Stata Bookstore | Survey Data Reference Manual, Release 17,” 2021). Svyset commands were developed for STATA to consider the survey design elements such as sample weights, PSU, clusters and strata (“Survey Data Analysis in Stata,” 2021).

**Results**

The occurrence of diarrhea among 0-5 years old children decreased from 7.1% in 2006 to 3.9% in 2012 then increased to 6.9% in 2019.  Moreover, among the age group 12–23-month children 10.0%, 7.7% and 10.1% had diarrhea respectively based on the MICS data of 2006, 2012 and 2019. Among underweight children, 8.5% of them had diarrhea in the MICS data of 2019, which was 4.0% in the MICS data of 2012. Based on the division in Barisal 8.9%, 6.3%, 14.1% children had diarrhea respectively as reported highest in 2006, 2012 and 2019 MICS data. Likewise, the MICS data from 2006, 2012, 2019 reported that in the Khulna division 4.4%, 3.3%, and 6.5% of under-five children had lowest diarrhea respectively. Among the under-five children whose mother's educational level was secondary completed or higher 5.5%, 3.9%, and 5.9% of them had lowest diarrhea in 2006, 2012, and 2019. In 2012, it was lowest in over 35 years age group, 3.2%. According to the wealth index, **among under age five children** who belonged ​to rich families 5.6% of them had lowest diarrhea in the survey time of 2006, in contrast, it was lowest 3.4% in middle and 5.5% in richest families in 2012 and 2019, respectively. Among the children under 5 years whose family didn’t consume adequately iodized salt 8.6% of them had highest prevalence of diarrhea in 2006 which was decreased to 8.0% in 2019, but lowest in 2012, 3.8% (Table 1).

From the univariate model, we have found that the age of the child, underweight, area of household, division, education level of mother, mother’s age, wealth status, religion, ethnicity, toilet facilities shared, toilet facility type, salt iodization variables were significantly associated with diarrhea at 5% level of significance (Table S2).

According to multivariate model, we found that, the children of 0-11 months had 1.81 (adjusted odds ratio (AOR): 1.81, 95% CI: 1.50-2.18), 4.35 (AOR: 4.35, 95% CI: 2.10-9.01), and 3.32 (AOR: 3.32, 95% CI: 2.63-4.19) times higher odds of having diarrhea compared with children aged 48-59 months in 2006, 2012 and 2019 respectively. The odds of having diarrhea for the children of all age group was higher than the children of 48-59 months respectively in all survey years. Compared with the children under age 5 from the Sylhet division in 2006, 2012, and 2019 survey, children of Barisal division had 1.27 (AOR: 1.27, 95% CI: 0.99-1.63) and 2.51 (AOR: 2.51, 95% CI: 1.74-3.63) times higher chance of having diarrhea, respectively. However, in 2012 survey, children of Barisal division had 33% (AOR: 0.67, 95% CI: 0.27-1.63) times lower chance of having diarrhea. Children from poorest family had 30% (MICS 2006 AOR: 1.30, 95% CI:1.01-1.65) and 14% (MICS 2019 AOR: 1.14, 95% CI: 0.90-1.44) higher odds of having diarrhea compared with children from richest family. We found that among the children whose families use the shared toilet had 7% (AOR: 1.07, 95% CI: 0.96-1.20) and 23% (AOR: 1.23, 95% CI: 1.07-1.42) higher odds of having diarrhea in 2006 and 2019 respectively, in MICS 2012, 40% (AOR: 0.60, 95% CI: 0.36-0.99) lower odds of having diarrhea in compared with the children whose family did not use the shared toilet (Table 2 and Figure 2).

The area under the ROC curve was found to be 0.6210 (P < 0.001), 0.6826 (P < 0.001), and 0.6717 (P < 0.001). This indicated that the final model chosen for the MICS-2006, MICS-2012, and MICS-2019 surveys each displayed an area under the curve that was higher than 0.50 (Figure 3). The improved goodness-of-fit statistics for the final multivariate logistic model lend credence to this inference. In comparison to the MICS-2006 (AIC = 14322.83, BIC = 14545.55) and MICS-2019 (AIC = 9610.21, BIC = 9870.85) final multivariate logistic model, MICS-2012 demonstrated (AIC = 1167.66, BIC = 1295.21). The MICS-2012 survey model therefore provided good fit, and a normal binary logistic model with variables included in this survey model suggested to use to describe this type of analysis (Table 3).

**Discussion**

This study targeted to explore the Multiple Indicator Cluster Survey data of 2006, 2012 and 2019 and assess the association of several factors with diarrhea and the change of it over time. There was a decrease in the prevalence of diarrhea from 2006 to 2012 and an increase in 2019 among 0-5 years old children in Bangladesh.

The prevalence was higher for 12-23 months’ children, followed by 0-11 month’s children, and the difference is significant compared with children of 48-59 months age group in 2006, 2012 and 2019. Children of 0-24 months age group are in the process of developing immune systems and depend on their mothers to be protected (Siziya, Muula, & Rudatsikira, 2009). Also, children from 6 to 24 months’ start crawling all over the house and put whatever they find around them in their month. As they gradually grow up, they learn what is not to eat or put in their mouths (Negesse, Taddese, Negesse, & Ayele, 2021). The findings from previous studies in Bangladesh, Ethiopia, Niger, Nigeria, Cameroon, and Ghana were similar to this (Bado, Susuman, & Nebie, 2016; Caruso, Stephenson, & Leon, 2010; Melese, Paulos, Astawesegn, & Gelgelu, 2019; Negesse et al., 2021; Rahman & Hossain, 2022; Tambe, Nzefa, & Nicoline, 2015).

Findings showed that the chance of having diarrhea was significantly higher for children from the poorest families in 2006 and children from the second wealth index in 2019. Children from poor families have more probability to be affected by several childhood illnesses due to poor living conditions, not having enough nutritious food, and poor condition of drinking water sources and toilet facilities (Richard L. Guerrant, DeBoer, Moore, Scharf, & Lima, 2013; Iannotti, Trehan, Clitheroe, & Manary, 2015; Negesse et al., 2021; Rahman & Hossain, 2022). Previous studies on Ethiopia and several developing countries reported similar scenario.

Children from households without improved toilet facilities in 2006 and in 2019 were more at risk of experiencing diarrhea. Using the composite toilet, bucket, hanging toilet/latrine and going to bush/field causes the unsafe disposal of stools in the neighborhood, which is connected with the chance of having diarrhea among children (Bawankule et al., 2017). Accessing improved toilet facilities can reduce the unsafe disposal of stools and the transmission of the virus from one human to another, which ultimately reduces the prevalence of diarrhea, supported by the findings from Ethiopia, Ghana and India (Fobil, Kraemer, Meyer, & May, 2011; Geruso & Spears, 2018; Mengistie, Berhane, & Worku, 2013; Sinmegn Mihrete, Asres Alemie, & Shimeka Teferra, 2014; Traoré et al., 1994).

After controlling the effects of several factors, we found that no factors were influencing the prevalence of diarrhea in 2012 but children from households that used shared toilet facilities had a lower chance of diarrhea in 2012. This finding contradicts the idea that sharing one facility with multiple families increases the chance of affecting each other by the viruses causing diarrhea (Just et al., 2018). We found from 2019 data that children from households that used shared toilet facilities were more at risk of experiencing diarrhea. However, it is not sure that the shared toilet facility caused diarrhea, but the unhygienic toilet facility contains the pathogens like norovirus, which caused diarrhea (Just et al., 2018). The toilet facility, whether shared or private, must be clean, and the people using the toilet must practice hand washing after using the toilet (Baker et al., 2016). Households using shared toilet facilities might prioritize hand washing practices over other households, which could cause the findings.

We found from 2019 data that the chance of having diarrhea was significantly higher for underweight children. Being underweight depicts the malnourished status of a child, and malnourished children are prone to infectious diseases due to the lack of proper nutrition and weak immune system. Underweight children were more likely to have diarrhea due to the malnourished condition, and previous studies conducted in Bangladesh supported these findings (Ahmed et al., 2012; Ferdous et al., 2013; Mata, 1992).

In 2006, Children from Khulna had a significantly lower chance of diarrhea than Children from Sylhet. Compared with Sylhet, children from Barisal were significantly more at risk, but children from Rangpur were less at risk of having diarrhea in 2019. The water-borne diseases like diarrhea are more observed in water-prone areas like the northeastern and southern parts of Bangladesh (Das, Chandra, & Saha, 2019). Sylhet division always faces sudden floods during the rainy season, and the water gets stuck in several areas of Sylhet for a long time, providing a favorable state to increase the infection of diarrhea among people. Moreover, some districts of the Khulna, Barisal and Chittagong divisions are part of the southern coastal region with salty water (M. A. Islam, Hoque, Ahmed, & Butler, 2019). The chance of having diarrhea was higher for children from these places than in other parts of Bangladesh.

We found that Muslim children were more at risk of having diarrhea in 2019. More than 90 percent of children were from Muslim families, and due to the unbalanced status of this factor, the finding related to this lacks accuracy (Salas-Eljatib, Fuentes-Ramirez, Gregoire, Altamirano, & Yaitul, 2018). To accurately assess the effect of religion on the prevalence of diarrhea through logistic regression require balanced data in terms of this factor or application of modified machine learning methods.

**Strengths and limitations**

MICS data, according to our knowledge, known to be perfectly comparable with Demographic Health Survey data and used for global statistics, were analyzed to fulfill the research purpose. The findings of this study represent the scenario of under-five children at the time of the survey years. Several variables were assessed during analysis which has chances of influencing diarrhea. Despite these benefits, there were a few flaws with our research. There was no control over the definition of variables and their measurement scales and criteria. Additionally, the survey was conducted in 2006, 2012, and 2019. Therefore, the diarrheal status may have changed since the survey's midpoint or at that time. In addition, information about children's food habits also needed to be given. Furthermore, the cross-sectional data only provide the power to analyze the association of the factors with the outcome variables. More information was needed about mothers' health to depict the actual picture.

**Recommendations**

Governments, international organizations, non-governmental organizations, and public health professionals should consider the results of this study when making decisions about how to improve child health over time and stop diarrhea in Bangladesh. Hopefully, this study will help policymakers to focus on interventions that are feasible and can be implemented to reduce the risk. Beyond the usual development standards, expanding nutrition and direct diarrhea interventions, water, sanitation, and hygiene (WASH), and basic sanitation practices like handwashing with soap can reduce the rate of childhood diarrhea. Implementing these measures can also reduce hospital burden. Additionally, efforts should be reassessed and stepped up to improve sanitary infrastructure, personal and food hygiene, and home waste management. Another choice, though pricy, is the creation and widespread distribution of vaccinations against Bangladesh's most prevalent diarrheagenic pathogens. Clinicians and caregivers may be better equipped to intervene when an illness is still in its early stages if they are able to identify children becoming extremely dehydrated.

**Conclusion**

Our study shows that factors such as age of the child, underweight, division, wealth status, religion, shared toilet facilities, and toilet facility type significantly influenced the chance of having diarrhea among 0-5 years old children in Bangladesh. Younger children, primarily those between the ages of 12 and 23 months, underweight children, children from the poorest households and households with inadequate sanitation facilities had higher chance of having diarrhea. Private and improved toilet facilities, hygiene practices, and proper nutrition for children can reduce childhood diarrhea. The findings of our study have some potential implications for our policymakers. Different government and non-government organizations, international agencies, and public health professionals work to improve children's health. Implementation of program regarding basic hygiene practice and child nutrition along with existing program can make substantial changes in childhood diarrhea.

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**Tables and Figures**

**Table.1 Distribution of several factors with the diarrhea status of children, MICS 2006, 2012, and 2019.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | 2006 | | | 2012 | | | 2019 | | |
| Diarrhea | | P-value | Diarrhea | | P-value | Diarrhea | | P-value |
| Yes | No |  | Yes | No | Yes | No |
| N (%) | N (%) |  | N (%) | N (%) | N (%) | N (%) |
| **CHILD CHARACTERISTICS** | | | | | | | | | |
| Age of child (in months) | | | | | | | | | |
| 0-11 | 483 (8.5) | 5185 (91.5) | **<0.001** | 213 (5.4) | 3769 (94.6) | **<0.001** | 421 (9.1) | 4184 (90.9) | **<0.001** |
| 12-23 | 606 (10.0) | 5423 (90.0) | 315 (7.7) | 3776 (92.3) | 448 (10.1) | 3986 (89.9) |
| 24-35 | 444 (7.0) | 5876 (93.0) | 140 (3.3) | 4048 (96.7) | 326 (7.1) | 4279 (92.9) |
| 36-47 | 388 (5.7) | 6398 (94.3) | 97 (2.2) | 4232 (97.8) | 247 (5.1) | 4570 (94.9) |
| 48-59 | 332 (4.9) | 6410 (95.1) | 61 (1.4) | 4242 (98.6) | 154 (3.3) | 4473 (96.7) |
| Child’s sex | | | | | | | | | |
| Male | 1200 (7.4) | 15017 (92.6) | 0.107 | 421 (3.9) | 10268 (96.1) | 0.931 | 860 (7.2) | 11144 (92.8) | 0.178 |
| Female | 1054 (6.9) | 14278 (93.1) | 404 (4.0) | 9799 (96.0) | 736 (6.6) | 10347 (93.4) |
| Inadequate Supervision | | | | | | | | | |
| Yes | - | - |  | 82 (5.1) | 1504 (94.9) | 0.057 | 120 (8.1) | 1367 (91.9) | 0.079 |
| No | - | - | 742 (3.8) | 18545 (96.2) | 1477 (6.8) | 20122 (93.2) |
| Underweight | | | | | | | | | |
| Yes | - | - |  | 259 (4.0) | 6167 (96.0) | 0.879 | 439 (8.5) | 4698 (91.5) | **<0.001** |
| No | - | - | 537 (4.0) | 12950 (96.0) | 1120 (6.5) | 16181 (93.5) |
| Stunned | | | | | | | | | |
| Yes | - | - |  | 323 (3.9) | 7893 (96.1) | 0.867 | 461 (7.4) | 5765 (92.6) | 0.132 |
| No | - | - | 447 (4.0) | 10752 (96.0) | 1071 (6.8) | 14747 (93.2) |
| Wasted | | | | | | | | | |
| Yes | - | - |  | 92 (4.7) | 1862 (95.3) | 0.148 | 178 (8.1) | 2028 (91.9) | 0.053 |
| No | - | - | 699 (4.0) | 16979 (96.0) | 1353 (6.8) | 18442 (93.2) |
| Overweight | | | | | | | | | |
| Yes | - | - |  | 44 (2.8) | 1529 (97.2) | 0.050 | 90 (5.5) | 1539 (94.5) | 0.057 |
| No | - | - | 781 (4.0) | 18538 (96.0) | 1507 (7.0) | 19952 (93.0) |
| COMMUNITY CHARACTERISTICS | | | | | | | | | |
| Place of residence | | | | | | | | | |
| Urban | 1630 (7.1) | 21394 (92.9) | 0.293 | 627 (3.8) | 15998 (96.2) | 0.098 | 1255 (6.9) | 16932 (93.1) | 0.896 |
| Rural | 611 (7.4) | 7661 (92.6) | 198 (4.6) | 4069 (95.4) | 342 (7.0) | 4560 (93.0) |
| Tribal | 13 (5.1) | 240 (94.9) | - | - | - | - |
| Division | | | | | | | | | |
| Barishal | 167 (8.9) | 1705 (91.1) | **<0.001** | 80 (6.3) | 1188 (93.7) | **0.002** | 185 (14.1) | 1129 (85.9) | **<0.001** |
| Chattogram | 515 (7.6) | 6279 (92.4) | 218 (4.6) | 4571 (95.4) | 380 (7.6) | 4651 (92.4) |
| Dhaka | 704 (7.1) | 9228 (92.9) | 224 (3.5) | 6231 (96.5) | 311 (5.7) | 5177 (94.3) |
| Khulna | 139 (4.4) | 3008 (95.6) | 67 (3.3) | 1942 (96.7) | 155 (6.5) | 2238 (93.5) |
| Mymensingh | - | - | - | - | 153 (8.7) | 1597 (91.3) |
| Rajshahi | 540 (7.4) | 6743 (92.6) | 85 (3.6) | 2319 (96.4) | 182 (6.6) | 2568 (93.4) |
| Rangpur | - | - | 90 (3.8) | 2282 (96.2) | 112 (4.5) | 2379 (95.5) |
| Sylhet | 189 (7.5) | 2333 (92.5) | 61 (3.8) | 1533 (96.2) | 119 (6.3) | 1753 (93.7) |
| PARENTAL CHARACTERISTICS | | | | | | | | | |
| Mother’s Education | | | | | | | | | |
| Primary incomplete | 1299 (8.0) | 14912 (92.0) | **<0.001** | 319 (4.2) | 7323 (95.8) | 0.786 | 199 (7.7) | 2387 (92.3) | 0.052 |
| Primary complete | 274 (6.7) | 3808 (93.3) | 118 (3.6) | 3137 (96.4) | 402 (7.3) | 5078 (92.7) |
| Secondary incomplete | 489 (6.2) | 7454 (93.8) | 282 (3.9) | 7003 (96.1) | 779 (6.9) | 10548 (93.1) |
| Secondary complete or higher | 178 (5.5) | 3027 (94.5) | 106 (3.9) | 2605 (96.1) | 217 (5.9) | 3478 (94.1) |
| Non-standard curriculum | 14 (13.6) | 92 (86.4) | - | - | - | - |  |
| Mother’s Age at the Survey Time | | | | | | | | | |
| 15 – 19 | 471 (7.8) | 5605 (92.3) | 0.390 | 71 (5.4) | 1251 (94.6) | **0.004** | 294 (6.9) | 3944 (93.1) | 0.991 |
| 20-34 | 938 (7.1) | 12322 (92.9) | 578 (4.5) | 12410 (95.5) | 715 (6.9) | 9620 (93.1) |
| 35+ | 620 (7.2) | 7947 (92.8) | 112 (3.2) | 3440 (96.8) | 475 (7.0) | 6334 (93.0) |
| HOUSEHOLD CHARACTERISTICS | | | | | | | | | |
| Wealth Index | | | | | | | | | |
| Poorest | 685 (8.6) | 7299 (91.4) | **<0.001** | 246 (4.8) | 4857 (95.2) | 0.071 | 421 (8.4) | 4615 (91.6) | **<0.001** |
| Poor | 502 (7.6) | 6107 (92.4) | 155 (3.6) | 4128 (96.4) | 371 (8.2) | 4159 (91.8) |
| Middle | 420 (7.1) | 5495 (92.9) | 130 (3.4) | 3752 (96.6) | 262 (6.1) | 4036 (93.9) |
| Rich | 326 (5.6) | 5526 (94.4) | 139 (3.7) | 3609 (96.3) | 281 (6.2) | 4226 (93.8) |
| Richest | 321 (6.2) | 4867 (93.8) | 155 (4.0) | 3722 (96.0) | 262 (5.5) | 4456 (94.5) |
| Religion | | | | | | | | | |
| Islam | 2082 (7.3) | 26611 (92.7) | 0.061 | 710 (4.0) | 17115 (96.0) | 0.904 | 1489 (7.0) | 19658 (93.0) | **0.026** |
| Others | 172 (6.0) | 2684 (94.0) | 80 (3.9) | 1956 (96.1) | 107 (5.5) | 1834 (94.5) |
| Household Head Sex | | | | | | | | | |
| Male | 2155 (7.2) | 27838 (92.8) | 0.285 | 689 (4.0) | 16519 (96.0) | 0.704 | 1483 (7.0) | 19626 (93.0) | 0.067 |
| Female | 99 (6.3) | 1456 (93.7) | 101 (3.8) | 2552 (96.2) | 114 (5.7) | 1865 (94.0) |
| Ethnicity | | | | | | | | | |
| Bengali | 2225 (7.2) | 28813 (92.8) | 0.144 | 768 (4.0) | 18505 (96.0) | 0.814 | 1571 (6.9) | 21263 (93.1) | **0.019** |
| Other | 29 (5.7) | 476 (94.3) | 22 (3.7) | 567 (96.3) | 25 (10.0) | 229 (90.0) |
| Toilet facilities shared | | | | | | | | | |
| Yes | 943 (7.5) | 11636 (92.5) | **0.016** | 175 (3.4) | 4942 (96.6) | **0.038** | 541 (7.8) | 6365 (92.2) | **0.001** |
| No | 1076 (6.6) | 15123 (93.4) | 603 (4.2) | 13815 (95.8) | 1027 (6.5) | 14781 (93.5) |
| Toilet facility type | | | | | | | | | |
| Improved | 1436 (6.5) | 20646 (93.5) | **<0.001** | 758 (4.0) | 18343 (96.0) | 0.868 | 1491 (6.8) | 20531 (93.2) | **0.001** |
| Non-improved | 814 (8.7) | 8597 (91.4) | 31 (4.1) | 729 (95.9) | 104 (9.8) | 958 (90.2) |
| Salt Iodization | | | | | | | | | |
| Yes | 1803 (6.9) | 24430 (93.1) | **<0.001** | 591 (4.0) | 14067 (96.0) | 0.601 | 1141 (6.6) | 16239 (93.4) | **0.002** |
| No | 449 (8.6) | 4793 (91.4) | 199 (3.8) | 5002 (96.2) | 455 (8.0) | 5244 (92.0) |
| Mass Media | | | | | | | | | |
| Yes | - | - | - | 398 (4.3) | 8845 (95.7) | 0.817 | 851 (6.6) | 11968 (93.4) | 0.059 |
| No | - | - | 363 (4.2) | 8250 (95.8) | 634 (7.4) | 7930 (92.6) |
| Household size | | | | | | | | | |
| <5 | 718 (6.9) | 9708 (93.1) | 0.322 | 426 (3.8) | 10960 (96.3) | 0.154 | 925 (6.7) | 12865 (93.3) | 0.191 |
| 5/5+ | 1536 (7.3) | 19587 (92.7) | 363 (4.3) | 8111 (95.7) | 671 (7.2) | 8626 (92.8) |
| Livestock ownership | | | | | | | | | |
| Yes | - | - | - | 452 (4.0) | 10773 (96.0) | 0.786 | 913 (6.9) | 12329 (93.1) | 0.858 |
| No | - | - | 336 (3.9) | 8234 (96.1) | 682 (6.9) | 9116 (93.1) |
| Source water type | | | | | | | | | |
| Improved | 2216 (7.1) | 28783 (92.9) | 0.854 | 772 (4.0) | 18590 (96.0) | 0.687 | 1566 (6.90) | 21122 (93.10) | 0.537 |
| Unimproved | 38 (6.9) | 508 (93.1) | 17 (3.5) | 481 (96.5) | 30 (7.54) | 370 (92.50) |
| Source of water | | | | | | | | | |
| Direct from source | - | - | - | 8 (3.7) | 218 (96.3) | 0.097 | 27 (8.7) | 290 (91.4) | 0.366 |
| Covered container | - | - | 113 (4.2) | 2570 (95.8) | 216 (7.4) | 2706 (92.6) |
| Uncovered container | - | - | 32 (2.7) | 1166 (97.3) | 88 (6.3) | 1304 (93.7) |
| Water treatment | | | | | | | | | |
| Yes | 170 (8.1) | 1917 (91.9) | 0.214 | 88 (4.6) | 1828 (95.4) | 0.256 | 168 (6.9) | 2271 (93.1) | 0.945 |
| No | 2078 (7.1) | 27344 (92.9) | 702 (3.9) | 17238 (96.1) | 1429 (6.9) | 19214 (93.1) |
| **Total** | **2254 (7.1)** | **29295 (92.9)** |  | **825 (3.9)** | **20067 (96.1)** |  | **1596 (6.9)** | **21492 (93.1)** |  |

**Table.2 Factors associated with the diarrhea status of children using multivariable logistic regression model (MICS 2006, 2012, and 2019)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Characteristics | 2006 |  | 2012 |  | 2019 |  |
| AOR (95% CI) | P-value | AOR (95% CI) | P-value | AOR (95% CI) | P-value |
| CHILD CHARACTERISTICS | | | | | | |
| Age of child (in months) | |  | |  | |  |
| 0-11 | 1.81 (1.50, 2.18) | **<0.001** | 4.35 (2.10, 9.01) | **<0.001** | 3.32 (2.63, 4.19) | **<0.001** |
| 12-23 | 2.22 (1.86, 2.65) | **<0.001** | 5.24 (2.51, 10.95) | **<0.001** | 3.36 (2.67, 4.22) | **<0.001** |
| 24-35 | 1.45 (1.22, 1.73) | **<0.001** | 1.59 (0.71, 3.59) | 0.261 | 2.26 (1.76, 2.89) | **<0.001** |
| 36-47 | 1.17 (0.97, 1.42) | 0.108 | 2.11 (0.92, 4.82) | 0.077 | 1.52 (1.18, 1.95) | **0.001** |
| 48-59 | Ref. | - | Ref. | - | Ref. | - |
| Child’s sex | |  | |  | |  |
| Male | 1.05 (0.95, 1.16) | 0.351 | - | - | 1.04 (0.92, 1.19) | 0.526 |
| Female | Ref. | - | - | - | Ref. | - |
| Inadequate Supervision | |  | |  | |  |
| Yes | - | - | 1.37 (0.69, 2.73) | 0.368 | 1.18 (0.94, 1.48) | 0.148 |
| No | - | - | Ref. | - | Ref. | - |
| Underweight | |  | |  | |  |
| Yes | - | - | - | - | 1.44 (1.20, 1.73) | **<0.001** |
| No | - | - | - | - | Ref. | - |
| Stunned | |  | |  | |  |
| Yes | - | - | - | - | 0.93 (0.77, 1.10) | 0.385 |
| No | - | - | - | - | Ref. | - |
| Wasted | |  | |  | |  |
| Yes | - | - | 1.61 (0.92, 2.84) | 0.097 | 0.89 (0.72, 1.10) | 0.294 |
| No | - | - | Ref. | - | Ref. | - |
| Overweight | |  | |  | |  |
| No | - | - | 3.46 (0.40, 29.65) | 0.310 | 1.43 (0.86, 2.38) | 0.165 |
| Yes | - | - | Ref. | - | Ref. | - |
| COMMUNITY CHARACTERISTICS | | | | | | |
| Place of residence | |  | |  | |  |
| Rural | 1.16 (0.65, 2.06) | 0.610 | 1.29 (0.75, 2.23) | 0.363 | - | - |
| Urban | 1.46 (0.81, 2.62) | 0.206 | Ref. | - | - | - |
| Tribal | Ref. | - | - | - | - |  |
| Division | |  | |  | |  |
| Barishal | 1.27 (0.99, 1.63) | 0.063 | 0.67 (0.27, 1.63) | 0.375 | 2.51 (1.74, 3.63) | **<0.001** |
| Chattogram | 1.09 (0.87, 1.36) | 0.439 | 1.01 (0.47, 2.20) | 0.973 | 1.33 (0.94, 1.90) | 0.112 |
| Dhaka | 0.96 (0.78, 1.19) | 0.724 | 1.01 (0.46, 2.16) | 0.999 | 0.91 (0.64, 1.30) | 0.597 |
| Khulna | 0.65 (0.50, 0.85) | **0.002** | 0.93 (0.41, 2.13) | 0.862 | 1.05 (0.72, 1.53) | 0.814 |
| Mymensingh | - | - | - | - | 1.22 (0.84, 1.79) | 0.296 |
| Rajshahi | 1.04 (0.83, 1.28) | 0.754 | 0.90 (0.36, 2.22) | 0.811 | 0.93 (0.64, 1.35) | 0.702 |
| Rangpur | - | - | 1.42 (0.63, 3.17) | 0.397 | 0.59 (0.40, 0.88) | **0.010** |
| Sylhet | Ref. | - | Ref. | - | Ref. | - |
| PARENTAL CHARACTERISTICS | | | | | | |
| Mother’s Education | |  | |  | |  |
| Non-standard curriculum | 2.58 (1.21, 5.51) | 0.015 | - | - | - | - |
| Primary incomplete | 1.29 (0.98, 1.69) | 0.064 | - | - | 1.21 (0.91, 1.61) | 0.188 |
| Primary complete | 1.19 (0.87, 1.63) | 0.266 | - | - | 1.08 (0.86, 1.36) | 0.518 |
| Secondary incomplete | 1.11 (0.86, 1.44) | 0.421 | - | - | 1.09 (0.88, 1.34) | 0.426 |
| Secondary complete or higher | Ref. | - | - | - | Ref. | - |
| Mother’s Age at the Survey Time | |  | |  | |  |
| 15-19 | - | - | 1.57 (0.69, 3.57) | 0.280 | - | - |
| 20-34 | - | - | 1.46 (0.77, 2.74) | 0.243 | - | - |
| 35+ | - | - | Ref | - | - | - |
| HOUSEHOLD CHARACTERISTICS | | | | | | |
| Wealth Index | |  | |  | |  |
| Poorest | 1.30 (1.01, 1.65) | **0.038** | - | - | 1.14 (0.90, 1.44) | 0.277 |
| Second | 1.13 (0.89, 1.44) | 0.325 | - | - | 1.32 (1.04, 1.66) | **0.020** |
| Middle | 1.12 (0.89, 1.41) | 0.331 | - | - | 0.95 (0.75, 1.20) | 0.667 |
| Fourth | 0.90 (0.71, 1.14) | 0.373 | - | - | 1.03 (0.81, 1.32) | 0.791 |
| Richest | Ref. | - | - | - | Ref. | - |
| Religion | |  | |  | |  |
| Islam | 1.05 (0.82, 1.35) | 0.684 | - | - | 1.39 (1.02, 1.88) | **0.036** |
| Others | Ref. | - | - | - | Ref. | - |
| Household Head Sex | |  | |  | |  |
| Male | - | - | - | - | 1.20 (0.92, 1.55) | 0.174 |
| Female | - | - | - | - | Ref. | - |
| Ethnicity | |  | |  | |  |
| Bengali | 1.27 (0.76, 2.13) | 0.684 | - | - | 0.59 (0.34, 1.01) | 0.056 |
| Other | Ref. | - | - | - | Ref. | - |
| Toilet facilities shared | |  | |  | |  |
| Yes | 1.07 (0.96, 1.20) | 0.210 | 0.60 (0.36, 0.99) | **0.047** | 1.23 (1.07, 1.42) | **0.004** |
| No | Ref. | - | Ref | - | Ref. | - |
| Toilet facility type | |  | |  | |  |
| Non-improved | 1.23 (1.08, 1.40) | 0.002 | - | - | 1.49 (1.08, 2.05) | **0.015** |
| Improved | Ref. | - | - | - | Ref. | - |
| Salt Iodization | |  | |  | |  |
| No | 1.13 (0.98, 1.30) | 0.103 | - | - | 1.15 (0.99, 1.34) | 0.065 |
| Yes | Ref. | - | - | - | Ref. | - |
| Mass Media | |  | |  | |  |
| No | - | - | - | - | 0.99 (0.87, 1.14) | 0.920 |
| Yes | - | - | - | - | Ref. | - |
| Household size | |  | |  | |  |
| 5/5+ | - | - | 1.13 (0.72, 1.77) | 0.595 | 0.91 (0.79, 1.04) | 0.171 |
| <5 | - | - | Ref. | - | Ref. | - |
| Livestock ownership | |  | |  | |  |
| Yes | - | - | - | - | - | - |
| No | - | - | - | - | - | - |
| Source water type | |  | |  | |  |
| Improved | - | - | - | - | - | - |
| Unimproved | - | - | - | - | - | - |
| Source of water | |  | |  | |  |
| Direct from source | - | - | 1.28 (0.53, 3.08) | 0.580 | - | - |
| Covered container | - | - | 1.37 (0.83, 2.27) | 0.218 | - | - |
| Uncovered container | - | - | Ref. | - | - | - |
| Water treatment | |  | |  | |  |
| Yes | - | - | - | - | - | - |
| No | - | - | - | - | - | - |

AOR: Adjusted odds ratio

**Table 3: Area under ROC Curve, AIC, and BIC for the final logistic regression model.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Survey Year | The area under ROC Curve | | AIC | BIC |
| AUC | P-value |
| MICS 2006 | 0.6210 | <0.001 | 14320.83 | 14545.55 |
| MICS 2012 | 0.6826 | <0.001 | 1167.66 | 1295.21 |
| MICS 2019 | 0.6717 | <0.001 | 9610.21 | 9870.85 |

The list of enumeration areas (EAs) for the total population of Bangladesh from Census of 2001 and 2011 and update household list within EAs in 2006, 2012, and 2018.

The main Sampling strata for the two-stage sampling were urban and rural areas within districts.

Within each enumeration area (EA), 20 households were sampled using systematic sampling.

68,247, 55,120, 64,400 households were selected from the EAs in the sample 2006, 2012-13, and 2019 survey years, respectively.

62,463, 51,895, and 61,242 households were completely interviewed with response rate of 92.5%, 98.5%, and 99.4%, respectively.

34,710, 23,402, and 24,686 children under age five were selected in the sample from the interviewed households 2006, 2012-13, and 2019 of survey years, respectively.

Completed data found from 31, 566, 20,903, and 23,099 children given a response rate of 90.9%, 89.3%, and 93.6%, respectively.

**Figure 1: Study population and selection of sample for MICS 2006, 2012-13, and 2019**

|  |
| --- |
|  |
| **Figure 2. Forest plot of Adjusted Odds ratios (ORs) and 95% confidence intervals (CIs) for factors associated with the diarrhea status of children (MICS 2006, 2012, and 2019)**   |  |  |  | | --- | --- | --- | |  |  |  | | **MICS 2006** | **MICS 2012** | **MICS 2019** | |

Figure 3. Sensitivity analysis of fitted final multivariable logistic regression model