**Association between caesarean delivery and early childhood diseases in Bangladesh**

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**Abstract**

**Introduction:** The rate of cesarean delivery (C-section) has increased worldwide including Bangladesh. Since the C-section is major surgery, it has a negative impact on the health of the mother and child. However, research on this area in ​​Bangladesh is scarce. Our objective was to inspect the association between C-section versus vaginal delivery and childhood diseases using negative binomial (NB) regression and propensity score (PS) method. **Methods:** We used the latest available nationally representative data from a multiple indicator cluster survey (MICS, 2012-13) and also Bangladesh Demographic and Health Survey (BDHS, 2014). After considering the inclusion and exclusion criteria, 7902 children were eligible for final analysis from MICS data and 4557 children were eligible for final analysis from BDHS data. The outcome variable was created using childhood diseases such as fever, fast and/or difficulty of breathing, blood in stools and diarrhea. Important confounding factors such as the age of child, child ever been breastfed, child's weight during survey, weight at birth, child's length or height, area, division, sex (child), mother's education, age, body mass index, religion of household head, and wealth index quintile were considered. We used the PS method to analyses our data. For sensitivity, we also used NB regression with a log link in which the outcome was a count variable. **Results:** We found 19.1% and 23.3% of children were born in the C-section and 80.9% and 70.7% of children were born in normally (vaginal delivery) in MICS and BDHS surveys respectively. From the PS method, we found the crude (the only type of delivery variable in the model) risk ratios (RR) for the C-section were 1.60 (95% confidence interval (CI): 1.30-1.97) and 1.11 (95% CI: 1.01-1.23) for MICS and BDHS, respectively. RR for adjusted (type of delivery and propensity scores in the model) model was 1.19 (CI: 0.99-1.43) for MICS and 1.17 (1.05-1.29) for BDHS. Almost similar findings were observed in the case of the NB regression model using the count outcome (e.g., the RR was 1.06 (95% CI: 1.02-1.09) for MICS and 1.08 (CI: 0.97-1.19) for BDHS and adjusted risk ratio (ARR) was 1.02 (95% CI: 0.98-1.06) for MICS and 1.15 (CI:1.05-1.27) for BDHS, respectively. **Conclusion:** Although the results indicate that children born in C-section compare to the vaginal delivery were at increased risk for developing childhood disease, we did not identify any significant causal association between the type of delivery and the childhood diseases in some models. However, we recommend increasing public awareness of the negative impact of unnecessary cesarean delivery in Bangladesh.

**Keywords:** Caesarean section; vaginal delivery; childhood disease; MICS, BDHS

**1. Introduction**

Cesarean delivery (C-section) is a surgical procedure that is often performed to reduce the risks for the mother and fetus during vaginal delivery (Zakerihamidi, Roudsari, & Khoei, 2015). However, today, the C-section is considered to be relieving from labor pain and people have a common belief that C-section is painless, safer, and healthier than vaginal delivery. Recently, it has become a preferred choice as mode of delivery among women (Lori & Boyle, 2011). But C-section should only recommend when the life of the mother or fetus is at risk.

The C-section is rapidly increasing in many developed and developing countries (Farmer et al., 2003; Gomes, Silva, Bettiol, & Barbieri, 1999). In recent years as a major surgery related to immediate risk of maternal and childbirth and may be important for pregnancy and long-term effects on child. C-section is rapidly increasing in many developed and developing countries. More than half of women voluntarily undergo C-section (Danforth & Gibbs, 2008). This choice is influenced by several factors, including ways to prevent labor pain, it is safer, healthier than vaginal delivery (Tatar, Günalp, Somunoglu, & Demirol, 2000), fear of vaginal delivery (Latifnejad-Roudsari, Zakerihamidi, Merghati-Khoei, & Kazemnejad, 2014) , incorrect cultural assumptions about C-Section delivery (Aziken, Omo-Aghoja, & Okonofua, 2007), and closure of the uterine tubes (Kasai, Nomura, Benute, de Lucia, & Zugaib, 2010). In contrast, most women prefer natural birth due to personal beliefs, cultural customs and values (Latifnejad-Roudsari et al., 2014), faster recovery after delivery (Kasai et al., 2010), economic problems (Zakerihamidi, Roudsari, Khoei, & Kazemnejad, 2014), lack of concern about the safety of mother and baby and fear of anesthesia (Black, Kaye, & Jick, 2005).

A trend analysis based on data from 121 countries reported that, from 1990 to 2014, the average C-section rates increased by 12.4% and it annually increased by 4.4% (Betrán et al., 2016). A 2004-2008 world health organization (WHO) survey recorded an average global rate of C-section was 25.7% in which 27.3% in Asia, 29.2% in Latin America and 19.0% in Europe (Lumbiganon et al., 2010; Villar et al., 2006). As stated by WHO, there is no justification for any region to have a caesarean rate higher than 10 -15%, which weighs a serious reason for worry in most of the countries worldwide (Rahman, Shariff, Shafie, Saaid, & Tahir, 2015). In Bangladesh, the C-section (either clinically necessary or unnecessary) rate increased from 3.5% in 2004 to 23% in 2014 (Khan, Islam, Shariff, Alam, & Rahman, 2017).

Women experiencing the C-section delivery without a clear intimation for the process have a risk of major morbidity including cardiac arrest, hysterectomy, puerperal infection, thromboembolism, wound hematoma, anesthetics complications than those undergoing planned vaginal delivery (Yuan et al., 2016). Besides, babies born in C-section are at risk of developing asthma, type 1 diabetes, allergic diseases (Ajslev, Andersen, Gamborg, Sørensen, & Jess, 2011; Darmasseelane, Hyde, Santhakumaran, Gale, & Modi, 2014), crohn's disease (Yuan et al., 2016), immune deficiencies, and leukemia and so on. A study was conducted to examine the distribution of C-section and its correlates in the northern part of Bangladesh (Rahman et al., 2015). Rahman et al showed that previous C-section, prolonged labor, higher education level, mother age of 25 years or more, lower order of birth, baby length greater than 45 cm, and unbalanced diet were some factors that were significantly correlated with C-section. Another study found that higher age of mother, lower birth order, higher education of parents, higher socioeconomic status, poor maternal history, and adoption of three or more ANCs were significantly associate with C-section delivery (Begum et al., 2017).

In Bangladesh, children are generally suffering from several common diseases such as fast and/or difficulty of breathing or acute respiratory infection, diarrhea with bloods, fever etc. However, to the best of our knowledge, there is no research has been conducted to determine the association between C-section and such early childhood diseases in Bangladesh. Hence, it is important to study the consequence of C-section delivery on the child health particularly on the early childhood diseases using a proper statistical method. Therefore, we aimed to investigate the causal association between C-section delivery and childhood diseases using a propensity score method. This study also looks for key factors associated with childhood diseases. The study uses data from the BDHS 2014 and MICS 2012 collected from the nationally representative cross-sectional survey. By identifying key factors, the present study is to assess the data on type of delivery and childhood diseases collected by MICS and DHS and compare C-section measures.

**2. Methods**

***Data source and Study design***

We used the latest available secondary dataset from the Bangladesh Demographic and Health Survey (BDHS, 2014) for our study. To compare the results, we also used another secondary survey data, the multiple indicator cluster survey (MICS, 2012-13) in Bangladesh (UNICEF, 2015). BDHS is large, household surveys produced by the Demographic and Health Surveys Program. The targeted sample is based on nationally representative sampling plans. The surveys highlighted on identical measures of fertility and child mortality, and indicators of access to maternal and child health interventions, illness, treatment, and nutritional status. These surveys also collect a wide range of identical socioeconomic status, demographic status, and other such information. These data-sets are fully open-access (Corsi, Perkins, & Subramanian, 2017). There 7886 number of mother-child pairs information was given which represents the seven divisions (Chittagong, Dhaka, Barisal, Sylhet, Rajshahi, Khulna, Rangpur) in Bangladesh. Districts are taken as the main sampling strata for the sample (NIPORT/Bangladesh, Associates, & International, 2016). Among them, the number of children living with their mother is 6650 and about 1236 children don’t live with their mother. From figure 1, 4557 children of three years of age are selected as a sample because BDHS only contains C-Section information of this age of child and 2093 children greater than 3 years are omitted for final analysis.



**Figure 1: Flow Chart of BDHS data for study population**

MICS is the largest, multi-dimensional household survey conducted by UNICEF. They focus on reproductive health, maternal and child health interventions, child nutrition status and early childhood development, and use similar methods and measurement protocols in DHS. MICS also collects an identical set of socioeconomic characteristics of individuals and households. Data-sets were open access for the public domain (Corsi et al., 2017). 2012-13 MICS is based on a sample of 51,895 households (43,474 rural, 8,421 urban) interviewed with a response rate of 98.5% and provides a comprehensive picture of children and women health in the seven administrative divisions (Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Barisal, Khulna) of Bangladesh. Districts were identified as the main sample strata for sample selection at 2 stages (UNICEF, 2015). In this study, the child age ranged from 0 to 24 months were included; 36197 women have not had a child and 15481 babies greater than 24 months were excluded from the analysis. Therefore, the sample included 7921 children and mother information for analysis. Among the 7921 children, the information about the type of delivery has only 2181 children and 2122 children have both types of delivery and disease information (Figure 2).



**Figure 2: Flow Chart of MICS data for study population**

Since their inauguration, BDHS and MICS surveys have played a key role in shaping the global agenda on tracking coverage and populating global databases. They have also influenced policies and intervention strategies. For example, DHS / MICS data is often used to fulfill the target of national economic and social development plans, to provide advocacy for programs to improve women’s and children’s health and to assist programs in identifying target groups in most need of interventions. The role that these data play at the national and international level makes it essential that the value of the data quality is the primary consideration when designing surveys.

**Potential confounding variables**

We considered important confounding variables and/or covariates including, religion, breastfed status, sex (child), education (mothers), child Age (in months), body mass index (mothers), wealth index quintile, area, division, child's length or height, weight at birth (child) and fathers’ education.

**Exposure variable**

The exposure variable was the type of delivery (C-section versus normal delivery), which is a binary variable.

**Outcome variable**

For creating the outcome variables disease, we used variables such as the child did not able to drink or breastfeed, becomes sicker, develops a fever, has fast breathing, has difficulty breathing, has blood in stools, drinking poorly and has diarrhea. During the analyses, two types of outcome variables were considered. First, a binary outcome in which 0 means children were suffered from lower than median value (diseases) and 1 means greater than median value (diseases); second, a count variable that means the frequency of the diseases.

**Statistical analyses**

Descriptive statistics of each of the selected confounding variables and distribution of type of delivery were shown by adjusting sampling weight. Similarly, weighted percentages were calculated to compare demographic and socioeconomic characteristics among the type of delivery. Pearson's chi-squared test was used to determine whether differences in demographic and socioeconomic characteristics between C-section and vaginal delivery were statistically significant. We applied a propensity score method for the first outcome (binary). The propensity score (PS) method is the probability of exposure (C-section versus vaginal delivery) assignment conditional on possible confounding. This approach helps us to design and analyze our observational survey data so that it mimics some of the characteristics (covariates) of a randomized controlled trial (Austin, 2011). Poisson regression models often display overdispersion, for that reason negative binomial (NB) regression models are perhaps the most convenient too with and have been used by various authors (Lawless, 1987). Hence for the second outcome, we applied a NB regression method with a log link to assess the sensitivity of the results from the PS method. We also reported the crude and adjusted exposure effects. All statistical analyses were performed with the program SAS (Statistical Analysis Software 9.4). Also, add the adjustment of survey weight, cluster, and stratum in the analysis.

***Ethics approval***

Our study was wholly based on an analysis of existing public domain health survey datasets obtained from BDHS 2014 and MICS 2012, which is freely available online with all identifier information removed. The BDHS 2014 data was reviewed and approved by the ICF Macro Institutional Review Board and the National Research Ethics Committee of the Bangladesh Medical Research Council. 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 with secondary data conducted by a publicly available dataset that did not disclose the identity of the respondents, thus, it did not require the ethical approval of the respective institution.

**3. Results**

**Descriptive analysis**

Table 1 outlines the participant characteristics as well as differences between participants with C-section and without C-section for both the data sources.. The proportion of cesarean deliveries were 19.1% and 23.3% in MICS and BDHS data, respectively.. Women who had undergone a C-section had a lower prevalence (11.7%) in higher age groups (35+ years) for MICS but in BDHS data, women with C-section delivery had lower prevalence for lowest age groups (15-19 years). There were significant differences in region of residence, mother’s education, wealth index, BMI, place of residence between mothers with and without cesarean delivery. Compared to non-cesarean delivery, there were more cesarean deliveries of mothers age 20-34 (20 vs.23.9%) in MICH and BDHS data, respectively.

According to MICS, the highest prevalence of C-section, 20.0%, was found in the age group 24-34 years and BDHS also shows the highest prevalence (23.9%) for similar age groups. Prevalence of C-section was significantly lower in Muslim than non-Muslim with the figures being 18.6% for Muslims and 25.1% for non-Muslim in MICS, but this prevalence is almost similar in BDHS, 23.1% for Muslim and 24.8% for non-Muslim. The highest percentages of C-section were delivered in Khulna 30.5% in MICS and 33.3% in BDHS, on the other hand, women’s lives in Barisal has the lowest percentage of C-section (10.5%) according to MICS and (10.9%) C-section delivery was conducted in Sylhet according to BDHS. But, according to MICS, Sylhet is the second lowest (10.8%) district where C-section delivery conducted compared to all other districts in Bangladesh.

As expected, the prevalence was higher among the children of mothers with secondary complete or higher education. The prevalence of C-section among the children whose mothers have secondary complete or higher education was 47.6%, instead, the prevalence was lower (5.5%) among the children of mothers with no education. In BDHS, this prevalence is reported as more acute (54.9%) for highly educated mothers comparing to MICS data. Both BDHS and MICS reports give similar result for household wealth quintile, the prevalence among the richest wealth quintile was 46.5% in MICS and 51.9% in BDHS, which it declined to 5.4% in MICS and 6.7% in BDHS among the poorest wealth quintile. There was a significant rural-urban gap in the prevalence of C-section in both data. Children living in urban areas being delivered by C-section were highest and the prevalence is 33.1% in MICS versus 15.4% of children living in rural areas. In BDHS, it is 17.9% in rural versus 38.7% in urban areas. Children born by C-section delivery was high prevalence in overweight mother at resulted by both MICS and BDHS data. The prevalence of overweight children born by C-section is 27.3% and 43.3% according to MICS and BDHS, respectively. According to child age, 19.6% (MICS) and 24.6% (BDHS) child were born by C-section which lay between the age group of 0-11 months. But, it lowest in the highest age group (12-23) in MICS (18.6%) and BDHS (21.1%). The size of the child is statistically significant at 5% level of significance with C-section. According to MICS, the very large child has the highest prevalence (45.5%) to borne by C-section and it declines at 16.5% when child size is very small. However, this result is contradictory with BDHS, according to BDHS, the highest C-section delivery occurred in large (larger than average) child and the prevalence is 32.3%.

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| Table 1: Distribution of parents and child characteristics with type of delivery | | | | | | |
|  | MICS 2012 | | | BDHS 2014 | | |
|  | Type of Delivery | | | Type of Delivery | | |
| Sources | Caesarean  N (%) | Vaginal  N (%) | p-value | Caesarean  N (%) | Vaginal  N (%) | p-value |
| **Mother Age** |  | | | | | |
| 15-19 | 171 (18.8) | 740 (81.2) | 0.000 | 191 (21.0) | 745 (79.0) | 0.402 |
| 20-34 | 1241 (20.0) | 4952 (80.0) |  | 802 (23.9) | 2550 (76.1) |  |
| 35+ | 93 (11.7) | 700 (88.3) |  | 69 (23.7) | 200 (76.3) |  |
| **Religion** |  | | | | | |
| Islam | 1343 (18.6) | 5894 (81.4) | 0.000 | 961 (23.1) | 3236 (76.9) | 0.705 |
| Other religion (Hinduism, Buddhism, Christianity) | 167 (25.1) | 498 (74.9) |  | 101 (24.8) | 259 (75.2) |  |
| **Division** |  | | | | | |
| Barisal | 50 (10.5) | 428 (89.5) | 0.000 | 105 (18.1) | 435 (81.9) | 0.000 |
| Chittagong | 267 (14.5) | 1577 (85.5) |  | 169 (18.2) | 716 (81.8) |  |
| Dhaka | 604 (24.4) | 1872 (75.6) |  | 262 (30.0) | 548 (70.0) |  |
| Khulna | 230 (30.5) | 524 (69.5) |  | 182 (33.3) | 346 (66.7) |  |
| Rajshahi | 189 (22.4) | 656 (77.6) |  | 148 (22.5) | 406 (77.5) |  |
| Rangpur | 104 (11.7) | 788 (88.3) |  | 108 (17.9) | 440 (81.1) |  |
| Sylhet | 66 (10.8) | 547 (89.2) |  | 88 (10.9) | 604 (89.1) |  |
| **Mother's education** |  | | | | | |
| None | 80 (5.5) | 1378 (94.5) | 0.000 | 43 (7.1) | 571 (92.9) | 0.000 |
| Primary incomplete | 78 (7.5) | 964 (92.5) |  | - | - |  |
| Primary | 142 (11.5) | 1096 (88.5) |  | 145 (11.8) | 1112 (88.2) |  |
| Secondary incomplete | 660 (21.9) | 2360 (78.1) |  | 572 (28.1) | 1580 (71.9) |  |
| Secondary complete/ higher | 539 (47.6) | 594 (52.4) |  | 302 (54.9) | 232 (45.1) |  |
| **Wealth Index** |  | | | | | |
| Richest | 735 (46.5) | 847 (53.5) | 0.000 | 471 (51.9) | 437 (48.1) | 0.000 |
| Richer | 351 (25.1) | 1046 (74.9) |  | 275 (29.5) | 673 (70.5) |  |
| Middle | 192 (12.8) | 1308 (87.2) |  | 165 (18.6) | 709 (81.4) |  |
| Poorer | 136 (8.7) | 1436 (91.3) |  | 99 (10.6) | 763 (89.4) |  |
| Poorest | 98 (5.4) | 1717 (94.6) |  | 52 (6.7) | 913 (93.3) |  |
| **Body Mass Index** |  | | | | | |
| Underweight | 50 (13.5) | 320 (86.5) | 0.000 | 153 (14.2) | 1005 (85.8) | 0.000 |
| Normal | 1034 (17.3) | 4934 (82.7) |  | 568 (21.6) | 2051 (78.4) |  |
| Overweight | 427 (27.3) | 1138 (72.7) |  | 336 (43.3) | 426 (56.7) |  |
| **Area** |  | | | | | |
| Urban | 548 (33.1) | 1110 (66.9) | 0.000 | 532 (38.7) | 925 (61.3) | 0.000 |
| Rural | 963 (15.4) | 5282 (84.6) |  | 530 (17.9) | 2570 (82.1) |  |
| **Breastfeed** |  | | | | | |
| Yes | 1483 (19.3) | 6208 (80.7) | 0.020 | 891 (77.5) | 3011 (66.1) | 0.018 |
| No | 27 (12.9) | 183 (87.1) |  | 171 (27.8) | 484 (72.2) |  |
| **Sex (child)** |  | | | | | |
| Male | 784 (19.6) | 3226 (80.4) | 0.331 | 575 (24.1) | 1768 (75.9) | 0.205 |
| Female | 727 (18.7) | 3166 (81.3) |  | 487 (22.4) | 1727 (77.6) |  |
| **Child age in months** | | | | | | |
| 0-11 | 766 (19.6) | 3138 (80.4) | 0.264 | 372 (24.6) | 1090 (75.4) | 0.168 |
| 12-23 | 744 (18.6) | 3254 (81.4) |  | 375 (24.2) | 1182 (75.8) |  |
| 24-35 | - | - |  | 315 (21.1) | 1223 (78.9) |  |
| **Size at birth** |  |  |  |  |  |  |
| Very large | 5 (45.5) | 6 (54.5) | 0.000 | 23 (20.0) | 78 (80.0) | 0.009 |
| Larger than average | 326 (31.2) | 718 (68.8) |  | 154 (32.4) | 327 (67.6) |  |
| Average | 881 (18.8) | 3794 (81.2) |  | 710 (22.7) | 2379 (77.3) |  |
| Smaller than average | 228 (16.7) | 1134 (83.3) |  | 118 (19.4) | 480 (80.6) |  |
| Very small | 44 (16.5) | 222 (83.5) |  | 57 (23.8) | 230 (76.1) |  |
| **Total** | 1510 (19.1) | 6392 (80.9) |  | 1062 (23.3) | 3495 (76.7) |  |

Table 2 shows the results from crude estimates of PS method and NB regression. From the PS method, we found the crude (only type of delivery variable in the model) model had significantly higher 1.60 (95% confidence interval (CI): 1.30-1.97) and risk ratios (RR) for the C-section were 1.11 (95% CI: 1.01-1.23) for MICS and BDHS, respectively. Similarly, the crude estimates from the NB regression analysis showed that the risk ratio (RR) for the C-section was 1.06 (95% CI: 1.02-1.09) for MICS and 1.08 (CI: 0.97-1.19) for BDHS, respectively, which indicates that children were born in C-section to compare to the vaginal delivery were at increased risk for developing childhood disease. However, the association was not statistically significant in the crude model (p-value=0.159) for BDHS data but significant for MICS data (crude p-value=0.001).

This result is also similar to the S1 table. Hence, both methods and both data showed similar conclusions.

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| Table 2: Parameter estimates from the Propensity Scores and the Poisson Regression methods | | | | | | | |
|  |  | Crude Estimates | | | | | |
|  |  | MICS 2012 | | | BDHS 2014 | | |
| Method | Exposure | RR | 95% CI | p-value | RR | 95% CI | p-value |
| PS | C-section vs.  Vaginal delivery | 1.60 | 1.30-1.97 | 0.000 | 1.11 | 1.01-1.23 | 0.042 |
| NB | C-section vs.  Vaginal delivery | 1.06 | 1.02-1.09 | 0.001 | 1.08 | 0.97-1.19 | 0.159 |

Table 3 depicts that, RR for adjusted (type of delivery and propensity scores in the model) model was 1.19 (CI: 0.99-1.43) for MICS and 1.17 (1.05-1.29) for BDHS, respectively. Similarly, the adjusted estimates from the NB regression analysis showed that the risk ratio (RR) for the C-section was 1.02 (95% CI: 0.98-1.06) for MICS and 1.15 (CI: 1.05-1.27) for BDHS, respectively. That means the babies born in C-section have a higher risk of getting diseases than vaginal delivery. When adjusting other confounding variables, the association was not statistically significant at a 5% level of significance in the adjusted model (p-value=0.068 (PS) and p-value=0.253 (NB)) in both method for MICS data but BDHS data shows significant in both adjusted methods.

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| Table 3: Parameter estimates from the Propensity Scores methods for adjusted model | | | | | | | |
|  |  | Adjusted Estimates | | | | | |
|  |  | MICS 2012 | | | BDHS 2014 | | |
| Method | Exposure | ARR\* | 95% CI | p-value | ARR\* | 95% CI | p-value |
| PS | C-section vs.  Vaginal delivery | 1.19 | 0.99-1.43 | 0.068 | 1.17 | 1.05-1.29 | 0.030 |
| NB | C-section vs.  Vaginal delivery | 1.02 | 0.98-1.06 | 0.253 | 1.15 | 1.05 - 1.27 | 0.004 |

**Risk factors associated with childhood diseases due to C-section delivery**

NB regression analysis for the status of childhood diseases reveals that the division, the level of education of the mother, wealth index and child size at birth were the main contributing factors to childhood diseases due to the type of delivery in MICS. In MICS, type of delivery, BMI, child sex and child age were the main contributing factors to childhood diseases due to type of delivery (S2 Table).

Table 4 shows the association between type of delivery and early childhood diseases when models adjusted for possible confounding factors. For instance, after adjusting all other factors, MICS explained that C-section delivered babies were 1.02 times (CI: 0.98–1.06) more likely to be affected by diseases and it is 1.15 times (CI: 1.05-1.27) more acute in BDHS. The risk of the children getting affected by diseases whose mothers aged between 15-19 years were 1.11 (CI: 0.97-1.26) more likely and aged between 20-34 years were 0.91 (CI: 0.76-1.09) less likely than those aged above years, respectively. Both MICS and BDHS explained similar conclusions, in BDHS, the mothers aged between 15-19 years were 1.05 (CI: 0.95-1.15) more likely and aged between 20-34 years were 0.91 (CI: 0.87-1.06) less likely to affected by diseases than those aged above, respectively.

According to MICS, Childs living with her mother with secondary incomplete 0.98 (CI: 0.92–1.04), who had primary completed 0.97 (CI:0.92-1.03) or who had primary incomplete were 0.94 (CI: 0.89-0.99) times less likely associated with diseases due to types of delivery, compared to their peers living with mothers whoever not attended any school. In BDHS, similar to MICS, a child who belongs to mothers with an academic background is less likely to get affected by diseases compared to mothers who hadn’t any academic qualifications. Childs who identify as belonging to the richest family were more likely to get affected by diseases due to C-section delivery (ARR=1.08, CI 1.03–1.14) and (ARR=1.17, 95% CI 1.03-1.34) in both MICS and BDHS, respectively.

Children who were born to underweight and overweight mothers were more likely to have the disease, ARR 1.06 (CI: 1.01-1.13) and ARR 1.08 (95 % CI: 1.01-1.16) in MICS and ARR 1.13 (CI: 1.01-1.26) and ARR 1.17 (CI: 1.03-1.32) in BDHS, due to C-section. Children who breastfed were 4 % (MICS) and 9% (BDHS) less likely to manifest diseases. Age of the children is recognized as an important factor for childhood diseases, and results showed that children with age between 0-11 months and 12-23 months were more at risk of suffering from diseases than 24–35 months aged children, ARR 1.15 (CI: 1.04-1.27) and ARR 1.14 (CI: 1.04-1.26). An unexpectedly and approximately similar ARR was found for children from rural areas in both MICS and BDHS data.

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| Table 4: Influence of factors associated with childhood diseases (lower diseases and vaginal delivery vs. higher diseases due to C-section delivery). | | | | | | |
|  | Adjusted Estimates | | | | | |
| Sources | MICS 2012 | | | BDHS 2014 | | |
| ARR\* | 95% CI | p-value | ARR\* | 95% CI | p-value |
|  |  |  |  |  |  |  |
| **Type of Delivery** |  |  |  |  |  |  |
| C-section | 1.02 | 0.98-1.06 | 0.253 | 1.15 | 1.05 - 1.27 | 0.004 |
| Vaginal | 1 | - | - | 1 | - | - |
| **Mother’s Age at birth** |  |  |  |  |  |  |
| 15-19 | 1.11 | 0.97-1.26 | 0.121 | 1.05 | 0.95-1.15 | 0.182 |
| 20-34 | 0.91 | 0.76-1.09 | 0.174 | 0.96 | 0.87-1.06 | 0.376 |
| 35+ | 1 | - | - | 1 | - | - |
| **Religion** |  |  |  |  |  |  |
| Islam | 0.99 | 0.95-1.04 | 0.812 | 1.06 | 0.92-1.21 | 0.431 |
| Other religion (Hinduism, Buddhism, Christianity) | 1 | - | - | 1 | - | - |
| **Division** |  |  |  |  |  |  |
| Barisal | 0.81 | 0.76-0.87 | 0.000 | 1.00 | 0.85-1.17 | 0.981 |
| Chittagong | 0.83 | 0.78-0.87 | 0.000 | 1.07 | 0.94-1.22 | 0.319 |
| Dhaka | 0.88 | 0.83-0.92 | 0.000 | 0.94 | 0.82-1.07 | 0.339 |
| Khulna | 1.00 | 0.95-1.06 | 0.973 | 1.04 | 0.89-1.21 | 0.636 |
| Rajshahi | 0.83 | 0.78-0.88 | 0.000 | 0.96 | 0.83-1.11 | 0.554 |
| Rangpur | 0.95 | 0.89-1.01 | 0.081 | 0.90 | 0.77-1.01 | 0.160 |
| Sylhet | 1 | - | - | 1 | - | - |
| **Mother's education** |  |  |  |  |  |  |
| None | 0.92 | 0.86-0.98 | 0.007 | 0.89 | 0.75-1.05 | 0.166 |
| Primary incomplete | 0.94 | 0.89-0.99 | 0.049 | 0.91 | 0.81-1.03 | 0.154 |
| Primary | 0.97 | 0.92-1.03 | 0.320 | 0.98 | 0.87-1.11 | 0.780 |
| Secondary incomplete | 0.98 | 0.92-1.04 | 0.577 | - | - | - |
| Secondary complete/higher | 1 | - | - | 1 | - | - |
| **Wealth Index** |  |  |  |  |  |  |
| Richest | 1.08 | 1.03-1.14 | 0.003 | 1.17 | 1.03-1.34 | 0.191 |
| Richer | 1.07 | 1.03-1.11 | 0.000 | 1.10 | 0.95-1.28 | 0.119 |
| Middle | 1.04 | 1.01-1.09 | 0.046 | 1.11 | 0.96-1.28 | 0.148 |
| Poorer | 1.03 | 0.99-1.07 | 0.051 | 1.11 | 0.98-1.25 | 0.110 |
| Poorest | 1 | - | - | 1 | - | - |
| **Body Mass Index** |  |  |  |  |  |  |
| Underweight | 1.06 | 1.01-1.13 | 0.043 | 1.13 | 1.01-1.26 | 0.025 |
| Overweight | 1.08 | 1.01-1.16 | 0.032 | 1.17 | 1.03-1.32 | 0.015 |
| Normal | 1 | - | - | 1 | - | - |
| **Area** |  |  |  |  |  |  |
| Urban | 1.02 | 0.97-1.06 | 0.469 | 1.00 | 0.91-1.10 | 0.969 |
| Rural | 1 | - | - | 1 | - | - |
| **Breastfeed** |  |  |  |  |  |  |
| Yes | 0.96 | 0.81-1.14 | 0.634 | 0.91 | 0.81-1.02 | 0.066 |
| No | 1 | - | - | 1 | - | - |
| **Sex (child)** |  |  |  |  |  |  |
| Male | 1.00 | 0.97-1.03 | 0.822 | 1.08 | 1.00-1.16 | 0.039 |
| Female | 1 | - | - | 1 | - | - |
| **Child age** |  |  |  |  |  |  |
| 0-11 | 1.00 | 0.97-1.03 | 0.951 | 1.15 | 1.04-1.27 | 0.006 |
| 12-23 | 1 | - | - | 1.14 | 1.04-1.26 | 0.005 |
| 24-35 | - | - | - | 1 | - | - |
| **Size at birth** |  |  |  |  |  |  |
| Very large | 0.87 | 0.69-1.09 | 0.213 | 0.93 | 0.80-1.07 | 0.314 |
| Larger than average | 0.88 | 0.70-1.10 | 0.249 | 0.95 | 0.79-1.14 | 0.585 |
| Average | 0.90 | 0.72-1.12 | 0.341 | 0.96 | 0.73-1.27 | 0.795 |
| Smaller than average | 0.99 | 0.78-1.24 | 0.900 | 1.07 | 0.90-1.27 | 0.418 |
| Very small | 1 | - | - | 1 | - | - |

*RR: Risk Ratio; CI: Confidence Interval; ARR: Adjusted risk ratio*

*\*Model adjusted with Propensity scores \*\*Model adjusted with confounding and/or covariates*

**4. Discussion**

We examined the causal association between C-section delivery (versus vaginal delivery) and early childhood diseases in Bangladesh. The PS method and NB regression methods showed that the odds of having childhood diseases were higher for the C-section child as compared to the vaginal delivery child. A similar study observed that C-section is associated with an increased risk of immune development, and increase the probability of allergy, atopy, and asthma and decreases intestinal microbiome diversity (Sandall et al., 2018). A meta-analysis, which conducted with the delivery by C-section children, was found to be associated with a moderately increased risk of type 1 diabetes (Cardwell et al., 2008). A similar result was observed by Marcotte et al, where they have shown an increased risk of acute lymphoblastic leukemia in young children born by cesarean delivery (Marcotte et al., 2016). Although the risk is higher, after adjusting for all possible confounding variables, we did not identify any significant causal association between C-section and childhood diseases in BDHS data for crude estimates and in MICS data for both estimates.

The analyses of this study confirmed that childhood disease is associated with maternal age. In earlier studies, children born to younger mothers (aged <20 years) were found to have a relatively high risk of diarrhea, cough, and fever in their young children (Kandala, 2006), probably because the relationship between maternal age is associated with some adverse pregnancy outcomes and a higher risk of medical conditions such as hypertension, diabetes or other causes.

From our findings, we have seen that the rate of C-section delivery was higher particularly in the Khulna division compared to other divisions of Bangladesh according to MICS data and it is also similar in the BDHS survey. A previous study has demonstrated that the women of Chittagong, Dhaka, Khulna, and Rajshahi division were more likely to avail of institutional delivery and cesarean sections. Where it is low in the Barisal division and Sylhet division. The risk of diseases did not differ noticeably across the divisions. For instance, the risk ratio of getting diseases is similar to the prevalence. The risk of disease was higher in Khulna in the MICS survey. It is clear that the vacancies of midwives and stuff in Barisal, Chittagong, and Sylhet divisions were higher, and access to maternity care services is less in these particular divisions is lower. Besides, the situation is different in Dhaka, Khulna and Rajshahi division for healthcare providers. Besides, the posts of health care providers have less vacant in Dhaka, Khulna and Rajshahi division (Kamal, 2013). This might be the reason for the high occurrences of C-section as well as high occurrences of diseases on that division.

As expected, among the educated women, the highest rate of C-section has occurred among secondary completed or higher educated women. We also observed that lower risk of diseases occurred for C-section babies than children born by vaginal delivery in all other education levels of mother compared to this group. Since education is directly related to the autonomy of women, they are economically more solvent and mostly living in urban areas, may decide to give birth through a C-section. However, some studies reported no visible link between women's preference for C-section and their level of education (Angeja et al., 2006; Chu, Tai, Hsu, Yeh, & Chien, 2010).

By wealth status, health care facilities were higher for the richest family than the middle and poorer family. Rates of C-section were also higher among the richest family compared to those belonging to the poorest or poorer families (Shahabuddin, Delvaux, Utz, Bardaji, & De Brouwere, 2016). This might be a reason for the high risk of diseases in the richest group in our study. However, economic anxiety is strongly associated with malnutrition of children, poor mental development and weak of the immune system, so it can increase the vulnerability to infectious diseases. Children from financially well-off families may enjoy a healthier and safer lifestyle, with greater access to health-promoting conditions compared to poorer families in later life (Yaya & Bishwajit, 2019).

**Conclusion**

In conclusion, although the C-section babies were at increased risk of getting a disease, we did not identify any significant causal association between the type of delivery and the childhood diseases in some models. An increase in the rates of cesarean section delivery is a burden on the health system and childhood diseases. Unnecessary cesarean delivery can also be a stress on the family and can complicate maternal and child health. Thus, the decision to perform a C-section delivery must be carefully chosen and not aimed at profit.

To reduce unnecessary C-sections and encourage vaginal birth, various strategies must be taken, such as the implementation of standardized protocols, requests of a second medical opinion prior to surgery, improving maternal empowerment during pregnancy and delivery, maternal and medical collaboration on birth plans. The use of partographs is important in emergency obstetric care, in addition, training of hospital staff, health officers, midwives, and health extension workers, as well as the decision to adopt a neonatal resuscitation skill and C-section, are critical. Nurses and midwives should explain carefully the benefits and the possible risks/complications associated with C-section to clients at the antenatal clinic. Prior to delivery, all available birthing procedures and its merit and demerit should be explained to the pregnant women during ANC period. Further studies are needed to enrich our knowledge on the negative impact of C-section delivery and its association with the development of childhood disease, the incidence of the chronic immune system and metabolic disorders in developing countries including Bangladesh. However, we recommend increasing public awareness of the negative impact of unnecessary cesarean delivery in Bangladesh.

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**Supporting information**

**S1 Table: Unadjusted LR statistics for type 3 analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | MICS 2012 | | BDHS 2014 | |
| **Source** | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** |
| **Type of Delivery** | 9.97 | 0.002 | 1.88 | 0.170 |

**S2 Table: Adjusted LR Statistics for Type 3 Analysis**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | MICS 2012 | | BDHS 2014 | |
| Covariates | **Chi-Square** | **P-value** | **Chi-Square** | **P-value** |
| **Type of Delivery** | 1.29 | 0.257 | 8.24 | 0.004 |
| **Mother Age** | 5.56 | 0.062 | 2.06 | 0.357 |
| **Religion** | 0.06 | 0.813 | 0.62 | 0.429 |
| **Division** | 113.01 | 0.000 | 9.48 | 0.148 |
| **Mother's education** | 12.87 | 0.012 | 3.76 | 0.288 |
| **Wealth Index** | 15.52 | 0.004 | 5.71 | 0.222 |
| **Body Mass Index** | 4.75 | 0.093 | 6.41 | 0.041 |
| **Area** | 0.52 | 0.472 | 0 | 0.969 |
| **Breastfeed** | 0.23 | 0.632 | 2.63 | 0.105 |
| **Sex (child)** | 0.05 | 0.822 | 4.26 | 0.039 |
| **Child age** | 0.00 | 0.951 | 9.71 | 0.008 |
| **Size at birth** | 11.50 | 0.022 | 7.63 | 0.106 |