**Association between cesarean 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 examine 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 applying 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, geographical location, 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 adjust for confounding effects for binary outcome. 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 76.7% of children were born in normally (vaginal delivery) in MICS and BDHS surveys respectively. From 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; survey, 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 may happen if it is vaginal delivery (Zakerihamidi, Roudsari, & Khoei, 2015). However, nowadays, the C-section believed to be painless, easy, safer, and healthier than vaginal delivery. Recently, it has become a preferred choice as a mode of delivery among women (Lori & Boyle, 2011). ~~But~~ However, 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 any major surgery related to immediate risk of maternal and childbirth and may be important for pregnancy and long-term effects on the child health. C-section is increasing significantly as evident 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), financial shortage (Zakerihamidi, Roudsari, Khoei, & Kazemnejad, 2014), lack of anxiety 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 cesarean 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 rate increased from 3.5% in 2004 to 23% in 2014 (Khan, Islam, Shariff, Alam, & Rahman, 2017).

There are several risks associated with the C-section for women and those risk of health conditions including cardiac arrest, hysterectomy, puerperal infection, thromboembolism, wound hematoma, anesthetics complications. (Yuan et al., 2016). In addition, 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. 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 and colleagues showed that previous C-section, prolonged labor, higher maternal education level, mother age of 25 years or more, the 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 the age of mother, lower birth order, higher education of parents, higher socioeconomic status, poor maternal history, and adoption of three or more antenatal cares? were significantly associated with C-section delivery (Begum et al., 2017).

In Bangladesh, children are generally suffering from several common diseases such as fever, fast and/or difficulty of breathing, blood in stools and diarrhea. However, to the best of our knowledge, there is no published record that any research has been conducted to determine the association between C-section and such early childhood diseases in Bangladesh. Therefore, it is important to study the consequence of C-section delivery on ~~the~~ child health particularly on ~~the~~ early childhood diseases applying an appropriate statistical method. To fill this gap in knowledge, we aimed to investigate the association between C-section delivery and childhood diseases using a propensity score method. This study also explores for key factors associated with childhood diseases.

**2. Methods**

The study uses data from the BDHS 2014 and MICS 2012 the nationally representative surveys for the comparison and strengthen its findings. By identifying key factors, the present study is to assess the data on the type of delivery and childhood diseases collected by the MICS and DHS and to compare the results.

***Data source and study design***

We used the latest available dataset from the Bangladesh Demographic and Health Survey (BDHS, 2014) for our study. To compare the results, we also used another parallel survey data, the multiple indicator cluster survey (MICS, 2012-13) in Bangladesh (UNICEF, 2015). The BDHS is large, household surveys produced by the Demographic and Health Surveys Program and MICS is also large, multi-dimensional household survey conducted by UNICEF. Both survey highlighted on identical measures of fertility and child mortality, and indicators of access to maternal and child health interventions, illness, treatment, and nutritional status. Both data-sets are fully open-access (Corsi, Perkins, & Subramanian, 2017). Both surveys represent the seven administrative divisions (Dhaka, Chittagong, Sylhet, Rajshahi, Rangpur, Barisal and Khulna) of Bangladesh. These administrative divisions are taken as the main sampling strata for the sample (NIPORT/Bangladesh, Associates, & International, 2016; UNICEF, 2015).

There 7886 number of mother-child pairs information was given. From figure 1 depicted that 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 the study population**

The 2012-13 MICS is based on a sample of 51895 households (43474 rural and 8421 urban) interviewed with a response rate of 98.5%. 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 7902 mother-child pair for analysis (Figure 2).



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

**Potential confounding variables**

We considered important confounding variables and/or covariates including, religion, breastfeeding status, child’s sex, age of mother and child, size of child at birth, mother’s education, mothers education, body mass index, wealth index quintile, area and geographical location (division).

**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 could 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 in the two weeks before the survey. 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 [<3 diseases] and 1 means greater than median value [≥3 diseases]; second, a count variable that means the frequency of the diseases.

**Statistical analyses**

**Descriptive statistics:** 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.

**Propensity score models:** We applied a propensity score method for the first outcome (binary) variable as a covariate in logistic regression models to control for the selection bias. The propensity score method is the probability of exposure (C-section versus vaginal delivery) assignment conditional on possible confounding. The probability of allocated exposure variable and that of experiencing the outcome were described by a logistic model. The propensity score models the probability that a given child would be exposed to the experimental treatment, conditionally to his(her) baseline covariates. The propensity score of the children was then estimated from the predicted probability of treatment given his(her) covariates as obtained by logistic regression. 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:**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 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.

**Model assessment:** We used three models to assess the relative performance that fits our data for evaluating the causal association between C-section and childhood diseases with the best model. To find the best model, we used AIC and BIC values to compare all models; the lowest value of AIC and BIC indicates a better fit of the data after accounting for model complexity (i.e. the number of model parameters). Using the best model, we reviewed the variability of the results from the models. In the crude model, only the C-section variable was used and for the adjusted model, other confounding variables with C-section variable were considered.

All statistical analyses were performed by SAS and SPSS (IBM SPSS 25). In SAS, the survey analysis procedures command was used to allow for the adjustments of the cluster sampling design used in both survey and to estimate weighted frequency for all explanatory variables.

***Ethics approval***

Our study was wholly based on an analysis of existing public domain health survey datasets obtained from the BDHS 2014 and MICS 2012, which is freely available online with all personal identifying information removed. The BDHS 2014 data were 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 the 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**

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. From the women who had undergone a C-section had a lower prevalence (11.7%) in highest age groups (35+ years) for the MICS but in BDHS data, women with C-section delivery had lower prevalence (21%) in the lowest age groups (15-19 years). In the three 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.

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 same age groups. The 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 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%) division where C-section delivery conducted compared to all other divisions in Bangladesh.

The prevalence was higher among the children of mothers with higher education. The prevalence of C-section among the children whose mothers have secondary complete or higher education was 47.6%, as compared with, the prevalence was lower (5.5%) among the children of mothers with no education. In BDHS, this prevalence is reported high (54.9%) for highly educated mothers in compared with 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 difference in the prevalence of C-section in both data. Mother living in urban areas being delivered by C-section were highest and the prevalence is 33.1% in MICS versus 15.4% of mothers 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 reported in 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. Delivery year showed some difference, 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 maternal and child characteristics with the 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’s age group in years at birth** | | | | | | |
| Mean (SD) | 25.4 (5.2) | 25.9 (6.0) | <0.001 | 24.9 (5.5) | 24.5 (5.8) | 0.038 |
| 15-19 | 171 (18.8) | 740 (81.2) | <0.001 | 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) | <0.001 | 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) | <0.001 | 105 (18.1) | 435 (81.9) | <0.001 |
| 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) |  |
| **Educational level (mother)** | | | | | | |
| None | 80 (5.5) | 1378 (94.5) | <0.001 | 43 (7.1) | 571 (92.9) | <0.001 |
| 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) | <0.001 | 471 (51.9) | 437 (48.1) | <0.001 |
| 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 (mother)** | | | | | | |
| Underweight | 50 (13.5) | 320 (86.5) | <0.001 | 153 (14.2) | 1005 (85.8) | <0.001 |
| 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) |  |
| **Place of residence** | | | | | | |
| Urban | 548 (33.1) | 1110 (66.9) | <0.001 | 532 (38.7) | 925 (61.3) | <0.001 |
| Rural | 963 (15.4) | 5282 (84.6) |  | 530 (17.9) | 2570 (82.1) |  |
| **Breastfeeding status** | | | | | | |
| 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** | | | | | | |
| 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’s age group 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) | <0.001 | 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 demonstrates the fitting goodness of two models PS, Poisson and NB regression model. The model with the smallest AIC, and BIC was PS model and NB model, among the three models considered. PS and NB model had the smallest AIC and BIC, suggesting the best goodness of fit. Therefore, the PS and NB model shown in Table 2 with bold letters was chosen as the best model and the Poisson regression model fitted the data worst.

**Table 2: Model selection criteria for PS and NB model**

|  |  |  |  |
| --- | --- | --- | --- |
| Data | Model | AIC | BIC |
| MICS | PS | **7371.98** | **7385.86** |
| Poisson | 25874.03 | 25887.95 |
| NB | **25700.61** | **25721.49** |
| BDHS | PS | **7950.26** | **7963.10** |
| Poisson | 13348.55 | 13361.40 |
|  | NB | **12565.08** | **12584.35** |

Table 3 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 compared with 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 similarity in results with different extents.

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| Table 3: Association between breastfeeding and selected childhood diseases from the PS models and the NB Regression methods for unadjusted model | | | | | | | |
|  |  | 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 | <0.001 | 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 4 depicts that, RR for from adjusted (type of delivery and propensity scores ) 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. C-section hasn’t any significant effect on diseases after adjusting for possible confounding factors. 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 4: Association between breastfeeding and selected childhood diseases from the PS methods and NB regression models for the 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 for childhood diseases related 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 contributing factors to childhood diseases related to the type of delivery in MICS. In MICS, type of delivery, BMI, child sex and child age were the contributing factors to childhood diseases. (S2 Table).

Table 4 shows the association between type of delivery and early childhood diseases when models adjusted for selected confounding factors. For instance, after adjusting all other factors, C-section delivered babies were more likely to be affected by diseases 1.15 times (CI: 1.05-1.27) in BDHS, however, did not reach statistical significant level in MICS. The risk of the children getting affected by diseases whose mothers aged between 15-19 years were 1.11 times (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 5: 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 group in years 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 | <0.001 | 1.00 | 0.85-1.17 | 0.981 |
| Chittagong | 0.83 | 0.78-0.87 | <0.001 | 1.07 | 0.94-1.22 | 0.319 |
| Dhaka | 0.88 | 0.83-0.92 | <0.001 | 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 | <0.001 | 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 | - | - |
| **Educational level (mother)** | | | | | | |
| 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 | <0.001 | 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 (mother)** | | | | | | |
| 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 | - | - |
| **Place of residence** | | | | | | |
| Urban | 1.02 | 0.97-1.06 | 0.469 | 1.00 | 0.91-1.10 | 0.969 |
| Rural | 1 | - | - | 1 | - | - |
| **Breastfeeding status** | | | | | | |
| Yes | 0.96 | 0.81-1.14 | 0.634 | 0.91 | 0.81-1.02 | 0.066 |
| No | 1 | - | - | 1 | - | - |
| **Sex** |  |  |  |  |  |  |
| Male | 1.00 | 0.97-1.03 | 0.822 | 1.08 | 1.00-1.16 | 0.039 |
| Female | 1 | - | - | 1 | - | - |
| **Child’s age group in months** |  |  |  |  |  |  |
| 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 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 for 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 association between C-section and childhood diseases in BDHS data for crude estimates and in MICS data for both estimates. The reason behind the contrasts of the results might be, both surveys on the same objective with the same variable often use different questions in a different household. There might be many other factors that give us different result, differences between these survey time and the inclusion-exclusion criteria (as MICS provides information about C-section delivery under 2 years of child’s, on the other side, BDHS provides same information of 3 years of child’s), this does suggest the possibility that much of the research findings cannot be similar.

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 C-section. 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 indicates that the availability of midwives and stuff in Barisal, Chittagong, and Sylhet divisions were low , and access to maternity care services is quite less. Dhaka, Khulna and Rajshahi division have much more healthcare providers (Kamal, 2013). Lower number midwifery services might be the reason for the high occurrences of C-section as well as high occurrences of diseases on those divisions.

The findings of our study also confirmed that 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 weakness 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).

**Recommendations**:

[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 |