**Title. Effect of Extreme Weather Events on Injury, Disability, and Death in Bangladesh**

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**Abstract**

While there is increasing evidence on the trends and impacts of climate change, both globally and in Bangladesh, there is limited quantitative analysis on the impacts of natural disasters on population health and the association with socioeconomic characteristics. Using data from the ‘Bangladesh Disaster-Related Statistics-2015’, we assessed disaster-related health outcomes namely, injury, disability, and death. We applied three logistic regression models to examine the relationships between individual socioeconomic characteristics, reported disaster-related injury, disability, and death. Our study found that 145.9 disaster-related injuries, 14.4 disabilities, and 21.0 deaths per 100,000 population were reported in Bangladesh over 2009-2014. Floods were responsible for the highest percentage of injury, disability, and deaths followed by thunderstorms. The elderly and children were more likely to suffer from disaster-related injuries compared to adults. Disaster preparedness was a protective factor for both disasters related injury and disability. We observed geographic variation in the number of injuries, disability, and death across the districts in Bangladesh. Policymakers can use the study findings to strengthen risk-monitoring, assessment, and preparedness strategies and actions for extreme weather events related to the rapidly changing climate.

**Key words: Natural disaster; injury; disability; death; thunderstorms; Bangladesh**

**Background**

The impacts of disasters on health outcomes have become a focus of increasing scientific study (Ustün, Wolf, Corvalán, Bos, & Neira, 2016; Watts et al., 2015; Whitmee et al., 2015). Globally, 23% of all deaths are attributable to environmental factors, including those related to climate change. While the occurrence of extreme weather events has increased, the coverage of emergency preparedness and broader climate adaptation plans to explicitly protect human health and well-being remains limited (Watts et al., 2017). This is particularly the case for the least developed countries, such as Bangladesh, where there is often limited capacity and resources to invest in, plan and implement effective policy and programmatic measures to reduce adverse impacts of disasters in the population.

There is limited understanding of the magnitude and distribution of disaster-related injury, disability, and deaths in Bangladesh, although this is one of the countries most affected by natural disasters (UNU, 2016). A large proportion of the country is geographically part of the Ganges Brahmaputra Meghna delta, which is particularly vulnerable to the impacts of climate change and can be classified as a climate change hotspot (Sylvia Szabo et al., 2015). Climate change is likely to increase not only the risk of flooding in this region, but is also associated with relative sea-level rise, salinity intrusion and changes in temperature and rainfall patterns (Balica, Wright, & van der Meulen, 2012; Le Dang, Li, Nuberg, & Bruwer, 2014; Sylvia Szabo et al., 2016, 2015). In 2007, Bangladesh suffered from a devastating cyclone Sidr, followed by a cyclone Aila in 2009. The latter caused injuries to approximately 7,100 people and caused 190 immediate deaths (Hossain & Paul, 2018). The Bangladesh Disaster-related Statistics-2015 reported high burden of natural disasters related health burdens in Bangladesh (BBS, 2016). Many factors affect vulnerability to environmental changes such as the level of exposure to extreme weather events as determined by geographic location (IPCC, 2014). At the individual level, age, existing health status, and poverty (Watts et al., 2015) affect vulnerability to global and local environmental changes. In Bangladesh, poorest households tend to be the most vulnerable to the effects of disasters (Hajra et al., 2017; S Szabo, Hossain, Matthews, Lazar, & Ahmad, 2015). For example, a recent study conducted in the Indian Sundarbans showed that the poorest households were significantly more likely to endure both material and human loss following a natural disaster and that this impoverishment made them in turn more vulnerable to a future climatic risk (Hajra et al., 2017). The environmental change increases inequities in health (Myers et al., 2013). Climate change is expected to exacerbate human health risks (IPCC, 2017). And yet, climate change is just one stressor acting together with others such as increasing population growth and related demand for basic needs such as food, water, and energy (Whitmee et al., 2015).

There is a limited number of quantitative analysis on the impacts of natural disasters on population health and socioeconomic characteristics of the adversely affected groups despite the increasing evidence on the trends of such disasters, both globally and in Bangladesh. Such analyses are critical for increasing understanding of the most at-risk communities and for applying that understanding to inform practical policies sat the sub-national and national levels. Identifying the associations between natural disasters and health outcomes as well as other potential factors affecting these relationships can enhance existing and future mitigation and adaptation strategies in the country. Besides, such investigation is required to contribute to the progress of the Sustainable Development Goals (SDGs), especially SDG 3, target 3.d, which aims to “strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks” (UN, 2015). Jayachandran (2009) assessed the effect of Indonesia’s wildfire on early-life outcomes and found that the prenatal exposure to such air pollution led to 15,600 missing children in the country (1.2 percent of the affected birth cohorts) (Jayachandran, 2009). A review study on the relationship between natural disasters and communicable diseases in Bangladesh showed that natural disasters as a risk factor for number of such diseases (e.g. diarrhoea, leptospirosis, hepatitis, pneumonia, malaria) (Uddin, 2017). Another study in Bangladesh found that the prevalence of injury and death also increased due to the cyclone Sidr in 2009 (Uddin, 2017). Hanies et al. 2006 argued that overall, of effects climate change and associated disasters on health is likely to be negative and populations in low-income countries are likely to be particularly vulnerable to the adverse effects (Haines, Kovats, Campbell-Lendrum, & Corvalan, 2006). Given the above context, this paper aims to assess socioeconomic equity in disaster-related health outcomes (e.g. injury, disability, and death) in Bangladesh. Because of the geographical and climatic context of Bangladesh, our inquiry focuses specifically on the impacts of the most frequently occurring disasters, such as drought, flood, waterlogging, cyclone, tornado, storm/tidal surge, thunderstorm, river/coastal erosion, landslides, and hailstorm.

**Methods**

**Data source and design**

In this study, we used data from the ‘Bangladesh Disaster-related Statistics-2015’, the largest and most recent disaster-related survey in the country conducted by the Bangladesh Bureau of Statistics (BBS) (BBS, 2016). A disaster was defined as a major adverse event resulting from natural processes of the earth e.g. cyclones, drought, floods, erosion, volcanic eruptions, earthquakes, tsunamis, and other geologic processes. The survey was designed to measure the socioeconomic characteristics of households and population, damage and loss of land and residence, health and sanitation conditions, different disasters faced, and perception and knowledge about climate change in the disaster-prone areas. The respondents were asked for the disaster-related information between 2009 and 2014. All 64 districts of Bangladesh were considered as a sampling frame consisting of mauzas/mahallas (lowest administrative unit). Respondents were selected from mauzas/mahallas that experienced at least one major natural disaster as the target population. The list of natural disaster-prone mauzas/mahallas was prepared during a pre-survey census in November to December 2013 and later considered as the primary sampling unit (PSU) for this survey.

The survey adopted a stratified two-stage random sampling design, in the first stage two level of stratification was considered. The first level of stratification corresponds to the major geographic domains; in this case, 64 districts were considered as 64 strata and the second level stratifications were based on the type of natural disasters within each district. Using simple random sampling technique, total 4,945 PSUs from the highest disaster-prone area of 21,892 were selected. In the second stage, total 143,980 households (HHs) from all the PSUs were selected using a systematic random sampling technique. A pretested questionnaire was used to collect data in two phases. In both phases, the field operation was conducted for 45 days. About 1,800 data collectors and employees of the Bangladesh Bureau of Statistics (BBS) were employed in the data collection after four days of comprehensive training.

**Study variables**

We estimated the impact of natural disasters on the selected outcome variables. The key outcome variables were injury, disability, and deaths due to different disasters in the last six years. The “Bangladesh Disaster-related Statistics-2015” survey collected self-reported injury and disability information associated with natural disasters. In this study, the injury was defined as any accidental force applied to the body during the natural disasters that caused harm (Schuh-Renner, Canham-Chervak, Grier, & Jones, 2019). The difficulty with mobility, basic activities (e.g. dressing and bathing) of daily living after affected by the natural disasters were considered as disability (Manini et al., 2017). The participant was asked, “Member of your household, who got sick, either injured or got disabled due to natural disaster during 2009-14” to capture the injury and disability information. The prevalence of injury, disability, and deaths were estimated per 100,000 populations across different socioeconomic characteristics (e.g. age group, sex, marital status, education, occupation, physically challenged condition, disaster warning, disaster preparedness, number of disasters faced, place of residence, region of residence, and asset quintile). Physical or psychological situation that hinders the daily movement, sensations, and activities of a man or woman was defined as the physically challenged condition (BBS, 2016). The dummy variable “got disaster warning” denoted 1 if a household received any advanced notice or forecast on disaster and 0 otherwise. Preparedness was defined as measures that are designed to ensure that communities will have the knowledge and understanding of their risk environment to enable them to better cope with disaster associated causalities (BBS, 2016). Number of disasters faced was defined by how many times the person was affected by a disaster. We analyzed the effects of drought, flood, water logging, cyclone, tornado, storm/tidal surge, thunderstorm, river/coastal erosion, landslides, hailstorm, and others disasters in this study. Households’ wealth was categorized into five quintiles ordered from the poorest to the richest based on the available assets of the household, including housing material, sanitation facilities, access to utility services, and access to drinking water.

**Statistical analyses**

Principal component analysis (PCA) was applied to survey responses on ownership of a set of key assets and the values of the index were based on the first principal component (Vyas & Kumaranayake, 2006). Household size was adjusted during estimating PCA score. PCA is a commonly used technique when computing asset indices; although traditionally applied to continuous variables (Filmer & Pritchett, 2001). Higher scores of the index indicated more affluent households. The chi-square test was performed to assess the association between categorical variables.

We applied three different logistic regression models to identify the associations between individual/household characteristics and disaster-related injury, disability, and deaths. In first 2 models, disaster-related injury and disability were treated as dependent variables and other socioeconomic characteristics as independent variables (e.g. age group, sex, marital status, education, occupation, physically challenged condition, disaster warning, disaster preparedness, number of disasters faced, place of residence, region of residence, and asset quintile). However, in the 3rd model, disaster-related death was analyzed for all of these characteristics except marital status, education, occupation, and physically challenged due to the unavailability of the information. All statistical analyses were performed using STATA version 13 (StataCorp., 2013).

**Results**

**Socio-demographic characteristics**

Table 1 presents the background characteristics of the participants included in this study. Most of the participants were adult (60.5%), male (51.8%) and having no institutional education (37.1%). Only 1.2% of the participants had any types of physical problem. About 81.1% got disaster warning; however, 89.1% among them took preparation for disaster. In the last six years, 69.0% faced at least one disaster and 31.0% faced two or more. The majority of the participants (88.1%) lived in the rural area and around 26.5% were from the Dhaka division.

Table 1. Socio-demographic characteristics of the participants

|  |  |  |
| --- | --- | --- |
| **Characteristics** | **N=667,740** | **%** |
| **Age group** |  |  |
| Child (0-14) | 225,641 | 33.8 |
| Adult (15-60) | 403,929 | 60.5 |
| Elderly (60+) | 38,170 | 5.7 |
| **Sex** |  |  |
| Male | 345,615 | 51.8 |
| Female | 322,005 | 48.2 |
| **Marital status** |  |  |
| Unmarried | 313,596 | 46.9 |
| Married | 330,976 | 49.6 |
| Others | 23,168 | 3.5 |
| **Education** |  |  |
| No institutional education | 247,407 | 37.0 |
| Primary level ( years 1-5) | 186,327 | 27.9 |
| Secondary and tertiary | 170,802 | 25.6 |
| Not applicable | 63,204 | 9.5 |
| **Occupation** |  |  |
| Not applicable | 104,197 | 15.6 |
| Agriculture | 135,718 | 20.3 |
| Service | 52,170 | 7.8 |
| Day-labor | 40,879 | 6.1 |
| Housewife | 120,528 | 18.1 |
| Student | 177,979 | 26.7 |
| Unemployed | 36,269 | 5.4 |
| **Physically challenged** |  |  |
| Yes | 7,888 | 1.2 |
| No | 659,852 | 98.8 |
| **Got disaster warning** |  |  |
| Yes | 544,131 | 81.5 |
| No | 123,609 | 18.5 |
| **Disaster preparedness** |  |  |
| Yes | 594,640 | 89.0 |
| No | 73,100 | 11.0 |
| **Number of disasters faced** |  |  |
| One | 460,962 | 69.0 |
| Two and more | 206,778 | 31.0 |
| **Place of residence** |  |  |
| Rural | 588,314 | 88.1 |
| Urban | 79,426 | 11.9 |
| **Region of residence** |  |  |
| Barisal | 65,247 | 9.8 |
| Chittagong | 106,266 | 15.9 |
| Dhaka | 176,586 | 26.5 |
| Khulna | 90,408 | 13.5 |
| Rajshahi | 88,042 | 13.2 |
| Rangpur | 72,287 | 10.8 |
| Sylhet | 68,904 | 10.3 |
| **Asset quintile** |  |  |
| Poorest | 126,161 | 18.9 |
| 2nd | 132,802 | 19.9 |
| 3rd | 136,706 | 20.5 |
| 4th | 133,923 | 20.0 |
| Richest | 138,148 | 20.7 |

**Effect of natural disasters on injury**

The total numbers of injured were estimated to 974 (145.9 per 100,000) (Table 2). The rate of injury was higher among the children (144 per 100,000) and elderly (293 per 100,000) and reported cases were significantly different across the age groups (p<0.001). In terms of occupational classification, the highest number of injuries occurred to day-labour (injury 213 per 100,000). The prevalence of injury (413 per 100,000) was higher among the individuals with the physically challenged condition compared to the individual without such condition and the proportion was significantly different (p<0.001). The prevalence (injury 163 per 100,000) was higher among who got disaster warning compared to who do not. However, the prevalence (injury 147 per 100,000) was lower among those who take the necessary measure for disaster. The rate of reported injury was significantly different (p<0.05) across the residential region and asset quintiles.

Table 2. Socio-economic characteristics of injuries caused by disasters (2009-2015)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Characteristics** | **N** | **Number per 100,000**  **(95% CI)** | **P-valuea)** |  | **Dependent=Injured**  **Odds ratio (95% CI)** |
| **Age group** |  |  |  |  |  |
| Child (0-14) | 324 | 143.6 (128.8 - 160.1) |  |  | 1.522\*\*\* (1.138,2.036) |
| Adult (15-60) | 538 | 133.2 (122.4 - 144.9) | <0.001 |  | 1 (Reference) |
| Elderly (60+) | 112 | 293.4 (243.9 - 353.0) |  |  | 1.708\*\*\* (1.338,2.181) |
| **Sex** |  |  |  |  |  |
| Male | 518 | 149.9 (137.5 - 163.4) |  |  | 1 (Reference) |
| Female | 456 | 141.6 (129.2 - 155.2) | 0.620 |  | 0.906 (0.774,1.060) |
| Transgender | 0 | 0 (0 - 0) |  |  | - |
| **Marital status** |  |  |  |  |  |
| Unmarried | 402 | 128.2 (116.3 - 141.3) |  |  | 1 (Reference) |
| Married | 499 | 150.8 (138.1 - 164.6) | <0.001 |  | 1.542\*\*\* (1.183,2.010) |
| Others | 73 | 315.1 (250.6 - 396.2) |  |  | 2.638\*\*\* (1.828,3.806) |
| **Education** |  |  |  |  |  |
| No institutional education | 428 | 173.0 (157.4 - 190.2) |  |  | 1 (Reference) |
| Primary level | 291 | 156.2 (139.2 - 175.2) |  |  | 0.993 (0.848,1.164) |
| Secondary and tertiary | 177 | 103.6 (89.4 - 120.1) |  |  | 0.763\*\*\* (0.629,0.924) |
| Not applicable | 78 | 123.4 (98.9 - 154.1) | <0.001 |  | 0.763\*\*\* (0.629,0.924) |
| **Occupation** |  |  |  |  |  |
| Not applicable | 165 | 158.4 (136.0 - 184.4) |  |  | 1 (Reference) |
| Agriculture | 206 | 151.8 (132.4 - 174.0) |  |  | 1.056 (0.784,1.423) |
| Service | 67 | 128.4 (101.1 - 163.1) |  |  | 1.042 (0.721,1.507) |
| Daylabor | 87 | 212.8 (172.5 - 262.5) | 0.001 |  | 1.499\*\* (1.063,2.114) |
| Housewife | 176 | 146.0 (126.0 - 169.3) |  |  | 1.109 (0.800,1.537) |
| Student | 239 | 134.3 (118.3 - 152.4) |  |  | 1.104 (0.815,1.497) |
| Unemployed | 34 | 93.7 (67.0 - 131.2) |  |  | 0.737 (0.481,1.129) |
| **Physically challenged** |  |  |  |  |  |
| No | 940 | 142.5 (133.6 - 151.9) | <0.001 |  | 1 (Reference) |
| Yes | 34 | 431.0 (308.1 - 602.7) |  |  | 2.809\*\*\* (1.985,3.974) |
| **Got disaster warning** |  |  |  |  |  |
| No | 772 | 141.9 (132.2 - 152.2) | 0.073 |  | 1 (Reference) |
| Yes | 202 | 163.4 (142.4 - 187.6) |  |  | 1.434\*\*\* (1.163,1.769) |
| **Disaster preparedness** |  |  |  |  |  |
| No | 873 | 146.8 (137.4 - 156.9) | 0.563 |  | 1 (Reference) |
| Yes | 101 | 138.2 (113.7 - 167.9) |  |  | 0.628\*\*\* (0.470,0.839) |
| **Number of disasters faced** |  |  |  |  |  |
| One | 660 | 143.2 (132.7 - 154.5) | 0.390 |  | 1 (Reference) |
| Two and more | 314 | 151.9 (136.0 - 169.6) |  |  | 1.057 (2.615,4.683) |
| **Place of residence** |  |  |  |  |  |
| Rural | 884 | 150.3 (140.7 - 160.5) | 0.01 |  | 1 (Reference) |
| Urban | 90 | 113.3 (92.2 - 139.3) |  |  | 1.514\*\*\* (1.209,1.896) |
| **Region of residence** |  |  |  |  |  |
| Barisal | 59 | 90.4 (70.1 - 116.7) |  |  | 1 (Reference) |
| Chittagong | 321 | 302.1 (270.8 - 336.9) |  |  | 3.500\*\*\* (2.615,4.683) |
| Dhaka | 161 | 91.2 (78.1 - 106.4) | <0.001 |  | 0.932 (0.676,1.286) |
| Khulna | 100 | 110.6 (90.9 - 134.5) |  |  | 1.181 (0.842,1.657) |
| Rajshahi | 144 | 163.6 (138.9 - 192.6) |  |  | 1.682\*\*\* (1.213,2.332) |
| Rangpur | 77 | 106.5 (85.2 - 133.2) |  |  | 1.17 (0.813,1.684) |
| Sylhet | 112 | 162.5 (135.1 - 195.6) |  |  | 1.710\*\*\* (1.219,2.399) |
| **Asset quintile** |  |  |  |  |  |
| Poorest | 173 | 137.1 (118.2 - 159.1) |  |  | 1 (Reference) |
| 2nd | 192 | 144.6 (125.5 - 166.5) |  |  | 1.054 (0.763,1.200) |
| 3rd | 261 | 190.9 (169.1 - 215.5) | <0.001 |  | 1.429\*\*\* (1.172,1.743) |
| 4th | 179 | 133.7 (115.5 - 154.7) |  |  | 1.019 (0.819,1.267) |
| Richest | 169 | 122.3 (105.2 - 142.2) |  |  | 0.957 (0.763,1.200) |
| Constant | - | - | - |  | 0.000\*\*\* (0.000,0.001) |
| **Total** | **974** | **145.9 (136.9 - 155.3)** |  |  |  |

a) Chi-square test; *\* p<0.10; \*\* p<0.05; \*\*\* p<0.01*

From the multiple logistic regression models, we found that the elderly population was significantly more likely to suffer from an injury due to a disaster compared to the adult population (Table 2). The disaster-related injury was also significantly associated with education, physically challenged condition, urban residence, administrative divisions (e.g. Chittagong, Rajshahi and Sylhet) and asset quintiles.

**Effect of natural disasters on disability**

In total 186 (14.4 per 100,000) individuals were disabled due to natural disasters between 2009-2015. The rate of disabilities due to disasters was significantly different across the age groups (p<0.001). Disability (228.2 per 100,000) was higher among the individuals with the physically challenged condition compared to the individual without such condition and the proportion was significantly different (p<0.001). The rate was higher among the individuals received the disaster warning and lower among those who take the necessary measure for disaster. Both the proportion of reported disabilities across the residential region and asset quintiles were significantly different (p<0.05).

Table 3. Association of disaster-related disability with socioeconomic characteristics.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Age group** | **N** | **Number per 100,000 (95% CI)** | **P-valuea)** |  | **Dependent= Disabled**  **Odds ratio (95% CI)** |
| Child (0-14) | 61 | 27.0 (21.0 - 34.7) |  |  | 1.245 (0.618,2.508) |
| Adult (15-60) | 94 | 23.3 (19.0 - 28.5) | <0.001 |  | 1 (Reference) |
| Elderly (60+) | 31 | 81.2 (57.1 - 115.5) |  |  | 2.303\*\*\* (1.380,3.842) |
| **Sex** |  |  |  |  |  |
| Male | 110 | 31.8 (26.4 - 38.4) |  |  | 1 (Reference) |
| Female | 76 | 23.6 (18.9 - 29.6) | 0.130 |  | 0.690\*\* (0.479,0.995) |
| Transgender | 0 | 0.0 (0.0 - 0.0) |  |  |  |
| **Marital status** |  |  |  |  |  |
| Unmarried | 73 | 23.3 (18.5 - 29.3) |  |  | 1 (Reference) |
| Married | 98 | 29.6 (24.3 - 36.1) | 0.001 |  | 2.493\*\*\* (1.284,4.840) |
| Others | 15 | 64.7 (39.0 - 107.4) |  |  | 3.154\*\*\* (1.321,7.528) |
| **Education** |  |  |  |  |  |
| No institutional educ | 87 | 35.2 (28.5 - 43.4) |  |  | 1 (Reference) |
| Primary level | 49 | 26.3 (19.9 - 34.8) |  |  | 0.9 (0.619,1.307) |
| Secondary and tertiary | 28 | 16.4 (11.3 - 23.7) |  |  | 0.621\*\* (0.389,0.993) |
| Not applicable | 22 | 34.8 (22.9 - 52.9) | 0.003 |  | 1.697 (0.752,3.829) |
| **Occupation** |  |  |  |  |  |
| Not applicable | 46 | 44.2 (33.1 - 58.9) |  |  | 1 (Reference) |
| Agriculture | 35 | 25.8 (18.5 - 35.9) |  |  | 0.646 (0.349,1.196) |
| Service | 15 | 28.8 (17.3 - 47.7) |  |  | 0.946 (0.443,2.019) |
| Daylabor | 14 | 34.3 (20.3 - 57.8) | 0.029 |  | 0.808 (0.378,1.726) |
| Housewife | 27 | 22.4 (15.4 - 32.7) |  |  | 0.764 (0.375,1.555) |
| Student | 40 | 22.5 (16.5 - 30.6) |  |  | 1.378 (0.668,2.845) |
| Unemployed | 9 | 24.8 (12.9 - 47.7) |  |  | 0.87 (0.372,2.032) |
| **Physically challenged** |  |  |  |  |  |
| No | 18 | 25.5 (21.9 - 29.6) | <0.001 |  | 1 (Reference) |
| Yes | 168 | 228.2 (143.8 - 361.9) |  |  | 7.878\*\*\* (4.770,13.01) |
| **Got disaster warning** |  |  |  |  |  |
| No | 149 | 27.4 (23.3 - 32.2) | 0.628 |  | 1 (Reference) |
| Yes | 37 | 29.9 (21.7 - 41.3) |  |  | 1.922\*\*\* (1.260,2.934) |
| **Disaster preparedness** |  |  |  |  |  |
| No | 175 | 29.4 (25.4 - 34.1) | 0.028 |  | 1 (Reference) |
| Yes | 11 | 15.1 (8.3 - 27.2) |  |  | 0.233\*\*\* (0.110,0.493) |
| **Number of disaster faced** |  |  |  |  |  |
| One | 135 | 29.3 (24.7 - 34.7) | 0.295 |  | 1 (Reference) |
| Two and more | 51 | 24.7 (18.7 - 32.5) |  |  | 0.861 (0.622,1.193) |
| **Place of residence** |  |  |  |  |  |
| Rural | 171 | 29.1 (25.0 - 33.8) | 0.107 |  | 1 (Reference) |
| Urban | 15 | 18.9 (11.4 - 31.3) |  |  | 1.503 (0.872,2.591) |
| **Region of residence** |  |  |  |  |  |
| Barisal | 20 | 30.7 (19.8 - 47.5) |  |  | 1 (Reference) |
| Chittagong | 29 | 27.3 (19.0 - 39.3) |  |  | 0.766 (0.421,1.395) |
| Dhaka | 19 | 10.8 (6.9 - 16.9) | <0.001 |  | 0.249\*\*\* (0.128,0.487) |
| Khulna | 22 | 24.3 (16.0 - 37.0) |  |  | 0.619 (0.326,1.177) |
| Rajshahi | 29 | 32.9 (22.9 - 47.4) |  |  | 0.777 (0.418,1.443) |
| Rangpur | 22 | 30.4 (20.0 - 46.2) |  |  | 0.778 (0.402,1.508) |
| Sylhet | 45 | 65.3 (48.8 - 87.5) |  |  | 1.612 (0.903,2.878) |
| **Asset quintile** |  |  |  |  |  |
| Poorest | 38 | 30.1 (21.9 - 41.4) |  |  | 1 (Reference) |
| 2nd | 29 | 21.8 (15.2 - 31.4) |  |  | 0.813 (0.499,1.326) |
| 3rd | 55 | 40.2 (30.9 - 52.4) | 0.022 |  | 1.613\*\* (1.051,2.474) |
| 4th | 30 | 22.4 (15.7 - 32.0) |  |  | 0.916 (0.557,1.507) |
| Richest | 34 | 24.6 (17.6 - 34.4) |  |  | 1.022 (0.623,1.678) |
| Constant | - | - | - |  | 0.000\*\*\* (0.000,0.001) |
| **Total** | **186** | **14.4 (11.7 - 17.6)** |  |  |  |

a) Chi-square test; *\* p<0.10; \*\* p<0.05; \*\*\* p<0.01*

From the multiple logistic regression models, we found that the elderly, being married, physically challenged condition, disaster warning, being in 3rd asset quintile was significantly associated with the higher risk of disabilities. Disaster preparedness, living in Dhaka division and being female were negatively associated with the disability due to natural disasters.

**Effect of natural disasters on death**

Due to the disaster in the last six years, the total number of deaths was estimated at 140 (21.0 per 100,000). Number of death due to the disaster was higher among the elderly compared to other age groups. The rate was higher among the female compared to male, rural residents compared to urban, Rangpur division compared to all other divisions, and poorest quintile compared to other quintiles.

Table 4. Socio-economic characteristics of fatalities caused by disasters (2009-2015)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Characteristics** | **N=667,880** | **Rate per 100,000 (95% CI)** | P-valuea) |  | **Dependent= Deaths**  **Odds ratio (95% CI)** |
| **Age group** |  |  |  |  |  |
| Child (0-14) | 30 | 13.3 (9 - 19) |  |  | 0.615\*\* (0.405,0.933) |
| Adult (15-60) | 85 | 21 (16.8 - 26) | <0.001 |  | 1 (Reference) |
| Elderly (60+) | 25 | 65.5 (42.4 - 96.7) |  |  | 3.354\*\*\* (2.143,5.250) |
| **Sex** |  |  |  |  |  |
| Male | 65 | 18.8 (14.5 - 24) | 0.444 |  | 1 (Reference) |
| Female | 75 | 23.3 (18.3 - 29.2) |  |  | 1.288 (0.924,1.797) |
| **Got disaster warning** |  |  |  |  |  |
| Yes | 115 | 21.1 (17.6 - 25.4) | 0.842 |  | 1.187 (0.651,2.162) |
| No | 25 | 20.2 (13.7 - 29.9) |  |  | 1 (Reference) |
| **Disaster preparedness** |  |  |  |  |  |
| Yes | 127 | 21.4 (17.9 - 25.4) | 0.529 |  | 0.834 (0.363,1.916) |
| No | 13 | 17.8 (10.3 - 30.6) |  |  | 1 (Reference) |
| **Number of disasters faced** |  |  |  |  |  |
| One | 100 | 21.1 (17.6 - 25.4) | 0.540 |  | 1 (Reference) |
| Two and more | 40 | 20.2 (13.7 - 29.9) |  |  | 0.895 (0.618,1.298) |
| **Place of residence** |  |  |  |  |  |
| Rural | 119 | 20.2 (16.9 - 24.2) | 0.256 |  | 1 (Reference) |
| Urban | 21 | 26.4 (17.2 - 40.5) |  |  | 0.745 (0.457,1.212) |
| **Region of residence** |  |  |  |  |  |
| Barisal | 8 | 12.3 (6.1 - 24.5) |  |  | 1 (Reference) |
| Chittagong | 31 | 29.2 (20.5 - 41.5) |  |  | 2.497\*\* (1.104,5.650) |
| Dhaka | 32 | 18.1 (12.8 - 25.6) |  |  | 1.495 (0.638,3.507) |
| Khulna | 14 | 15.5 (9.2 - 26.1) | 0.055 |  | 1.277 (0.508,3.207) |
| Rajshahi | 20 | 22.7 (14.7 - 35.2) |  |  | 1.768 (0.722,4.332) |
| Rangpur | 23 | 31.8 (21.1 - 47.9) |  |  | 2.420\* (0.993,5.902) |
| Sylhet | 12 | 17.4 (9.9 - 30.7) |  |  | 1.497 (0.571,3.924) |
| **Asset quintile** |  |  |  |  |  |
| Poorest | 36 | 28.5 (20.6 - 39.6) |  |  | 1 (Reference) |
| 2nd | 28 | 21.1 (14.6 - 30.5) | 0.243 |  | 0.749 (0.455,1.233) |
| 3rd | 24 | 17.6 (11.8 - 26.2) |  |  | 0.626\* (0.369,1.063) |
| 4th | 29 | 21.7 (15.1 - 31.2) |  |  | 0.733 (0.442,1.215) |
| Richest | 23 | 16.7 (11.1 - 25.1) |  |  | 0.519\*\* (0.300,0.898) |
| Constant |  |  |  |  | 0.000\*\*\* (0.000,0.000) |
| **Total** | **140** | **21 (17.64 - 24.74)** |  |  | **N= 667,880** |

a) Chi-square test; *\* p<0.10; \*\* p<0.05; \*\*\* p<0.01*

Multiple regression model showed that child age group and better of socioeconomic status (e.g. 3rd and richest quintiles) were negatively associated with the deaths due to disaster.

**Geographic distribution of the effect of natural disasters**

Geographic variations in the number of injuries (Figure 1), disability (Figure 2), and death (Figure 3) per 100,000 population were observed across districts in Bangladesh.

Figure 1. Distribution of disaster-related injury per 100,000 population across districts in Bangladesh (2009–2014)



Figure 2. Distribution of disaster-related disability per 100,000 population across districts in Bangladesh (2009–2014)



Figure 3. Distribution of disaster-related death per 100,000 population across districts in Bangladesh (2009–2014).

**Injury, disability and deaths by natural disasters types**

We found that in terms of the different types of disasters, the impact of the flood was greater than the impact of other disasters causing the highest percentage of total disaster-related injury (36.7%), disability (50.5%), and deaths (29.3%) (Figure 4).

Figure 4. Distribution of disaster-related injury, disability, and death by types of disasters in Bangladesh (2009–2014)

**Discussion**

This is the first study that used data from a national survey to evaluate the socioeconomic characteristics of disaster-related injury, disability, and deaths. The cross-sectional analysis revealed significant socioeconomic inequalities in the affected population. We found that 145.9 injury, 14.4 disability, and 21 deaths, per 100,000 population occurred during 2009-2014 in Bangladesh. The study considered the major types of natural disasters, which occurred over the last six years in Bangladesh. Among these disaster types, floods were responsible for the highest percentage of injury, disability, and deaths while thunderstorms were responsible for the second-highest percentage. Floods and thunderstorms are the most frequent disaster events in Asia and the Pacific region, accounting for 64 percent of the total number of such events reported between 1970 and 2014 (ESCAP, 2015). In Bangladesh, floods affect more people compared to any other natural disaster (World Bank, 2011).

Total numbers of injuries, disabilities, and deaths were estimated at 974, 186, and 140 respectively in the last six years. Among the population studied, children and the elderly were the most vulnerable to disaster-related injury and disability possibly because, compared to adults, they were not as able to quickly move in response to an emergency. Physiological changes associated with ageing make senior citizens more susceptible to illness or injury, or even death during disaster events (Bodstein, de Lima, & de Barros, 2014). Our findings were similar to those in previous studies which reported that children and the elderly are the most vulnerable groups to the immediate impacts of disasters (Bodstein et al., 2014; ESCAP, 2015; Lawler, 2011). Physically challenged individuals were more likely to be injured and disabled possibly due to inaccessible evacuation, response (including shelters, camps, and food distribution), and recovery efforts (United Nation, 2019). This group has additional needs before, during, and after a disaster, including those related to transportation, supervision, and medical care. A study showed that these people were more likely to be adversely affected in terms of their physical safety and access to immediate aid, shelter, evacuation, and relief (Hemingway & Priestley, 2006).

We observed that injury and disability were significantly associated with disaster warning. Despite receiving disaster warnings, some were more likely to be injured and disabled during disaster events. Just receiving a disaster warning was insufficient to prevent or reduce disaster-related casualties. Their level of preparedness may have been affected by the timeliness of the information. If the warnings are issued too late, or if there is no means of disseminating the information, then there will not be enough time to effectively respond to the warning (Nelson, 2019). Another possible reason could be that warnings are generally provided by the national and/or local government for the disasters (e.g. flood, tornado, and cyclone) which are predicted to be hazardous to the population. These include disasters which have resulted in more injury, disability and death as compared to less hazardous disaster types (e.g. drought, river erosion). Even in situations of imminent disaster, there can be low levels of compliance with advice to take protective action (Sharma, Patwardhan, & Parthasarathy, 2009). Factors related to personal circumstances, beliefs and attitudes, societal response, and the characteristics of the authorities may have influenced whether individuals chose to take preparation measures (Sharma et al., 2009). Comes et al. 2014 argued that despite the potential of new technologies and the improvements of early-warning systems, damage and harm caused by disasters do not stop to increase due to gaps in risk management and preparedness (Comes, Mayag, & Negre, 2014). Fakhruddin et al., 2015 found that for flood risk management, communities more or less depending on their indigenous knowledge in Bangladesh and decision-making based on medium-range forecasts was not a practice in any area (Fakhruddin, Kawasaki, & Babel, 2015). Therefore, only disaster warnings may not be effective to reduce health hazards (e.g. injury). People with better knowledge about disaster preparedness and capacity to understand the warning are more likely to take disaster preparation (Lam et al., 2017). In our analysis, we found that disaster preparedness significantly reduced the likelihood of injury and disability by 38% and 77%, respectively.

We also found that urban populations are more likely to suffer from a disaster-caused injury compared to the rural populations. People living in the hill tract areas (Chittagong) were more likely to be injured and deaths. This is because landslides often victimize these people. In 2007, a massive landslide occurred in several areas near Chittagong causing the death of 127 people (Islam, Islam, & Islam, 2017). People living in the Rangpur region were more likely to die due to disasters. Rangpur division located in the northern part of the country which is one of the most vulnerable divisions to multiple natural disasters (e.g. floods, droughts and riverbank erosion). The natural disasters related health burden (e.g. injury, disability and death) in this division was high may be due to high frequency of these disasters (Rahman, Hiya, Auyon, & Islam, 2018; Reza, Islam, Tasnuva, Islam, & Haque, 2015). Besides, a large number of individuals in the Rangpur region used to work in the field and lives beside the river. Our findings showed that people living in the Dhaka region were less likely to become injured. This is because the emergency response in this region is better than in any other region in Bangladesh (Stott & Nadiruzzaman, 2014; The World Bank, 2018). The economic status of the individuals was not consistently associated with injury and disability. However, for disaster-related mortality, the richest people were less likely to die. Previous studies showed that poverty was associated with increased disaster vulnerability, and poor people suffer the most during and after a disaster (Hajra et al., 2017; South, Programme, & Affairs, 1998). On the other hand, 3rd asset quintile was more likely to have an injury compared to the poorest quintile. This result can be affected by the self-reporting bias which is a limitation of this study. While death event is easy to memorize and report by the respondent of all socio-economic class, perception of injury may vary across these groups. The poor are more likely to ignore non-fatal, non-severe injuries as they do not consider this as important to report (Khan et al., 2016; Sauerborn, Adams, & Hien, 1996).

Our analysis identified significant socioeconomic determinants of disaster-related injury, disability, and death. These determinants can help local, regional and national level government decision-makers design and target their disaster planning and response efforts while paying special attention to the most vulnerable groups such as children, the elderly, and the physically challenged. Certainly, there is a need to improve disaster preparedness and warnings. Warnings must be clear, shared widely in a timely way, and unambiguous as to how people should prepare, what they should expect, and how they can respond. A “first responder” interagency group could be assigned the shared responsibility to improve and promote disaster warnings. Community health workers could also play an important role to advocate health and safety behaviours and to encourage compliance with preparedness advice. Application of spatial mapping techniques which include these important socioeconomic factors could help policy-makers visualize who is most at risk and where including their relative proximity to critical infrastructures such as roads and healthcare facilities. Such tools could help identify additional important social inequities.

This is the first study to examine the socioeconomic characteristics associated with disaster-related injury, disability, and death. We used self-reported data for disaster-related health outcomes that may be affected by recall bias and reporting bias. Another limitation is that we used cross-sectional survey data. Therefore, the estimates regarding the association between disaster-related health outcomes and socioeconomic characteristics may not reflect cause-effect relationships. However, the survey was administered nationally with appropriate sample design to generate a national estimate of disaster-related health outcome between 2009 and 2014. This kind of survey is limited in LMIC settings. The response rate of the survey was 100%.

There is a high burden of disaster-related injury, disability and death b in Bangladesh. The study findings showed that age, education level, physically challenged condition, urban residency, and asset quintiles were important socioeconomic factors associated with the reported disaster-related health outcomes. This understanding can inform national and regional level policy planning including the allocation of scarce resources to the highest risk areas. Such understanding can help to identify practical policy interventions to improve socioeconomic conditions in the most at-risk areas which could mitigate the adverse health impacts of disasters. This should be a high priority in Bangladesh given its highly dense population and vulnerability to disasters.

**Author contributions**

SA, MZH, and SS conceptualized the study and performed the data analysis. SA, MZH, SS, MWA, MJP, and SS interpreted findings and wrote the manuscript. All authors reviewed and approved the final version of the manuscript.

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