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Title page

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Extreme Weather Events (EWEs)-Related Health Complications in Bangladesh: A Gender-based Analysis on the 2017 Catastrophic Floods

Abstract

Floods are major Extreme Weather Events (EWEs) that are more frequent and intense. Floods has multifarious dire impacts on human health, but health implications of floods are limitedly examined from a gender lens, particularly in developing countries like Bangladesh. Floods periodically hit in Bangladesh. The 2017 was a catastrophic year for Bangladesh. The year experienced two consecutive floods that were more catastrophic in the last couple of decades and direly affected 24 districts of the country. The floods resulted in health stress and intensifying exposure to manifold health vulnerabilities. Our study aimed to investigate gendered health complications caused by the floods and the impacts of the confluence of the floods and vulnerabilities relating to water, sanitation, health care facilities on reproductive health. To achieve this, we conducted 280 household surveys, 4 Focus Group Discussions, 4 In-Depth Interviews, and 6 Key Informant Interviews within the framework of mixed-method research in a northern flood-prone district named Jamalpur. Our findings showed that 84.6% of the respondents stated water gets polluted during floods, and 69.6% identified polluted water as a major challenge while collecting water during floods. Due to living with polluted floodwater, fever (66.4%) and diarrheal diseases (55.4%) were most common among women. In respect to reproductive health, 75% of the females reported improper menstrual management causing mental shocks and vaginal infections; over 66.4% females noted remaining without any measures. To mitigate health vulnerability, majority of the rural women (78.6%) encountered challenges – including the dearth of available medicine and poor transportation and communication. Health vulnerability also increased when poor communities failed to afford the

cost of medicine because of poor economic condition and food insecurity. Consequently, our study recommends for fostering health education and the immediate deployment of health care facilities on an emergency basis to reduce health complications, especially among marginal groups (e.g., women and children). Future research can explore how the intersection of economic insecurity and flood whet differential health complications among poor and non-poor.

Keywords: Bangladesh, Extreme weather event (EWE), Flood, Health, Gender, Reproductive health

1. Introduction

Extreme Weather Events (EWEs) are weather variables near the higher or lower end ranges of observed values (WMO, 2023; Radović and Iglesias, 2019). In general, the condition of weather falling out of the spectrum of normal weather patterns can be termed as "Extreme Weather" (Vose et al., 2014). Anthropogenic climate change has resulted in the rise in frequency and intensity of weather extremes worldwide, and there is increasing consensus attributing climate change as a major contributing factor behind EWEs (Stott, 2016; Xu and Xu, 2021; Zanocco et al., 2018). Events –such as typhoons, hurricanes, tropical cyclones, floods, and droughts – have been more intense and frequent in recent times, with devastating effects on health of vulnerable communities (Bell and Masys, 2020). Such events have an incremental impact on human health – both physical and mental. As Rataj et al. (2016) assert, the most distressed populations are in the developing countries where severe mental and physical health impacts are arising from EWEs. In the aftermath of EWEs, health and social care systems and infrastructures face immense strain for which preparedness and adaptation measures are scarce in the developing world due to massive damage to life and properties (Curtis et al. 2017; Xu and Xu, 2021).

Understanding of the linkage between the increasing temperature and the occurrence of natural hazards has grown, and studies have distinctly correlated the warming and the future flood risk at a global level, with Asia being the most vulnerable (Alfieri et al., 2017). Flooding events have become a global pandemic in the past few decades, resulting in the loss of lives and causing economic damage (Asumadu-Sarkodie et al., 2015). The impacts of flooding can decimate an entire regional economy by damaging the production chain (Zeng et al., 2019). Flood risks are more catastrophic in the developing countries, like Bangladesh due to the lack of effective management to control rapid urban development. This is because economic losses are harder to recover from (Ahiablame and Shakya, 2016). The location of properties within a floodplain further, reduces the effective economic value of properties (Zhang, 2016).

The Asia Pacific region is often considered one of the most disaster-prone and vulnerable areas of the world. More than 1.2 billion people in this region are severely exposed to hydro meteorological hazards, witnessing deaths, injuries, and fatal communicable diseases (Hashim and Hashim, 2014). Exposure to EWEs influences the preparedness for new hazards, and the traumatic experiences of such exposures negatively affect mental health and psychological functioning (Sattler, 2017). Bangladesh is vulnerable to different meteorological, hydrological, and geological hazards. These hazards often lead to devastating disasters such as floods, droughts, tornadoes, earthquakes, cyclones, tidal surges, landslides, river erosion, waterlogging, salinity, building collapse, and various forms of pollution (Chowdhury et al., 2020). Bangladesh has historically faced several natural disasters annually; however, floods appear to be responsible for the highest percentage of injuries, disabilities, and deaths, ranking ahead of thunderstorms (Ahmed et al., 2020). Extreme weather has been associated with internal migration in Bangladesh as an adaptation measure, while the migrants often face new challenges regarding

social protection and health service facilities at their new locations (Carrico and Donato, 2019). Impoverished families often hasten to marry off their daughters as early as possible after EWEs as a coping strategy that has long-term impacts on the health and wellbeing of women and children in the community (Carrico et al., 2020). Studies on the aftermath of Cyclones Sidr (November 2007) and Aila (May, 2009) have revealed the despair of the health status of the coastal people of Bangladesh. People mostly face diarrheal, skin diseases, and mental health issues after cyclones, and the situation is even more difficult for the economically vulnerable communities to cope with (Azad and Khan, 2015; Kabi and Khan, 2017).

The affected population has an average level of knowledge of climate change (Kabi and Khan, 2017). However, the perception and awareness of the effects of climate change-related events and their impact on physical and mental health are higher due to the increasing level of education in the country (Kabir et al., 2016; Hasan et al., 2020). Community-based prevention measures also contribute to this awareness, and school or education-based interventions appear to effectively increase people's knowledge regarding EWEs, climate change, and their impacts on health (Azad et al., 2020; Kabir et al., 2016; Hasan et al., 2020). Generally, males are the majority in fatalities due to flooding events. The over-representation of males compared to females is statistically significant and does not very much in time (Salvati et al., 2018). The factors associated with females are generally more critical for flood adaptation strategies (Ahmad et al. 2021; Jerin et al., 2023). Women demonstrate a deeper level of understanding in the flood risk perceptions, household caring attitudes and are more willing to help flood victims (Cvetković et al. 2018; Jerin et al., 2023). Studies also exhibit females with lower food security and access to safe drinking water restrained for the most part after flood events (Azad et al., 2013; Ajaero 2017).

The health impact of floods could be considered short-term, intermediate, and long-term concerning time, water, and sanitation (Bich et al., 2011). Flood-induced health effects could be drowning, injuries, skin diseases, and outbreaks of gastrointestinal diseases (Ohl and Tapsell, 2000; Bich et al., 2011). The intermediate or mid-term health effects of floods could include starvation, infections, wounds, complications from injuries, poor mental health, and communicable diseases (Bich et al., 2011). In the long-term, health impacts of floods could be malnutrition, chronic diseases, disabilities, poor mental health, and poverty-related diseases (Ohl and Tapsell, 2000; Bich et al., 2011). However, short-term and intermediate impacts lead to long-term adverse health consequences (Okaka and Odhiambo, 2019). Despite a plethora of studies on the health impacts of floods (e.g., Ohl and Tapsell, 2000; Davis et al., 2010; Bich et al., 2011; Kabir et al., 2016; Curtis et al., 2017; Islam et al., 2017), the application of a gender-based approach to understanding health vulnerability is insufficient (Cvetković et al., 2018; Ahmad et al., 2021).

In Bangladesh, flood is one of the extreme weather events (EWEs) of global climate change, affecting health and wellbeing detrimentally. The CPD reported that the catastrophic floods in 2017 were more detrimental than the floods of 2004 and 2007, and 2008 (CPD, 2017). Where several studies examined floods impact on health and agriculture (Milojevic et al., 2012; Uddin, 2018; Jagnoor et al., 2019), meteorological and hydrological perspectives and humanitarian interventions (Gros et al., 2019; Philip et al., 2019), and physical vulnerability to flooding (Bhuiyan and Dutta, 2012; Rahman and Salehin, 2013; Dewan, 2015), he issue of EWEs, especially floods and impacts on health remains relatively unexplored in Bangladesh, from a gender perspective. Against this backdrop, this study aims to investigate gendered health vulnerability of women to floods in northern Bangladesh. The specific objectives of the study are

three folds: (i) to examine how the interacting determinants – water, sanitation, health care facilities, and reproductive health services – had been deleteriously influencing the state of health of the flood-affected people, particularly women; (ii) to explore the impacts, challenges of the affected communities, and their coping mechanisms to overcome the situation, and (iii) to develop a conceptual framework that can assist with developing a comprehensive approach to prevention, mitigation, and management (P2M) of the health impacts of EWEs, particularly floods.

1.1. Conceptual framework

Among all of the extreme weather events (EWEs), flood has one of the most prolonged and destructive effects, and it is projected that increased flooding will lead to widespread damage to all aspects of livelihood in South Asian countries, especially in Bangladesh (IPCC, 2014). Floods affect communities unevenly and in different ways (Alderman et al., 2012), exposing households and individuals to vulnerable conditions that has substantial impacts on all aspects of well-being including health (Okaka and Odhiambo, 2019). The global burden of disease is expected to rise due to increased flood risks and it has already been stressing health services in the developing countries (Alderman et al., 2012). Effects of floods are multiplex and destructive as they range from immediate health consequences, such as diseases, injury, drowning, mortality to long term impacts on communities and individuals by damaging public health infrastructure, communication system, and water sources (Okaka and Odhiambo, 2019). Through an intensive literature review (Ohl and Tapsell, 2000; Paul and Routray, 2010; Shimi et al., 2010; Alderman et al., 2012; Okaka and Odhiambo, 2019). As Figure-1 shows, flood events interacting with socio-economic settings, water, sanitation condition, and state of public health infrastructure are

contributing to the acceleration of health complications. Health complications are also triggered by an interaction of poor health facilities and socio-cultural challenges. For example, poor health facilities (e.g., absence of doctors, long waiting, poor quality) and cultural barriers (e.g. fear of abuse, privacy problems) combinedly heighten health problems in poor and marginal communities. While several steps are undertaken, such as reducing operation and medicine cost, they are very limited. Benefits only go to politically influenced person in rural Bangladesh. While a number of studies (e.g., Paul and Routray, 2010; Shimi et al., 2010; Azad et al., 2013; Dewan, 2015; Hossain et al., 2020b) have been conducted in this context, the focus on the complex interaction is inadequate. As our study aimed to explore the health complications due to flood from a gender perspective, such literatures regarding gender issues (Ashraf & Azad, 2015; Azad et al., 2013; Nasreen, 2012) were partial as females had received more focus than males due to social and economic vulnerability. In this study, males are given the same priority as females to understand the overall health complications from gender point of view and to investigate how they are affected, as well as the difference between their challenges and coping strategies.

[Fig. 1 is Here]

2. Review of Existing Literature

2.1. Flood as an Extreme Weather Event in Bangladesh

With the increase in extreme weather events around the world, the world is confronting the reality of climate change, and it is unequivocal that the expected future risks and changes have already begun to appear (Eckstein et al., 2021; IPCC, 2014). Over 11000 extreme weather events occurred around the world between 2000 and 2019, resulting in over 495000 deaths and $2.56 trillion in losses (Eckstein et al., 2021). Though the world is experiencing climate change effects,

South Asia, particularly Bangladesh, is at high risk of experiencing unfavorable climate change effects due to its geomorphological and socioeconomic condition (IPCC, 2012). Bangladesh is the 7th most affected country in the Global Climate Risk Index 2021, with a total of 185 extreme weather events between 1999 and 2018, both in terms of fatalities and losses (Eckstein et al., 2021). When some aspects of an occurrence, such as magnitude, duration, or intensity, surpass the observed or general threshold or norm of the event, it is deemed extreme, and changing climate is influencing the frequency, timing, severity, and duration of weather events worldwide making those extreme (Karl et al., 1995; WMO, 2023). Seasonal and regional variations in precipitation and other weather variables, as well as longer-term climatic changes, affect the frequency, location, and intensity of floods (Penning-Rowsell et al., 2005). Due to the consequences of global warming, the frequency and intensity of flooding around the world, as well as the resulting losses and human health impacts, is predicted to grow during the next 50 to 100 years (Penning-Rowsell et al., 2005; IPCC, 2007). Worldwide, a significant increase in the number of large flood events, as well as a decrease in the return period of floods with increasing severity and harmful impacts on people, has been seen in recent decades (Jongman et al., 2012; Najibi and Devineni, 2018; Kabir and Hossen, 2019; Tellman et al., 2021).

It is predicted that Bangladesh will experience significant change in its weather pattern, with sea levels rising, temperatures rising, monsoon precipitation increasing, and more intense and frequent disasters. The changed climatic features will exacerbate existing stresses, such as reducing water and food security, poverty, health, migration, and destroying essential infrastructure, obstructing the country's overall development (BCCSAP, 2009; IPCC, 2007). Flood has been one of the most common climatic events in Bangladesh, with increased intensity, frequency, and changing patterns in recent years (Hossain et al., 2020a; Kabir and Hossen,

2019). For example, some of the worst floods occurred in the years 1987, 1988, 1998, 2004, 2007, and 2017 with one every six years on average (Dewan, 2015; Hossain et al., 2020). Regular river floods submerge 20–25 percent of the country each year, rising to 68 percent in extreme circumstances; floods in 1987, 1988, and 1998 swamped more than 60 percent of the country, taking thousands lives and displacing millions of populations (Dewan, 2015; Smith, 2013). In August 2017, Bangladesh witnessed one of the worst river flooding episodes in recent history, with record-high water levels (Philip et al., 2019). The Ministry of Disaster Management and relief reported this flood as the worst in at least 40 years – inundating 42% of the country (Das and Rahman, 2018; Philip et al., 2019; UNICEF, 2017). The August 2017 floods were particularly devastating since they struck consecutively after two successful flooding events that hit in late March and July (Philip et al., 2019). The National Disaster Response Coordination Centre (NDRCC) reported that around 6.9 million people were affected, killed 114 people, displaced more than 297250 people from their origin. Approximately 593250 homes were damaged, displacing residents to temporary shelters, and 650,000 hectares of crops were damaged (Philip et al., 2019). This resulted severe economic and social insecurity among poor and marginal populations in the river basin areas in Bangladesh (Philip et al., 2019).

2.2. Flood and Health Complications: A Gender Perspective

Weather and climate change are critical indicators of health and wellbeing (Menne, 2005). As climate variability changes and increases, there is rising fear that the consequences, such as extreme weather events, will have a negative influence on public health in a variety of ways (Menne, 2005). Flooding is a common occurrence that inundates roughly 30% of the total land area each year (Dewan, 2015; Hossain et al., 2020; Kabir and Hossen, 2019; Nasreen, 2012). However, as the climate changes, the situation is becoming more extreme, and climate change-

induced vulnerabilities are exacerbating flood impacts and challenges to the respondents in major ways, particularly in terms of creating health complications. Flooding's negative human health implications can be complicated and far-reaching, with direct and indirect effects on the community and household livelihoods (Hajat et al., 2003; Menne, 2005; Okaka and Odhiambo, 2019). Hajat et al. (2003) also acknowledged that better preparedness measures, rescue operations, relief measures can reduce the direct health impacts of flood. In line with this, Kreibich et al. (2017) identified that better flood forecasting and early warning systems, increased awareness and preparedness have contributed to reducing mortality rates in Bangladesh (Gain et al., 2015; Kreibich et al., 2017; Ferdous et al., 2020).

Gender concerns have taken center stage in discussions about disaster management and climate change, as vulnerable groups, particularly women, bear the brunt of catastrophes' negative consequences. Climate change consequences are seen to vary from country to country, region to the community, and individual level, with gender being a particularly relevant vulnerability factor (Nasreen, 2012; Jerin et al., 2023). Gender takes into account not only women and their responsibilities, but also men and their duties, as well as their independent relationships. As a result, while studying disasters, vulnerability, or any other subject of study through a gender lens, it must be analyzed and mirrored in practice for men and boys as well as women and girls (Ashraf and Azad, 2015; Enerson and Chakrabarti, 2009). Moser (1993) argues that disparities between men and women are socially and culturally produced within and between households, civilizations, and countries, and these differences evolve through time. These distinctions are seen in the roles people play, the responsibilities they perform, their access to resources, the constraints they encounter, the opportunities they receive, their needs, their knowledge, and their perspectives. Climate change and disasters have an impact on all sectors,

including women's and men's socially imposed roles and duties. Flood has varied effects on men's and women's health and well-being. Women are thought to be more vulnerable than males since they rely on natural resources and the environment for more of their activities than men (Jerin et al., 2023; Sharmin and Islam, 2013). Furthermore, women's caring nature and sacrificing minds for their families sometimes force them to overlook their health requirements and the right to access health care. Furthermore, from a biological standpoint, women's reproductive health is far more delicate than men's, resulting in an additional load of health difficulties for women. There is a pressing need to investigate flood-related health problems from a gender viewpoint (Nasreen et al., 2017).

Flood risks, causes of flood risk, flood impacts on various sectors, flood mapping, flood induced vulnerabilities, mitigation, coping and adaptation techniques, flood protection measures, challenges faced by flood victims, risk assessment, and so on are all covered in extensive literature both globally and nationally. The impacts floods have on human health through a gender lens is less explored, especially in the context of Bangladesh. Several epidemiological studies (e.g., Hashizume et al., 2007, 2009, 2012; Haque et al., 2010; Dewan et al., 2013, 2017) show the association between climate variables and various diseases, such as diarrhea, typhoid, extreme fever (known as *Kala-ajar*), and dengue. In some studies (e.g., Hajat et al., 2003; Ahern et al., 2005; Menne, 2005; Penning-Rowsell et al., 2005; Jongman et al., 2012; Uddin, 2018; Okaka and Odhiambo, 2019), floods impacts on health was explored, but the total health complications due to flood was not addressed. The review study (Ahern et al., 2005) looked at the epidemiologic evidence of flood-related consequences and noted that there was a lack of evidence on the health effects of floods, as well as evidence on public health interventions in the

aftermath of floods on a worldwide scale. Likely, in Bangladesh, a link between natural disasters and communicable diseases is noted (Ahmed et al., 2020; BBS, 2016; Uddin, 2018).

Socio-economic inequity in disastrous situations is also drawn attention in disaster scholarship. Several authors (e.g., Ahmed et al., 2021; Nasreen et al., 2017; Zaman et al., 2023) looked at socio-economic equity in disaster-related health outcomes (such as injury, disability, and mortality) in Bangladesh, and found that floods were the leading cause of injury, impairment, and death. Multiple interacting factors such as socio-economic settings, water, sanitation condition, state of public health infrastructure, and others are contributing to the acceleration of flood-related health complications, according to an extensive literature review (Alderman et al., 2012; Ohl and Tapsell, 2000; McCluskey, 2001; Okaka and Odhiambo, 2019; Paul and Routray, 2010; Shimi et al., 2010). As this study aimed to explore the health complications due to flood from a gender perspective, literature regarding gender issues (Alam and Rahman, 2014; Ashraf and Azad, 2015; Azad et al., 2013; Nasreen, 2012; Fatema et al., 2019, 2021; Fatema, 2020; Zaman, 2021) shown that females are more vulnerable than males as they are economically and socially in disadvantaged position. A few studies (Hossain et al., 2019, 2020a, 2020b; Philip et al., 2019; Rahman et al., 2019; Ferdous et al., 2020) explored several aspects, such as flood susceptibility assessment, the relationship between flood protection measures and mortality, human displacement, impacts on livelihood, etc. of 2017 flood. From the extensive literature review, it is evident that flood-related health complications from a gender perspective are scant. To fill this gap, this study tried to investigate the overall health condition during the 2017 floods from a gender perspective along with exploring how interacting determinants – water, sanitation, health care facilities, and reproductive health services – had been deleteriously influencing the state of health of the flood-affected people. In connection with

the health impacts of floods, the study also examined constraints and the coping strategies of the affected communities.

3. Methods and materials

A mixed-method approach (both quantitative and qualitative) has been applied in this research. First, an exploratory visit was conducted before preparing a questionnaire. Then, for quantitative data, a field-level survey was done with local people. Accordingly, qualitative data were garnered through a number of tools, for example Focus Group Discussions (FGDs), In-Depth Interviews (IDIs), and Key Informant Interviews (KIIs). The underlying reason to apply both perspectives is to engage both researchers and informants in bringing critical sense of knowledge in the nature of health complications. Engaging both groups provides multifaced perspectives and guide researchers to explain results of the study from participants' experience (Gioia, 2021).

3.1. Study area

In the 2017 monsoon flood, almost 24 districts in the northern, north-eastern, and central parts of Bangladesh were affected (BDRCS, 2017). For our study, Jamalpur district was selected from the northern region of the country. Around 24% of people were affected by the 2017 flood (BDRCS, 2017). This study area is located between $24^0$34' and $25^0$26' north latitudes and between $89^0$40' and $90^0$12' east longitudes with an area of 2115.16 km^2 and 22,92,674 population (BBS, 2013) (Supplementary Table 1).

We selected two Upazilas, namely Sarishabari and Jamalpur Sadar Upazila from Jamalpur district. Four unions were chosen from these two Upazilas; of these, two unions namely Pogoldigha and Pingna from Sarishabari Upazila and Dewanpara union and Lakshmir Char from

Jamalpur Sadar Upazila were chosen. Then, after field observation and discussions with the local people, Nolsanda Char from Pingna, Boyra Bazar from Pogoldigha, Char Nauvanga from Dewanpara, and Baruamari from Lakshmir Char were selected as the study area (Fig. 2). The following multistage sampling procedure was applied to select specific study locations from district to char areas.

[Fig. 2 is here]

3.2. Sample size and data collection

A total of 280 households (confidence level= 5%, percentage of the flood-affected population in Jamalpur= 24% (BDRCS 2017), z score value= 1.96) were selected using the following equation (1), where the participation of both male and female was balanced. The respondents were interviewed face to face using a semi-structured interview questionnaire at the household level (Supplementary Part A). The study participants were the adult residents of the villages who had experienced the 2017 flood.

$$n=\frac{z^2 pq}{d^2} \quad \text{..... Equation (1)}$$

Here, z= z score value= 95%= 1.96, p= percentage of the population affected by flood in Jamalpur= 24%= 0.24, q= 1-p= 1-0.24= 0.76, and d= 0.05 (degree of accuracy).

Furthermore, for the qualitative data, 4 Focus Group Discussions (FGDs) (two male and two female groups for each sub-districts) were conducted where 8-10 people participated in each FGD. Besides, four In-Depth Interviews (IDIs) were conducted with the local affected people, and 6 Key Informant Interviews (KIIs) were conducted with different stakeholders from government and non-government sectors, including the local representatives and school

318 headmasters from the study areas. We followed an open-ended structure of questions for
319 conducting the KIIs and FGDs. The data was collected in February and March of 2018.

320 During data collection, ethical issues were appropriately maintained, where verbal and
321 written consent letters were taken. It was also confirmed that all of the data would be presented
322 in summation form; no data would be presented as individual findings. All of the personal
323 information would be maintained with confidentiality. Besides, this study was conducted as a
324 post-graduation dissertation, while exam committee approved the methodology and findings. All
325 of the ethical issues were maintained properly with acknowledgement of the "IDMVS (Institute
326 of Disaster Management and Vulnerability Studies) Ethical Committee".

327 **3.3. Data analysis**

328 For quantitative analysis, primary data were analyzed in descriptive statistics using Statistical
329 Product and Service Solutions (SPSS) software (IBM SPSS 25). Besides, the qualitative data
330 were summarized. In order to analyze qualitative data, we applied a first-order informant-
331 centered approach. This approach serves as a main foundation to explore the critical nature of
332 data, features of data, and guide to understand thematic issues in qualitative data (Gioia, 2021).
333 Qualitative data were analyzed based emerging themes evolved from the data. Then the findings
334 were compared with the results of the questionnaires following the objectives of the research.
335 Here, the significance of the differences for categorical variables was assessed using Chi-squared
336 tests of association. Continuous variables were assessed using analysis of variance, representing
337 the difference between genders.

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339

4. Results and analysis

4.1. Demographic description of the sample

Among 280 respondents, the respondents were between the ages of 18 to 58 and more. The majority of the respondents were in the 28-37 age group (51.8%), followed by the 38-47 age group (27.9%) (Supplementary Table 2). Most of the respondents (95.7%) were married. In terms of education level, 56.1% were able to sign only, whereas only 12.1% had primary education, with very few having higher than primary level of education. From a gender perspective, only 40% of the respondents could sign their name, 13.6% with primary education and 32.9% were illiterate.

Occupational status was considered as a major socio-economic factor. Our data showed that 36.4% were housewives followed by 14.3% farmers and 12.1% shopkeepers, 6.8% agricultural labor, and 7.1% non-farming worker, and above 23% engaged in other occupations. Most of the respondents (72.1%) had 3-5 household members, and 26.4% had more than 5 household members. The respondents were mostly from nuclear families (50.4%), and joint families (45.4%). Significantly, 91.4% of the respondents mentioned that there was only 1 earning member in the family. This indicates that the families are completely dependent on the earning member and have less financial adaptive capacity in the event of illness or death of the earning member. Above 62% of the respondents mentioned their monthly household expenditure is between BDT 5000-14999 (USD 60.39 – 181.15), while 58.6% reported their monthly income is between the same ranges (5000-14999) (USD 60.39 – 181.15). Over 21% reported their monthly expenditure to be between BDT 15000-24999 (USD 181.16 – 301.92); more than 24% reported their monthly income as between BDT 15000-24999 BDT (USD 181.16 – 301.92); nearly 9% had monthly income of BDT 25000-34999 (USD 301.93 – 422.69), and 3.2% had

BDT 35000 (USD 422.70) and more as income. This situation can be interpreted as most of the households having to use up their monthly income in their monthly expenditure, which leaves little money to save up for future emergencies and increases the vulnerability of the whole family.

Furthermore, people drank water from their tube well after boiling, and also, they used water purification tablets to have pure drinking water while they bathed in the flood water as there was no other choice. Accordingly, some people mentioned that they lack pure drinking water (Source: FGDs). Focusing on this, one of the female respondents from noted:

> "During the flood, we had to suffer mainly for drinking water. As we had to collect water for the family members, we tried to store water in clean bottles and drums to manage the situation. As there was water everywhere and we could not move, we sometimes used the surface water for washing our clothes, utensils, and also for bathing."

From the qualitative findings, it was found that very few people who have financial stability could install sanitary latrines. However, most people have an open-pit latrine in their house, and some still use open space for defecation. Based on the status of sanitation, one of the female respondents from Boyra Bazar expressed:

> “Sanitation facility is quite poor in our village as most of the villagers are poor; they normally use open-pit latrines and the sewage system is not so proper. During floods, these latrines and sewage systems get damaged and unable to use it.”

4.2. Water situation and vulnerability

Table 1 describes the overall water collection scenario including water sources, challenges and steps taken to overcome the constraints in the study area. Most of the people

(99.6%) have access to their own tube wells during normal times. Only 0.7% had to use others' tube well for drinking purposes. However, this situation worsens during flood times. Only 55.7% people can use their own tube wells for drinking water during such times, and 39.6% have to rely on others' tube wells. The rest (4.6%) have to resort to surface water sources. When this data was broken down by gender, it reveals that 9.3% of the females have to rely on surface water for drinking purposes while males appear to have access to own tube wells or others' tube wells.

A similar situation is revealed when considering the water source for cooking and other uses. Most of the respondents (98.6%) use their own tube well for these purposes during normal time. The access to their own tube well gets constrained during flood times, and many people have to rely on others' tube well (47.9%), surface water (9.6%) or rainwater (3.2%). 19.3% of the females responded that they use surface water for cooking and other uses during floods. This is a cause of concern as it can facilitate the outbreaks of water-borne diseases, if polluted surface water is used for domestic purposes.

[Table 1 is here]

Moreover, everyone has a tube well in their house, but the number of sanitary latrines is low. During non-flooded conditions, the people do not suffer, but if their houses go underwater, they have to suffer a lot. During floods, many people of this Char area take shelter on the embankment beside the road as there is no shelter center in the village, and they have to live there for at least twenty days without any water and sanitation facility. People who have houses on the high land do not have to suffer (Source: FGDs). Considering flood impacts on water sources, one of the female respondents from Char Nauvanga described:

"During flood time, water gets into our house. That is why we have to leave our house and stay on the road. At that time, we do not have any water sources from which we can collect pure drinking water. So, we have to ask the people who live beside the road to use their tube wells to get water. However, most of the time, they do not let us use their tube wells. We cannot afford to buy water every time. The local government or any organization does not take any steps to establish a temporary tube well or any makeshift water sources for us, although they know that we are suffering and have to go a long distance to collect water. This is the big challenge during floods."

People who have their houses on lowlands have to suffer more as the water enters their houses, submerging their tube wells and latrines. During these times, they collect water from the neighbors whose houses are safe from the floodwater. At present, social bonding appears to be diminishing, and people seem to lack a helpful mentality. Some flood-affected people report that they do not have to suffer for drinking water, but they have to bathe in floodwater during floods, causing water-borne diseases and skin diseases. Often, they applied kerosene to the body to mitigate itchiness caused by the polluted floodwater. In some cases, the Upazila Parishad has provided tube wells and sanitary latrines to the villagers, which has lessened their suffering in recent times (Source: KIIs and IDIs).

Most villagers use tube well water for drinking, and the village people are not equally vulnerable to flood. The people who live on the west side are more vulnerable than those on the east because of low-lying lands. During floods, people who live on the embankment and road pollute the environment as they do not get water, sanitation, and cooking facilities. They have to live through hardships during those days. No one seems to take any steps for them, even though they take shelter for at least two months almost every year (Source: KIIs and IDIs).

4.3. Sanitation condition and vulnerability

In the case of status of sanitation, the majority of the respondents (51.1%) used pit latrines or open pits (31.8%) during normal times which indicates the access to basic sanitation facilities for most of the people (Table 2). Nearly 10% of people still resort to river/pond/open spaces, while only 7.5% of the respondents had access to the improved water sealed facilities. During flood times the pit latrines appear to remain safe and accessible, as a similar percentage of respondents mentioned they can use it (48.2%). However, the access to open pits falls down to only 13.9% while the use of river/pond/open spaces increases to 30.4%. This affects women disproportionately as the percentage of female open pit users during normal times (50%) falls drastically to 22.1% during flood times. On the other hand, 9.3% of females report using river/pond/open spaces in the normal times, but it increases to 42.9% during flood times. The fact that male responses remain at similar levels in both normal and flood times indicates that the sanitation situation is very sensitive to floods for women in the study area.

The major impact of flood on sanitation is reported to be improper sewage system according to 72.9% of the respondents followed by polluted water (60%). These appear to be linked, as an inadequate and often non-existent sewage system is repeatedly damaged by floodwater – resulting in polluting the water during flood times. Damage to latrines (56.8%), disturbing personal hygiene (48.6%) and lack of water (45%) are other major impacts on sanitation as reported by the respondents. Lack of water appear to be particularly challenging for women as 76.4% of the female respondents report it.

As for steps taken to overcome the challenges, 51.1% of the respondents (25.7% of the males and 76.4% of the females) mention they try to manage the situation with polluted water. This is alarming as using polluted water can cause serious skin diseases and also harm

452 reproductive health. On the other hand, 78.6% of the males report that they use neighbor's
453 latrines during flood times while only 16.4% of the females can take this step. The responses also
454 show that 36.1% of the respondents have to resort to using open places for sanitation. These
455 reveal the increased vulnerability for women in flood situations.

456 **[Table 2 is here]**

457 The status of the sanitary latrine is quite dire in this area. During floods, many females
458 have to go to open places for defecation, and they take less food so that they do not have to go to
459 the latrines more often. Besides, they reported that they try to go for defecation at night so that
460 no one can see them. Also, they have to go to an open place at night by boat. In this way, the
461 environment and the water are getting more polluted (Source: FGDs). One of the female
462 respondents from Baruamari said:

463 "We do not have sanitary latrines in our house as it is costly to build. We have an open-
464 pit latrine, and we use a polythene sheet to cover it. During floods, the latrine also gets
465 flooded, making it quite impossible to use. We have to go to open space and thus we
466 cannot have sanitation facilities during daytime. Therefore, the open pits are very much
467 challenging for use, especially for females."

468 In addition, one of the male respondents from Char Nauvanga described:

469 "We do not have that much capacity to take steps, but we try to cope with the situation as
470 we have to survive. The condition of sanitation facilities is deplorable in our village. As
471 we have to live on the road and there is no sanitation facility, we often go to open places
472 at night. We consume less food so that we do not have to go to the latrine."

On the other hand, local representatives and NGOs share that people had activities related to WASH two years ago. However, now the villagers are aware, and the government has provided tube wells to the villagers and those who can build tube wells for themselves. Many villagers have sanitary latrines in their houses, and they are now aware of hygienic practices. For this reason, they have closed their projects related to WASH, but they provide loans to those poor people who want to build a sanitary latrine, but for this, they have to be members of the Grameen Bank. Also, 40% of the people have sanitary latrines, and the union Parishad is trying to provide more support to build sanitary latrines (Source: KIIs).

4.4. Reproductive health and vulnerability

The reproductive health scenario at the study area is expressed in Table 3, among the female respondents, 67.9% mentioned that there are accessible facilities regarding reproductive health, and 47.14% mentioned they take the services. The reproductive health services provided in the villages were mostly limited to the supply of contraceptives (63.6%), and maternal and neo natal care (57.9%). Along with abortion (1.4%), HIV counselling appears to be minimal (2.1%). Menstrual counselling (15.7%), nutritional services (17.1%) and primary health care services (25%) are also not very widespread.

The women menstruating during flood times reported a wide range of problems. The major problems reported were itchy feeling (84.3%), improper menstrual management (75%) and wet weather (72.9%). Availability of dry clothes (65%) and disposal of used napkins (50.7%) were also the prominent problems they faced. Most of the affected women could not take any action to overcome their problems during such discomfort as 66.4% of the respondents mentioned they bear the problems staying as usual. Only 35% of the respondents mentioned they could use dry and clean clothes, while the rest (24.3%) mentioned they had to use the polluted

water. This also poses serious health risk to the women in the study area. Accessible and widespread healthcare facilities are necessary to help the affected women.

[Table 3 is here]

On the other hand, qualitative observation derived that the scenario of reproductive health situation is quite similar in different areas of the study area. There is one female health service provider in each village. They only provide service to the pregnant mother and advise them about neo-natal care. If someone specifically asks them about the management of menstruation or hygiene or nutrition, they give answers. Otherwise, they do not. They visit only once a month at regular times. Moreover, during floods, they usually cannot visit as the roads get flooded. Therefore, they are not well equipped to check pregnant mothers' overall health, like, checking weights, blood pressure, etc. Though the health staffs lack many facilities, females are satisfied with their services (Source: FGDs). One of the female respondents said:

"The health staff took regular updates of me during my pregnancy. I found that following the health staff's advice was good for my baby and me."

Most of the villagers are not aware of maintaining their hygiene. Most females use pieces of clothes during menstruation and use the same cloth repeatedly without drying correctly. This situation is prevalent not only during flood time but also at regular times. The perception is that these should be hidden so that no one - especially male members - can see the clothes (Source: FGDs and KIIs). Focusing this issue related to menstruation, one of the respondents from Dewanpara expressed:

"I have started using sanitary napkins, not just for a long time, maybe two years ago. Most of my friends use clothes instead, and they wear those clothes over and over. They

cannot dry those properly and cannot maintain their menstrual hygiene. If they feel sick or experience irregular periods, they never discuss as they feel shy and think this topic as a taboo."

Furthermore, if anyone wants to have family planning issues, the health staff provide the necessary information. It is seen that health staffs are more active in rural villages (Sarishabari Upazila and Baruamari village) than the area which is near the main town (Jamalpur Sadar) in providing their services. The probable reason for this is that Jamalpur Sadar has more medical facilities than the rural places (Source: KIIs).

4.5. Overall Health Situation and Complexities

Table 4 presents the overall health situation of Jamalpur District. 68.9% of the respondents reported that they suffered from illness. This was higher among the women as 81.4% of the female respondents mentioned about suffering from illness. The common diseases suffered by the respondents were fever (66.4%), diarrheal disease (55.4%) and skin disease (52.9%). This is largely in line with the expectation as the water supply and sanitation scenario – particularly during floods – makes the population in the study area vulnerable to water borne and skin diseases. 31.1% of the respondents mentioned they suffered for more than a week with their ailments. This also indicates that the health situation of the people in the study area is deteriorated – probably due to the combined effects of floods, inadequate water supply and sanitation infrastructure, and lack of easy access to healthcare.

Pharmacies (55.4%) and community clinics (50%) were the major medical facilities at the villages. Only 26.1% of the respondents mentioned government hospitals, and 25% mentioned about family planning hospitals. 84.6% of the respondents mentioned they take services from

pharmacies, while 67.9% mentioned about going to the government hospital and 38.6% mentioned about upazilla health complex. The reliance on the local pharmacies means they may not always get the required health services from qualified doctors.

[Table 4 is here]

From FGDs, people mention that there is adequate health facility in their village because a community clinic, family planning hospital, pharmacy, and homeopathy chambers are situated in their village market. Also, the government hospital is situated nearby, and schools are also not very far. This scenario is different in some of the areas like the Char area. As Nolsonda is a Char area, last year flood inundated almost half of the village. People moved to the embankment as they could not stay in their houses. There is no health facility in the Char area. They have to go to Pingna and Boyra Bazar, and for the emergency cases, they go to Sarishabari or Tangail (Source: FGDs).

The IDIs and KIIs reveal that the health facility is poor in the village. For any kind of emergency, they have to go to Sarishabari, Jamalpur, Tanagil. In this case, sometimes, patients die on the road before reaching the hospital. Moreover, there is no ambulance facility in their union. They have a Surjer Hashi Clinic in their village, remaining only by name. However, they do not have any activities there (Source: IDIs and KIIs).

During floods, people have to bathe in floodwater, and it causes water-borne diseases. However, considering previous flood situations, though the 2017 flood was intense, people have become more aware and do not suffer as they did in the past. In addition, the relevant organizations are extending their assistance and making preparations so that the situation can be managed better (Source: IDIs and KIIs).

562 The 2017 flood swept away all the crops, damaged properties, roads, caused poverty and
563 unemployment, hindered education, people–- especially children–- suffered from water-borne
564 diseases like diarrhea, dysentery, and skin diseases. There are 63 community clinics in Jamalpur
565 district, which provide treatment for primary diseases. In addition, there are sub-health centers in
566 unions, and in each ward, there is a health staff from family planning to serve the medical
567 facilities (Source: IDIs and KIIs).

568 **4.6. Impacts of the flood on health facilities**

569 Transportation problems were reported to be the main problem by 84.3% of the
570 respondents. 68.6% identified disruption in communication which is linked with transportation
571 problem (Supplementary Table 3). Unavailable services were reported by 55% of the
572 respondents, and 48.2% reported that doctors cannot come due to flood. Both these points along
573 with long distance (reported by 32.1% of the respondents) can also be associated with the
574 transportation issue. The other major issue was the lack of sufficient healthcare providers
575 reported by 38.9% of the respondents. This indicates a need to develop and enhance the
576 healthcare infrastructure along with the transportation infrastructure in the study area.

577 Furthermore, qualitative observation depicts that during floods, many wastes come with
578 the water flow. It creates nuisance and bad smell everywhere, causing breathing problems.
579 Sometimes they suffer from headaches and disorientation from the bad smell. Also, when the
580 water goes down, the smell stays, and they spray kerosene around the house so that the smell
581 goes away. In flood times, water enters most of the houses and the fear of snakes increases. As
582 the transportation system is poor, they have to suffer a lot. They cannot go to community clinics,
583 send their children to schools, and go to the market and nearby urban centers. Though men can

584 manage to go outside, females have to remain in the house as they have to look after the other
585 family members (Source: FGDs).

586 Besides, even when the village has good health facilities, they cannot access them due to
587 the damaged transportation systems. According to them, the major problem is the flawed
588 transportation system of the village, and everything else can be managed by themselves as they
589 have been experiencing floods since birth (Source: IDIs). Focusing the transportation status, one
590 of the female respondents from Nauvanga stated:

591 "Transportation problem is the major impact of the flood against getting health facility.
592 The road is damaged, and water stays in the road. Thus, we cannot use any transportation
593 to go to the hospital at that time."

594 **4.7. Challenges and ways to overcome the obstacle to ensure health facilities**

595 In the case of challenges to ensuring health facilities and steps to take to overcome the
596 challenges. The majority of the respondents (78.6%) identified the lack of medicine as the
597 foremost challenge to health facilities, followed by poor transportation and communication
598 (58.4%) (Table 5). 52.1% of the respondents mentioned long distance – which is linked with the
599 poor transportation infrastructure in the study area. 56.4% of the respondents complained about
600 the poor-quality services at the healthcare facilities. These indicate that there is a large margin
601 for improvement in terms of infrastructure and service. 25.7% of the respondents also mentioned
602 the costly medicines and service, and 25% raised the issue of long waiting hours.

603 As for steps to take, an overwhelming majority (99.3%) suggested lowering the price of
604 medicine and making the medicines available free of cost if possible. This reflects on the socio-
605 economic situation in the study area as the people often suffer from long-term diseases. 93.2% of

606 the respondents also mentioned adequate supply of medicines should be ensured. The medicine
607 distribution and availability should be made equitable to improve the present situation. Other
608 major steps to take according to the respondents were to ensure sufficient staff (61.1%) at the
609 healthcare facilities, and to provide access to specialized doctors (49.3%) as well as 24/7 service
610 (35%).

611 **[Table 5 here]**

612 Furthermore, the qualitative perception of the respondents described that the main
613 challenge for the villagers is communication and transportation. For people living in the
614 Nolsonda area of Sarishabari, transportation and communication are quite impossible during
615 floods. Commuting to Pingna, they have to cross the river by boat, which is dangerous during
616 floods. They report getting used to all the sufferings because they have to experience all every
617 year. Also, during floods, many males stay unemployed, which exacerbates their vulnerabilities.
618 Though those villages are at the center point of Jamalpur, the villagers do not get many facilities
619 (Source: FGDs).

620 When communication is hampered during floods, people make floating vehicles with
621 banana trees called "*Bhela*." People with boats or Bhela give free rides to the villagers who
622 cannot pay during floods. During floods, people of the village help each other with whatever
623 they realistically can. The communal bond among the villagers remains strong, and there is unity
624 among them. For any challenge, they come together (Source: IDIs).

625 Public support from outsides and the help of the NGOs reduce the burdens of life. For
626 example, "Grameen Bank" provides small-scale loans to the villagers. This NGO has no official
627 activities directly regarding flood, but they take some special steps voluntarily to support the

flood-affected people. For example, in the previous flood, they provided relief items such as dry foods, water purifiers (locally called "*fitkiri*"), water purification tablets, and saline voluntarily (Source: KIIs). Based on this issue, one of the male respondents said:

> "During floods, we have to face many challenges while getting health facility. The only health complex near our village is 2 km away, and it takes 1:30 hours to get there. As water remains stagnant and damages the road, it becomes quite hard to get there for any medical facility. Also, the service quality is very poor, and most of the time, they do not have adequate medicine."

5. Discussion

Bangladesh is at risk of facing the impacts of climate change. In the global climate risk index 2020 report, Bangladesh is ranked 7th of the most affected countries, with 191 EWEs during the 1999-2018 period in fatalities and economic losses (Eckstein et al., 2019). With the increased intensity, frequency, and changing patterns observed in the last few years, the flood is considered one of Bangladesh's extreme weather events (MoEF, 2009; Eckstein et al., 2019). Here, geographical location and other socio-economic characteristics accelerate the susceptibility to natural disasters (Rahman and Salehin, 2013). Flood hits almost every year and damages property and takes lives. Also, an increasing number of people reside in flood-prone areas, making themselves vulnerable (Azad et al., 2013; Rahman and Salehin, 2013). The 2017 flood was identified as one of the most devastating and long-lasting floods in recent times that had significant damage to livelihood and property (Hossain et al., 2020b). This study revealed that the 2017 flood exacerbated the health vulnerability of both males and females by interacting with socio-economic factors. The study findings provide a whole scenario of the socio-demographic

profile of the study area, gender-based nature of climate change-induced vulnerabilities on health, constraints, and coping strategies of the affected communities.

Flood hampers the normal daily life activities while most of the impacts appear in the affected area's water supply and sanitation facilities (Gaillard et al., 2008). Field level observation depicts that most villagers do not have their tube wells, and they have to suffer from a lack of pure drinking water and other uses only during flood events. Here, Nolsonda Char in Sarishabari and Char Nauvanga in Jamalpur Sadar are the most vulnerable areas. They are low-lying areas surrounded by rivers, and most of the land goes underwater during floods. As a result, water gets contaminated and smells. When scarcity of resources increases and shortage of daily necessity happens, social bonding diminishes, and people are less willing to help and support others. Besides, though most of the people of these two areas have to take shelter on the embankment and road every year, the government has not taken many steps to ensure pure water or sanitation facilities. Here, flood damage and socio-economic aspects are highly related, which coincides with the previous observations (Ohl and Tapsell, 2000; Zaman et al., 2023).

The health effects of floods are complex and have both direct and indirect impacts on the community (Okaka and Odhiambo, 2019). The number of people themselves or their families had suffered from illnesses proves that people are still very much at health risks due to floods despite taking many flood response measures. Though the mortality rate has been significantly reduced compared to the past, the morbidity rate still needs attention (Milojevic et al., 2012). As floods increase in frequency and intensity, they pose a more significant threat to human health. People suffering from fever, diarrhea, eye diseases, and skin diseases mainly indicate the dearth of pure and fresh drinking water and sanitation facilities due to floods. With the increasing impacts of climate change, there is a strong possibility of vector-borne diseases emerging in

673 flood-prone areas along with water-borne diseases. Generally, people suffered for about a week,
674 but with the increasing intensity and magnitude, sufferings may be prolonged, which could
675 exacerbate the overall health situation of the flood-affected people. Similarly, a study also
676 described that drowning and snake bites are the most common apart from the water-borne
677 diseases (Uddin, 2018).

678 Moreover, if we compare the casualties of previous major floods in Bangladesh, the
679 1988 flood caused between 200-6500 deaths, the 1998 flood caused 1100 deaths, the 2004 flood
680 caused 700 deaths, the 2007 flood took 649 lives (MoEF, 2009), and the 2017 flood cost 145
681 people's lives (Hossain et al., 2020b). By taking preparedness and relief measures, the direct
682 health impacts of the disasters, like the number of deaths, have been reduced (Hasan et al.,
683 2019). However, the related health effects of flooding: drowning, injury, skin disease, infectious
684 diseases, diarrhea, respiratory infections have not been considered and given the same
685 importance (Bich et al., 2011; Okaka and Odhiambo, 2019), which is reflected in the responses
686 from local people in this study. Additionally, floods causing limited access to health care,
687 impaired health infrastructure, lack of safe drinking water and sanitation facilities, etc.,
688 exacerbates the health complications of the flood-affected people (Davis et al., 2010). Therefore,
689 the scarcity of facilities and physical health issues usually get the priority. At the same time,
690 studies have also highlighted the mental health aspect due to disaster-related trauma and
691 psychological disorders (Islam et al., 2017; Zaman, 2021).

692 Furthermore, female reproductive health issues are still considered taboos (Placek et
693 al. 2017), and during floods, no one considers this an important issue. Females have to suffer a
694 lot due to this attitude, especially adolescent girls and pregnant women. They do not take any
695 measures and usually tend to stay as they are. This situation is making females more vulnerable

696 than males. Generally, most females, including adolescent girls, use clothes instead of sanitary
697 napkins or pads during their menstrual period. In some cases, women cannot take any measure,
698 as there is no facility for cleaning clothes during floods. Lack of space, absence of privacy,
699 unsafe transportation, unavailable service, and absence of doctors hinder proper hygiene
700 management during menstrual times. Many interacting varieties of determinants, e.g., social,
701 biological, genetic, environmental, nutritional, economic pressures, cultural and behavioral
702 patterns, are linked with the health of individuals and communities, and these are regarded as
703 critical influencing factors (Sayers, 2009; Jerin et al., 2023). The study has considered socio-
704 demographic profile, water, sanitation, food insecurity as some important interacting
705 determinants that influence the overall health complications of the flood-affected people, and
706 these are increasing the health vulnerability of the affected males and females at different levels
707 (Okaka and Odhiambo, 2019).

708 On the other hand, the majority of the people not going to the government hospital or
709 government-designated family planning hospital is a clear sign of impaired health care facilities.
710 Study results show that rural people do not have spontaneous access to health care facilities
711 (Davis et al., 2010), which is also observed in this study. This study's field experiences - not
712 having the infrastructure in their villages, unsatisfactory service, not getting proper treatment and
713 medicines, absence of a doctor at the hospital during floods, and other findings regarding the
714 healthcare status coincide with other study observations (Milojevic et al., 2012). The dependency
715 of local people on pharmacy for medical service during floods indicates an alarming situation on
716 their health status and proves the lack of awareness and unwillingness to get diagnosed
717 accurately. This can be considered as a substantial hindrance towards individual level
718 preparedness for floods. For mitigating health vulnerability, it is necessary to establish a robust

719 public health infrastructure and educate the people to take proper steps. The percentage of males
720 and females stating about the availability of medical facilities reveals that females lag on access
721 to accurate information and communication, making them more vulnerable to health. This result
722 is congruent with Echendu's research in Nigeria. Echendu's study (2023) showed that flood
723 events were more intense due to the dearth of appropriate infrastructure, poor planning and
724 governance system, and poor enforcement of disaster risk reduction policies.

725 The gender focal point makes this study exclusively important. It is evident from this
726 study how sophisticated roles water, sanitation, and healthcare facilities play for the overall
727 health and wellbeing of the community during floods. The immediate health effects of floods
728 reported in this study could lead to long-term effects if not addressed appropriately (Okaka and
729 Odhiambo, 2019). Hence, the health-based need assessment for the whole community should be
730 prioritized as a disaster-risk mitigation measure against prolonged health impacts such as
731 morbidity, malnutrition, and mother and child mortality in the long run (Ahmed et al., 2020). As
732 floods and other EWEs generate internally displaced populations (Chowdhury et al., 2020), it is
733 also essential to mobilize these people to shelters and rehabilitation facilities with adequate
734 resources to meet health-based needs. For this purpose, developing an advanced mobility map
735 could be helpful to organize people in flood shelters and rehabilitation centers, ensuring adequate
736 facilities for them. In this case, the development of the communication infrastructure, which is
737 functional during floods, should be given utmost priority. The outcome of this research suggests
738 that further research is needed for better health measures and stronger epidemiological designs to
739 improve understanding of the risks of floods and the long-term health consequences on both
740 males and females. Future studies are also required to address the mechanisms by which such
741 consequences can best be prevented or alleviated.

742 The application of the study results is manifold. As reported in this case study of
743 Bangladesh, flooding has compromised access to crucial health services in many neighboring
744 countries of Bangladesh and countries where infrastructure is poor, and the population is at risk
745 due to poor infrastructure and limited economic resources (Bich et al., 2011; Milojevic et al.,
746 2012; Asumadu-Sarkodie et al., 2015; Ahiablame and Shakya, 2016; Okaka and Odhiambo,
747 2019; Ahmad et al., 2021). Thus, similar conditions may prevail in all those areas, which would
748 need the attention of the policymakers. The findings also reveal that particular focus should be
749 given on healthcare facilities in the rural communities during EWEs, which is also evident in
750 some other studies (Davis et al., 2010; Milojevic et al., 2012; Jagnoor et al., 2019). The
751 challenges faced by the respondents described in this study represent the flood impacts vividly.
752 While listing out the steps they take to overcome the situation, it is seen that people are reluctant
753 to take any resilient steps on their own. They reflect on some people's lack of scope and
754 knowledge for taking long-term steps, which leads them to depend on the authority to look after
755 them. The steps they are taking at present are short-term, to face the situation at that particular
756 instance. Besides, the 'challenges' and 'steps taken to overcome the challenges' differ from a
757 gender perspective. For overcoming the obstacles, emphasis should be given to resilience issues,
758 including establishing financial security, sustainable livelihood, and infrastructure development
759 (Jagnoor et al., 2019).

760 **6. Conceptual Framework: Approach to Prevention, Mitigation, and Management (P2M)**
761 **of the health impacts of EWEs**

762 Based on the findings and discussion, we argue that the 2017 floods brought deleterious
763 impacts on the health situation of the affected people. Additionally, the findings showed us that
764 the affected people were taking short-term measures to cope with the situation. But these

765 strategies are at a very limited scale and are not improving resilient mechanism. Based on the
766 findings, we develop a conceptual framework that offers a pathway for comprehensive strategy,
767 especially for prevention, mitigation, and preparedness and management (P2M) for the health
768 effects of extreme weather events (EWEs), with a focus on flooding (Figure 3). Our framework
769 suggests that locally led and nationally led institutions first need to explore health risks resulted
770 by EWEs. By anticipating and assessing health risks, institutions need to undertake preventive
771 measures, for example, providing early warning system, proper floodplain management, dam
772 construction, health impact assessment, and specific health care provision guidelines for
773 effective flood related health risk management. In the mitigation stage, efforts should aim at
774 reducing the severity of health impacts, which includes strong health care infrastructure, vector
775 control initiatives, education and awareness, provision of safe drinking water and sanitation,
776 available medical services, trained doctors, nurses and hospital nurses, and deploying emergency
777 medical team. Finally, preparedness and management measures need to be undertaken to ensure
778 that healthcare facilities are ready to respond to the health impacts of floods, including readiness,
779 supplies, and medical response teams. Gender sensitive issues also need to be addressed while
780 executing this framework as EWs, like floods cause differential health vulnerability in terms of
781 biological identity and economic situation.

782 **[Fig. 3 is here]**

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6. Conclusions

Bangladesh faces natural and manmade disasters almost every year, such as floods, cyclones, earthquakes, thunderstorms, riverbank erosion, landslides, drought, fire, road accidents, building collapse, etc. In addition, the increasing impacts of climate change such as excessive rainfall, irregular weather pattern, seasonal changes, etc. are also being observed. The climatic variables are contributing to the increase of extreme weather events - especially the flood. The frequent intense flooding is causing trouble and suffering to the people of the floodplain area and impacting every sector and aspect of human lives. Results of this study asserted that the flood had a pressing effect on health as the flood events and interacting factors of health issues crafted a flood-prone community more susceptible to the deleterious impacts. With the increasingly extreme weather events, it is high time to reconsider our preparedness and response mechanisms to address the health complications - keeping the interacting factors in mind.

As impacts vary by location and context, region-specific and contextual interventions should be considered systematically and coordinated with a particular focus on gender-based needs. The primary purpose was to explore the extreme weather events related to health complications of flood-affected people to assess how people are experiencing and coping with the situation and what things should be rethought and reconsidered. The study findings have triggered the fact that we must think from the individual level while taking any measures, as local level preparedness can play an active role in combating health complications related to extreme weather events. Future research on the health impacts of extreme weather events should focus on the interacting factors that profoundly aggravate health complications. Local needs and awareness must be given the utmost importance, without which any kind of mechanism cannot

be appropriately implemented. Reducing vulnerabilities and building up resilient coping capacities in the local population can minimize the health impacts of extreme weather events. Overall, the study findings thus suggest taking context-specific interventions, need-based health education, and providing available reproductive materials to mitigate health-related threats, especially among marginal groups (e.g., women and children). Future research can explore how the intersection of economic insecurity and flood whet differential health complications among poor and non-poor.

Declaration of competing interest

The authors declare that there is no conflict of interest or financial interest.

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Table 1: Types of water sources, impacts of flood on water sources, challenges and steps taken to overcome the constraints regarding water collection during flood.

Aspects		Total (%)	Gender identity (%)		Sig.
			Male	Female	
		(n=280)	(n=140)	(n=140)	
Water sources					
Normal period	Own tube well	99.6	100.0	99.3	***
	Others tube well	0.7	-	1.4	
During Flood	Own tube well	55.7	45.0	66.4	***
	Others tube well	39.6	55.0	24.3	
	Surface water	4.6	-	9.3	
Water sources for cooking and other use					
Normal period	Own tube well	98.6	100.0	97.1	***
	Others tube well	1.1	-	2.1	
	Rain water	0.4	-	0.7	
During Flood	Own tube well	59.3	39.3	79.3	***
	Others tube well	47.9	85.0	10.7	
	Surface water	9.6	-	19.3	
	Rain water	3.2	-	6.4	
Impacts of floods on water					
Water gets polluted		84.6	100.0	69.3	***
Flood water rises and water source gets under water		61.4	35.0	87.9	***
Water gets contaminated and unusable		23.2	25.7	20.7	***
Road damage		12.5	23.6	1.4	***
Water source damage		24.3	6.4	42.1	***
Long distance		14.3	8.6	20.0	***
Challenges encountered by gender during flood					
Long distance		4.6		9.3	***
Polluted water		69.6	84.3	55.0	***
Water source get damaged		41.8	20.7	62.9	***
People don't let to use their water sources		21.8	4.3	39.3	***
Transportation problem		11.8		23.6	***
Fear of snake		18.9	12.9	25.0	***
Steps adopted to overcome water crisis					
Store water		40.0	18.6	61.4	***
Use water purification tablets		24.6	16.4	32.9	***
Use transport to collect water		20.0	13.6	26.4	***
Take assistance from family members		40.0	20.7	59.3	***
Use surface water instead of going long way		12.5	-	25.0	***
Use others tube well		62.9	83.6	42.1	***

*P<0.05, **P<0.01, ***P<0.001

Table 2: Sanitation status, impacts of flood on sanitation, challenges and steps taken by both males and females

Key aspects		**Total (%)**	**Gender identity (%)**		**Sig.**
			Male	Female	
		(n=280)	(n=140)	(n=140)	
Sanitation facilities by gender					
Normal time	Water sealed	7.5	3.6	11.4	***
	Pit latrine	51.1	72.9	29.3	
	Open pit	31.8	13.6	50.0	
	River/pond/open space	9.6	10.0	9.3	
Flood time	Water sealed	7.5	3.6	11.4	***
	Pit latrine	48.2	72.9	23.6	
	Open pit	13.9	5.7	22.1	
	River/pond/open space	30.4	17.9	42.9	
Impacts of flood on sanitation					
Latrine goes under water as flood water rises high		43.9	39.3	48.6	***
Latrine gets damaged		56.8	57.1	56.4	***
Improper sewage system		72.9	80.0	65.7	***
Sewage system gets damaged		26.4	13.6	39.3	***
Polluted water		60.0	45.7	74.3	***
Lack of water		45.0	27.1	62.9	***
Disturbs personal hygiene		48.6	27.9	69.3	***
Challenges encountered by gender					
Damage infrastructure		20.0	20.0	20.0	***
Poor sewage system		32.1	45.0	19.3	***
Lack of water		63.9	51.4	76.4	***
Unable to use		29.6	29.3	30.0	***
People don’t let to use their latrines		14.3	14.3	14.3	***
Can’t use at day time		46.8	46.4	47.1	***
Steps taken to overcome the challenges by gender					
Use at night		30.0	25.0	35.0	***
Use neighbors latrine		47.5	78.6	16.4	***
Manage the situation with polluted water		51.1	25.7	76.4	***
Go to open place		36.1	25.0	47.1	***
Store water		11.1	-	22.1	***
Take less food		32.9	19.3	46.4	***

*P<0.05, **P<0.01, ***P<0.001.

Table 3: Reproductive health scenario in northern Bangladesh

Aspects		**Based on all female respondents (%) (n=140)**
Facility regarding reproductive health		67.9
Services taken by female respondents		47.14
Service provider	Health Assistant	67.9
Reproductive health interventions in the villages	Supply of contraceptives	63.6
	Maternal and neo natal care	57.9
	Primary health care services	25.0
	HIV counselling	2.1
	Menstrual counselling	15.7
	Nutritional services	17.1
	Abortion	1.4
Problems encountered by females during menstruation in flood situation		
Improper menstrual management		75.0
Wet weather		72.9
Not having sanitary napkins		13.6
Feeling shy		17.9
Cant dry clothes		65.0
Cant dispose used napkins		50.7
Feel itchy		84.3
Measures adopted by women		
Use dry and clean clothes		35.0
Stay as usual		66.4
Use polluted water		24.3

Table 4: Overall health situation of Jamalpur district, Bangladesh

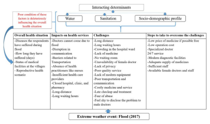
Variables		**Total (%)**	**Gender identity (%)**		**Sig.**
			Male	Female	
		(n=280)	(n=140)	(n=140)	
Health sufferings		68.9	56.4	81.4	***
Diseases	Fever	66.4	56.4	76.4	***
	High pressure	2.1	-	4.3	
	Diarrheal disease	55.4	56.4	54.3	
	Pregnancy related problems	2.5	-	5.0	
	eye disease	4.6	-	9.3	
	Gastric	10.7	-	21.4	
	Anemia	2.9	-	5.7	
	Malnutrition	1.1	-	2.1	
	Skin disease	52.9	56.4	49.3	
	Asthma	1.1	-	2.1	
	Cold	17.5	-	35.0	
Duration (Days)	1-2	.7	1.4	-	***
	3-4	19.6	14.3	25.0	
	5-6	13.2	14.3	12.1	
	More than a week	31.1	26.4	35.7	
Medical facilities in locality	Government hospital	26.1	27.1	25.0	***
	Community clinic	50.0	50.0	50.0	
	Doctors chamber	31.4	31.4	31.4	
	Village doctor	30.0	30.0	30.0	
	Homeopathy doctor	27.9	27.9	27.9	
	Pharmacy	55.4	55.0	55.7	
	Family planning hospital	25.0	25.0	25.0	
Services taken by gender	Government hospital	67.9	59.3	76.4	***
	Upazilla health complex	38.6	32.9	44.3	
	Community clinic	16.4	12.9	20.0	
	Doctors chamber	18.6	18.6	18.6	
	Village doctor	16.4	22.9	10.0	
	Homeopathy doctor	.4	-	.7	
	Pharmacy	84.6	85.7	83.6	
	Kobiraj	1.1	-	2.1	
	Family planning hospital	6.1	-	12.1	
Availability of medical facility		56.1	75.0	37.1	***
Average distance (Meter)		2374.6429	2688.5714	2060.7143	***
Average time (Minute)		75.0893	73.4286	76.7500	***

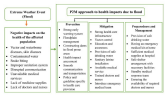
*P<0.05, **P<0.01, ***P<0.001.

Table 5: Challenges and ways to overcome the obstacle to ensure heath facilities during and aftermath of floods.

Aspects	Total (%)	Based on gender (%)		Sig.
		Male	Female	
	(n=280)	(n=140)	(n=140)	
Challenges				
long distance	52.1	50.0	54.3	***
Long waiting hours	25.0	20.0	30.0	***
Crowding in the ward	19.6	18.6	20.7	***
Lack of medicine	78.6	70.7	86.4	***
No waiting room	15.0	15.0	15.0	***
No female doctor	5.4	5.7	5.0	***
Lack of privacy	5.7	4.3	7.1	***
Poor quality service	56.4	56.4	56.4	***
Lack of modern equipment	20.7	20.7	20.7	***
Poor transportation and communication	58.9	71.4	46.4	***
Costly medicine and service	25.7	20.0	31.4	***
Late checkup and treatment fear of abuse	7.9	7.9	7.9	***
Feel shy to disclose the problem to male doctors	9.3	9.3	9.3	***
Suggestions to overcome the challenges				
Low price of medicine if possible free	99.3	100.0	98.6	***
Low operation cost	20.7	20.7	20.7	***
Specialized doctor	49.3	43.6	55.0	***
24/7 service	35.0	30.0	40.0	***
Modern diagnostic facilities	27.1	18.6	35.7	***
An adequate supply of medicines	93.2	89.3	97.1	***
Sufficient staff	61.1	51.4	70.7	***
Available female doctors and staff	22.5	20.7	24.3	***

*P<0.05, **P<0.01, ***P<0.001.





Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: