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An index-based holistic approach to evaluate flood preparedness: evidence from Bangladesh

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Introduction: This study aims to assess individual flood preparedness in the flood-prone Islampur Union of Sunamganj District, Bangladesh, using an index-based Holistic Individual Preparedness Model (HIPM).

Methods: A total of 510 respondents participated in a face-to-face field survey, which employed 21 flood preparedness indicators. The key objectives were to evaluate the extent of individual preparedness and its determinants. Statistical methods such as multiple linear regression and Spearman's rank correlation were used to analyze the relationship between preparedness and various sociodemographic factors.

Results and discussion: The results show that 91% of respondents felt insecure during floods and 86% experienced damage to their homes. A significant proportion (87%) rated flood warnings as inadequate, while 84% did not seek refuge in flood shelters. Notably, 54% of respondents demonstrated limited knowledge of flood preparedness measures. Factors like gender, housing type, monthly income, and evaluation of flood warnings were associated with preparedness levels, with females and residents of kacha (unsafe) houses being less prepared. The study underscores the need for targeted campaigns and educational initiatives to improve preparedness, particularly for vulnerable groups.

KEYWORDS

flood safety, flood risk, rural areas, disaster preparedness, Bangladesh

1 Introduction

Globally, floods are among the most frequent natural hazards and can cause severe damage to both people and the environment (Fakhruddin et al., 2015; Marfai et al., 2015; Mondal et al., 2020; UNFCCC, 2021; Zhu et al., 2024). Significant destruction is frequently inflicted by flooding due to its high volume, frequency, and severity; furthermore, its economic impact and the number of affected individuals are expanding (Marfai et al., 2015; Dias et al., 2018; Win et al., 2018; Komolafe et al., 2019; Haque et al., 2023). Floods can adversely affect the social and economic well-being of individuals and the economy of an entire nation (Kawasaki and Rhyner, 2018). Flooding may severely damage numerous assets—residences, farms, livestock, poultry, and other agricultural products; transportation and communication networks and structures utilized for social, institutional, and educational objectives—including residences, farms, livestock, poultry, and other agricultural products (Parvin et al., 2016).

Furthermore, it is envisaged that the combined impacts of socioeconomic development and climate change will exacerbate future flooding hazards (Bubeck et al., 2012). The socioeconomic systems of developing nations are more prone to natural hazards than developed countries, with more sectors affected and more severe repercussions (Loayza et al., 2012; De Silva and Kawasaki, 2020). Rural areas prone to natural hazards are more frequently inhabited by destitute individuals due to their limited financial means to reside in less disaster-prone locales (Adelekan, 2010; Askman et al., 2018).

Bangladesh is highly susceptible to natural hazards resulting from climate change and geophysical phenomena (Ozaki, 2016). Numerous cyclones, floods, storm surges, lightning strikes, fires, and disease epidemics have struck the nation (Hsan et al., 2019; Rahman et al., 2021, 2022d). Bangladesh is among the most flood-prone countries on the planet due to its complex river system comprising numerous transboundary rivers (Abedin and Khatun, 2019; Newage, 2022; Rahman et al., 2024). With the exception of the Netherlands, Bangladesh exhibits a greater proportion of its populace—nearly 60%—that is susceptible to high flood risk. Furthermore, the greatest segment of its population—approximately 45%—is afflicted by high fluvial flood risk (Rentschler et al., 2022). Bangladesh experiences annual flooding that damages the country by an estimated $1 billion (Letsch et al., 2023). Climate change, in addition to causing increasingly costly financial and humanitarian devastation, is further exacerbating this risk. Several challenges impede Bangladesh's implementation of more effective flood risk management. These include a lack of comprehension regarding local vulnerabilities and needs, insufficient capabilities within local institutions such as the Ministry of Disaster Management and Relief, governance issues, and restricted access to funding for adaptation investments (Letsch et al., 2023). Climate-related risks commonly affect Bangladeshi rural people's livelihoods and vulnerability (Alam et al., 2018).

It is not sufficient to comprehend disasters just in terms of the risks they present. The effects they will have on valuables vulnerable to their impact must also be considered (Wisner et al., 2014). Depending on various circumstances, including age, gender, ethnicity, living conditions, and income, various people and groups are impacted differently by the events and have varying capacities to deal with them (Morrow, 1999; Wisner et al., 2014). Due to its ability to increase the number of alternatives available for risk reduction actions, this unique method of comprehending catastrophes has proven essential for disaster risk management. Disaster risk management may go beyond merely regulating nature to include preparedness, nonstructural mitigation, and addressing underlying issues like structural unfairness (Coppola, 2006; Wisner et al., 2014). Socioeconomic conditions, land ownership, population, health, coping capacity, neighborhood characteristics, and risk perception are the primary determinants of societal vulnerability to flooding, according to prior research (Rufat et al., 2015).

Study showed that the most often voiced concerns at the official institutional level included preparing communities for floods and controlling the negative consequences of floods through prompt and effective relief efforts (Azad et al., 2022). The local community's passivity is particularly tied to disaster preparedness, such as planning shelter areas and emergency food and medication preparation (Marfai et al., 2015). Disaster relief and recovery from its aftermath reduced the need for last-minute work. In contrast, disaster preparedness ensures an effective reaction to its impacts as a measure of action taken before the disaster (Hossain, 2020). Therefore, understanding what to do in a disaster, knowing how to do it, and having the necessary equipment to accomplish it properly are the goals of flood disaster preparedness. Before reaching an appropriate level, this difficult process may take years, and maintaining such levels requires constant effort (Coppola, 2006).

Research has been conducted on Bangladesh's floods (Rahman et al., 2010, 2015a, 2024; Fakhruddin et al., 2015; Chakma and Hokugo, 2020; Mondal et al., 2020, 2021; Alam et al., 2021; Haque et al., 2024). Most existing literature on flood preparedness in Bangladesh emphasizes institutional responses or community-based measures, overlooking individual-level preparedness and the sociodemographic factors that shape how people respond to flood risks. Previous studies have assessed flood risks, flood impacts, and responses in Bangladesh, this study differs in its use of the Holistic Individual Preparedness Model (HIPM) to measure preparedness levels. This is where our study, applying the HIPM, fills the gap by focusing on factors such as knowledge, social integration, and adaptive capacity across different population groups The HIPM offers a more comprehensive framework by evaluating six dimensions: knowledge, subsistence, loss minimization, social integration, technological integration, and adaptive capacity. This approach allows for a nuanced understanding of how individuals across different sociodemographic groups prepare for and respond to floods.

The study aims to assess flood preparedness at the individual level in flood-prone areas of Bangladesh using the HIPM. This research specifically addresses the following key objectives and questions:

To measure the level of preparedness of individuals in Islampur Union, Sunamganj District, across six dimensions of HIPM: knowledge, subsistence, loss minimization, social integration, technological integration, and adaptive capacity.

To determine how individual factors such as age, gender, income, and housing conditions influence individual preparedness for floods. The key research question here is: Which sociodemographic factors significantly impact individual flood preparedness?

To identify gaps in current flood preparedness efforts at institutional and community levels and how individual-focused strategies can enhance overall disaster resilience.

By applying HIPM, we aim to fill the research gap discussed above and provide valuable insights that can inform more tailored flood preparedness policies and interventions at both local and national levels. The use of HIPM in this context emphasizes the multifaceted nature of preparedness, going beyond structural measures to incorporate behavioral and social dimensions, which are often underexplored in disaster risk management literature. Therefore, this study offers a unique contribution by providing a holistic evaluation of individual preparedness for floods, with potential implications for global disaster management strategies.

2 Conceptual framework

Our study uses the Holistic Individual Preparedness Model (HIPM), originally developed by Jensen (2014) and later expanded by Nojang and Jensen (2020), to assess individual preparedness in flood-prone areas (Jensen, 2014; Nojang and Jensen, 2020). The rationale for selecting the HIPM is based on its comprehensive nature. It incorporates six key dimensions that cover both practical and psychosocial aspects of preparedness: knowledge, subsistence, loss minimization, social integration, technological integration, and

mental and physical adaptive capacity. This model allows for a multidimensional analysis, capturing the complexities of how individuals and communities prepare for and recover from hazards.

A theoretical conception of what preparedness is or has not been produced by the existing research on household and individual preparedness, according to Nojang and Jensen (2020). They argued that such a conceptualization must: (a) incorporate findings from studies on the response and recuperation of households and individuals; (b) promote cumulative investigation; and (c) facilitate operationalization across geographical, temporal, perilous, and cultural boundaries (Nojang and Jensen, 2020). They implemented HIPM, an early conceptual framework that met the requirements they deemed crucial (Jensen, 2014; Nojang and Jensen, 2020). This concept states that "individual holistic preparedness is a state of readiness for effective reaction and holistic recovery to hazard occurrences dictated by both the community environment around them and the status to related six aspects at any one time" (Jensen, 2014). The six theoretical dimensions are "knowledge, subsistence, loss minimization, social integration, technological integration, and mental and physical adaptive capacity."

As a result of how researchers operationalized the concept of preparedness in their study, academicians have identified the initial three of these dimensions as their foundational theoretical interests (Nojang and Jensen, 2020). The remaining three dimensions, illustrated in Figure 1, are derived from studies on response and recovery outcomes and how those outcomes could contribute to our comprehension of what preparation is and involves (Nojang and Jensen, 2020). For more information on these dimensions, see Figure 1 and previous studies (Nojang and Jensen, 2020; Rahman et al., 2022b, 2022c).

The HIPM stands out for its holistic approach, addressing physical preparedness (such as subsistence and technological integration) and social and mental dimensions like social integration and adaptive capacity. It makes it particularly suitable for complex, multidimensional hazards like floods. The model has been applied successfully across different geographical and hazard contexts, including fire preparedness in Bangladesh and earthquake response in Dhaka, proving its flexibility (Rahman et al., 2022b, 2022c). By incorporating behavioral, social, and physical aspects, the model encourages cumulative research that bridges gaps between disciplines, enabling a more nuanced understanding of preparedness.

However, this model may have some limitations as well. Due to its broad scope, the HIPM may present data collection and operationalization challenges, especially in resource-limited settings. Measuring intangible aspects like mental adaptive capacity can be subjective and difficult to quantify precisely. While the model excels in long-term recovery and social resilience, it may not prioritize immediate, short-term responses, which are critical during the onset of a disaster.

Alternative models, such as the Community-Based Disaster Risk Management (CBDRM) framework (Andrew, 2011), primarily emphasize community-level interventions and may not capture the detailed individual-level preparedness that HIPM focuses on. Similarly, the Protective Action Decision Model (PADM; Lindell and Perry, 2012) emphasizes decision-making processes during a disaster but does not provide the same breadth of preparedness dimensions as the HIPM. Given its holistic, adaptable, and interdisciplinary nature, the HIPM provides the most appropriate conceptual framework for understanding individual flood preparedness in our study, addressing tangible and intangible factors contributing to preparedness.

We have employed relevant indicators under the six dimensions of HIPM. The primary objective of our study was to derive findings using the index-based HIPM regarding the proportion of individuals who are adequately or inadequately prepared for flood risk and the methods by which they are prepared (e.g., how individuals were prepared in relation to one dimension as opposed to another). The relationship between independent variables (sociodemographic information and flood-related information) and each preparedness dimension (dependent variables), as well as total preparedness, was the secondary objective of our study. The analysis of independent variables has an extensive historical background in the study of individual and household preparedness (Okayo et al., 2015; Duží et al., 2017; Askman et al., 2018; Kamal et al., 2018; Ahmad and Afzal, 2020; De Silva and Kawasaki, 2020; Mondal et al., 2021). Nevertheless, we have also done so here, following the practice of exploring these independent factors.

3 Methods

3.1 Study area

The cross-sectional survey was conducted in Islampur, northeastern Bangladesh, a flood-prone Union of Sunamganj District (Figure 2). Selected participants were adults (18 years and older) residing in this union. A field visit was carried out in person (Figure 3). Islampur Union lies in the Meghalaya River basin and is characterized by a low-lying topography. This region is enclosed by the Himalayan Mountain ranges of Assam and Meghalaya, contributing to its vulnerability to flooding. The area is intersected by major transboundary rivers, such as the Piyain and Ichamati, exacerbating the flood risks due to seasonal river overflows (Bangladesh National Portal, 2023).

The area experiences significant rainfall, with an average of 5357.56 mm (SD = 784.68 mm) annually, as recorded from 1997 to 2016 by Flood Forecasting and Warning Centre (FFWC), (2017). This heavy rainfall, combined with the area's geophysical characteristics—such as its proximity to hilly regions and water flow from upstream during the monsoon season—makes Islampur Union particularly susceptible to floods. The region's arid conditions in parts of the Sylhet Division contrast sharply with the frequent flooding it experiences, driven by both geophysical factors and the transboundary river systems. These conditions make it a focal point for studying flood vulnerability due to its combination of heavy precipitation, river overflow, and geographic positioning. The range of livelihoods in this union, where nearly 35,000 people reside, is quite limited (Bangladesh National Portal, 2023). 25.5% of the people of this union are literate.

3.2 Preparedness index

Several studies are based on indexes to evaluate flood risk perception and climate change risk perception (Moghadas et al., 2019; Okunola et al., 2022; Shah et al., 2022). We considered several indexes based on previous relevant research (Becker, 2007; Marfai et al., 2015; Atreya et al., 2017; Foudi et al., 2017; Diakakis et al., 2018;

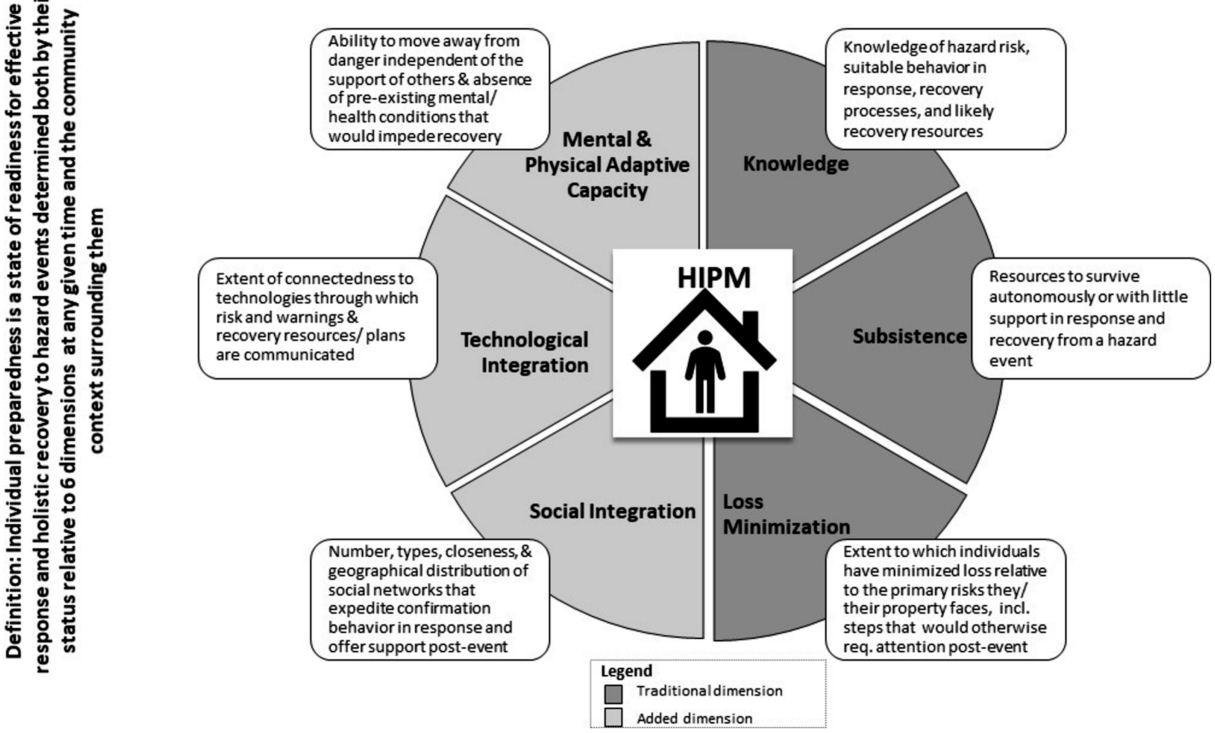

FIGURE 1
Holistic individual preparedness model (HIPM; Jensen, 2014).

Owusu-Ansah et al., 2019; Hossain, 2020; Mondal et al., 2020, 2021; Azad et al., 2022; Gomez-Cunya et al., 2022), to calculate each dimension of HIPM. After that, we prepared a draft questionnaire (based on the selected indexes). KoboToolbox was used to develop the questionnaire (KoboToolbox, 2023). We have also conducted a preliminary pilot survey with a representative sample of Islampur Union participants. They were not included in the final analysis. As an additional measure of the questionnaire's reliability, Cronbach's alpha was approximately 0.70 for all six dimensions. An internal consistency of the questionnaire has been validated when the Cronbach's alpha value is larger than 0.60 (Radhakrishna, 2007; Ursachi et al., 2015). We have also considered expert opinions where required. Thus, we have considered literature reviews, pilot surveys, expert opinions, and Cronbach's alpha value for the reliability of the questionnaire. This process has been used in several previous studies to validate the questionnaire (Rahman et al., 2022b, 2022c). The final questionnaire comprised sociodemographic data, flood-related information, and the HIPM index (Table 1). The initial segment comprises obligatory demographic inquiries (such as gender, age, monthly income, occupation, etc.). The subsequent part comprises information about floods (how did they rate their safety regarding flood, the main source of flood-related information, major impact due to the flood, evacuation behavior during flood, etc.). The last segment comprised HIPM-based preparedness cues. The HIPM portion comprised a total of 21 indexes (converted to questionnaire items), as follows: "knowledge (05), subsistence (02), loss minimization (05), social integration (03), technological integration (03), and adaptive capacity (03)." The scoring range for each item was a 0–1 scale, with 0 representing disagreement, 0.50 for neutral, and 01 representing agreement. The technique utilized in our previous studies to assess fire preparedness in Dhaka city (the capital of Bangladesh) was comparable (Rahman et al., 2022b, 2022c).

3.3 Sampling technique

Our research was carried out in the union's primary language. We initially identified a local individual who could aid us in data collection. We proceeded to gather data by visiting residences that were convenient for us. By adopting this approach, we utilized a non-probability sampling technique. We conducted this field survey in June 2023. We applied our previous data collection experience in remote areas (Rahman et al., 2023c; Rahman et al., 2023a; Rahman et al., 2022a; Rahman et al., 2023b; Mostafizur Rahman et al., 2023). Yamane's formula was employed to compute the sample size (Yamane, 1967):

$$n = \frac{N}{1 + N\left(e^2\right)}$$

N = population, where n = sample size, and e = error tolerance.

The required sample size was calculated at 395 (error tolerance of 0.05 and total population of 35,000; Bangladesh National Portal, 2023). In total, 510 participant responses were incorporated into the final analysis.

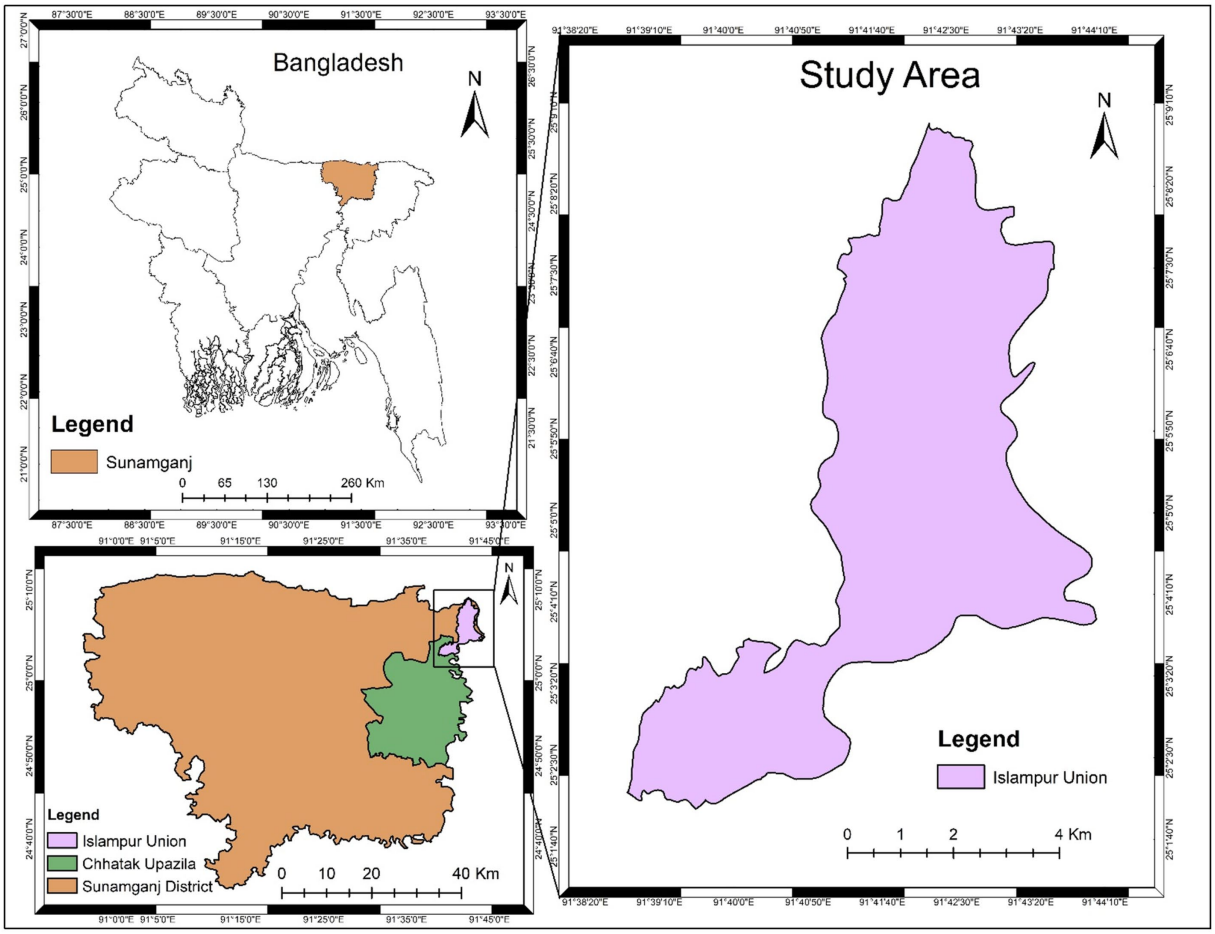

FIGURE 2
Study area.

3.4 Statistical analysis

Initially, the mean score was calculated to ensure that the identical scale was applied consistently throughout the research. Before continuing, the sum of the scores of each component was utilized to determine the total score for the dimension. The average score for the dimension was subsequently determined by dividing the sum of all scores by the number of items comprising the dimension (equation 1). Thus, the same method was utilized to scale each of the six dimensions (0–1 score range). Following this, the aggregate holistic individual preparedness (HIP) score was computed utilizing (equation 2).

$$average\ score\ of\ dimension = \frac{\sum score\ in\ items}{\sum item\ number}. \quad (1)$$

$$\text{Knowledge Score (KS)} = \sum_{1}^{05} \frac{S_i}{n.}$$

$$\text{Subsistence Score (SS)} = \sum_{1}^{02} \frac{S_i}{n}$$

$$\text{Loss Minimization Score (LMS)} = \sum_{1}^{05} \frac{S_i}{n}$$

$$\text{Social Integration Score (SIS)} = \sum_{1}^{03} \frac{S_i}{n}$$

$$\text{Technological Integration Score (TIS)} = \sum_{1}^{03} \frac{S_i}{n}$$

$$\text{Adaptive Capacity Score (ACS)} = \sum_{1}^{03} \frac{S_i}{n}$$

Where *Si* is for the *ith* item's score (*S* = score, *i* = ith item) and *n* is the total number of items.

$$HIP\ score\left(HIPS\right) = \frac{KS + SS + LMS + SIS + TIS + ACS}{6} \quad (2)$$

We have employed Python (2.7; Beaverton, OR 97008, United States) and the 'R' program, version 3.6.3 (Welcome to Python.org, 2021; RStudio, 2022), for data management and statistical analysis. Descriptive statistics were calculated as needed. An evaluation was conducted on the relationship between sociodemographic data, flood-related information, and the HIPM. A multiple linear regression analysis was utilized to investigate these associations. In contrast to simple linear regression analysis, multiple

FIGURE 3
Photographs of data collection: **(A)** Islampur local government office; **(B)** Interaction with the community people on flood water (photograph was taken with the permission).

linear regression analysis exclusively incorporated significant variables. Furthermore, Spearman's rank correlation was applied to determine the degree of correlation between HIPM and the remaining six dimensions.

4 Results and discussion

4.1 Sample characteristics

The study sample comprised 38% females and 62% males (Table 2). Cultural restrictions in Islampur Union limited female interaction with outsiders, leading to higher male participation (Koenig et al., 2003; Shohel et al., 2023). The majority (57%) were aged 36–55, with 61% illiterate, reflecting the region's 25.5% literacy rate (Bangladesh National Portal, 2023). Most lacked stable income: 26% worked as day laborers and 17% as farmers. Monthly earnings were low, with 38% under 15,000 BDT. Housing varied, with 67% in semi-pucca houses, and 94% of households included vulnerable members.

4.2 Flood-related information

A significant 91% felt "very unsafe" during floods, and 86% reported floodwaters affecting their homes (Table 3). Islampur Union frequently suffers from flooding impacts, leading to 90% experiencing severe property damage and 70% facing mobility challenges. Health issues, primarily waterborne diseases, affected 84% of respondents. Despite flood awareness efforts, 87% found government warnings inadequate, with "warning fatigue" and distrust lowering effectiveness. Research shows the Bangladesh Meteorological Department (BMD) issues flood warnings via TV and radio, but their acceptance remains low (Fakhruddin et al., 2015). Insufficient local capacity, such as in the Ministry of Disaster Management, also hinders flood risk management (Letsch et al., 2023). Studies confirm Bangladesh has a robust early warning system, but implementing an integrated system faces challenges (Haque et al., 2024). Only 16% sought refuge in shelters, with 51% citing shelter unavailability. Flood-prone houses often become uninhabitable, necessitating emergency sheltering (Azad et al., 2013). Effective flood shelters require strategic location for accessibility and flood resistance (Uddin and Matin, 2021). In close proximity to a community, the flood shelter must be accessible for efficient relocation and evacuation (Uddin and Matin, 2021). While coastal areas have secure cyclone shelters, flood-prone regions lack adequate emergency shelters, limiting evacuation options.

4.3 Levels of individual flood preparedness

While all participants had prior flood experience, 54% lacked preparedness knowledge, and 88% were unaware of risk reduction strategies (Table 4). A study in Northern Malawi's Mzuzu City showed 61.4% unprepared for emergencies (Munthali et al., 2024). However, most respondents in Tangail District, Bangladesh, reported basic flood preparedness due to early NGO awareness efforts, helping them apply learned skills (Ansari et al., 2022). Lack of flood preparedness knowledge increases vulnerabilities. Effective programs require active community involvement and community education campaigns to

TABLE 1 Preparedness index.

No.	Dimensions	Index
01	Knowledge	Flood experience (Diakakis et al., 2018; Gomez-Cunya et al., 2022).
02		Actions (such as calling the authorities, moving to the shelter, etc.) should be followed during a flood emergency (Diakakis et al., 2018).
03		All adult family members know how to swim (Mondal et al., 2020).
04		During floods, special assistance is necessary for vulnerable individuals (Old People, Children, Disabled; Chakraborty et al., 2019; Mason et al., 2021).
05		Information to carry out precautionary flood prevention and implement the necessary measures (Becker et al., 2014).
06	Subsistence	Emergency savings money for any future flood situation (Mondal et al., 2020).
07		Store foods (Rice, pulses, dry food, special food for babies, etc.) for the family members before the flood season (Chanda Shimi et al., 2010).
08	Loss Minimization	Reinforcing houses or raised elevations to obstruct the entry of floodwaters (Yin et al., 2021).
09		Saving for the recovery of any damages on the property and valuable assets due to the flood (Gomez-Cunya et al., 2022).
10		Houses can withstand flooding (Gomez-Cunya et al., 2022).
11		Community and individuals have taken adaptive and mitigation measures for flooding (building dikes, improving drainage, etc.; Becker et al., 2014; Marfai et al., 2015; Gomez-Cunya et al., 2022).
12		Shelter is available when flooding (Atreya et al., 2017).
13	Social Integration	Emergency contact numbers and contact information of relatives to get help during the flood (Gomez-Cunya et al., 2022).
14		Community people offer help and exchange services or goods with their neighbors during or after the flood (Atreya et al., 2017; Mondal et al., 2020).
15		Governments or organizations have taken initiatives for community flood preparedness, such as preparatory meetings, training programs, Shelter preparation, and medical preparation (Hossain, 2020).
16	Technological Integration	Receive timely notification of flood warnings and community alerts (Gomez-Cunya et al., 2022).
17		Emergency plan for a flood in family (Atreya et al., 2017).
18		Electronic devices (TV/ Radio / Mobile) are needed (Nojang and Jensen, 2020).
19	Mental and Physical Adaptive Capacity	Sufficient financial resources to cope with future flood risks (Becker et al., 2014).
20		Evacuate or move valuable assets and equipment to a higher place before flooding begins (Gomez-Cunya et al., 2022; Marfai et al., 2015).
21		Physically and mentally able to decide in different situations during floods (Foudi et al., 2017).

boost preparedness (Forsyth et al., 2023). The majority (98%) believed that those with disabilities, older people, and small children were particularly vulnerable to floods and needed more help in an emergency. Research has shown that during an emergency, such as a flood, those with disabilities, older people, and children need special help (Chakraborty et al., 2019; Mason et al., 2021). The effects of natural hazards are often severe for those with disabilities (Alexander, 2015). Table 4 contains the responses to the knowledge dimension prompt (as well as the remaining ones), and Figure 4 displays the dimension averages for knowledge and the remaining dimensions. Compared to other HIPM dimensions, overall knowledge scores are higher (0.66 ± 0.14 on a 0–1 scale) than the others.

Subsistence preparedness was low. Only 56% stored food before floods, and 67% lacked emergency savings (Table 4). Disasters inevitably impact food safety; essential nonperishables for at least 3 days should be stored in a safe area (Gupta, 2017). In Bangladesh, households typically stock dry foods like chira-muri, gur, rice, dal, oil, and salt in anticipation of floods. A rural survey showed 45% of households prepared dry food ahead of flooding (Chanda Shimi et al., 2010). A study on flood-prone river areas found few households took financial precautions due to lower income, limited access to financial institutions, and lack of awareness (Mondal et al., 2020). Experience with past floods may reduce fear of adverse outcomes in future events (Fox Gotham et al., 2017). On a 0–1 scale, subsistence preparedness scored 0.46 ± 0.38 (Figure 4).

Only 10% of participants had reinforced homes or elevated floors to prevent flood damage, with loss minimization scoring lowest (mean: 0.14; Figure 4). Research in Ghana, suggests elevated floors or reinforced buildings effectively mitigate flood damage (Yin et al., 2021). In Ghana, 8.67% raised their homes above flood levels, while Jakarta residents employed low-cost adaptations like terraced housing, raised floors, and small dikes to prevent water entry (Marfai et al., 2015). These measures are popular due to their affordability.

Around 76% of participants reported strong social ties, crucial for mitigating flood risks (Table 4). Informal networks like friends, family, and neighbors significantly bolster community resilience (Babcicky and Seebauer, 2017). Government and NGO interventions were insufficient in fostering preparedness. During disasters, organizations play a critical role in providing essential assistance and accurate information (Hossain, 2020). Many government and NGO staff conduct disaster operations across Bangladesh, using diverse techniques to gather data and issue proactive alerts for imminent

TABLE 2 Sociodemographic information.

Features	Frequency	Percentage
1. Gender		
Male	314	61.57
Female	196	38.43
2. Age group (year)		
18–25	35	6.86
26–35	117	22.94
36–45	150	29.41
46–55	146	28.63
More than 55	62	12.16
3. Marital status		
Married	484	94.90
Unmarried	26	5.10
4. Education		
Illiterate	312	61.18
Primary school	160	31.37
Secondary school or more	38	7.45
5. Occupation		
Agri Farmer	89	17.45
Fisher	53	10.39
Business	38	7.45
Wage Labor	132	25.88
Employee in gov or non-gov organization	9	1.76
Unemployed	170	33.33
Others	19	3.73
6.Monthly Income		
No income	162	31.76
Less than 15,000	192	37.65
15,000–29,999	128	25.10
>30,000	28	5.49
7. Housing type		
Kacha	136	26.67
Pucca	30	5.88
Semi-pucca	344	67.45
8. Family with vulnerable member (children, pregnant woman, older person, etc.)		
Yes	478	93.73
No	32	6.27

disasters. Prior studies link high information access to the actions of these organizations (Hossain, 2020). The overall social integration score was 0.46 ± 0.24 (Figure 4).

Technological preparedness was low, with 92% not receiving timely flood warnings despite 94% having electronic devices. This aligns with earlier findings showing many participants found the warning system inadequate. Current inefficiencies highlight the need for improved communication strategies to better reach isolated communities. In the 2017 Rangpur flood, 93.7% received timely information, enabling 85.3% to take protective action, while others missed warnings due to limited access to electronic media or being away from home (Hossain, 2020). Regarding this, the respondents stated that their inability to comply with electronic media—such as radio and television—and that some of them were away from home while the organization was supplying information prevented them from receiving information on time. As a result, they were unable to act promptly. Technological integration lagged behind social integration among the participants (Figure 4). Technological integration lagged behind social integration, scoring 0.42 ± 0.18 (Figure 4).

Adaptive capacity was low, with only 18% believing they could protect assets before floods. After the severe 2017 flood, many lost all possessions, including tools, livestock, and boats, leaving them jobless and defenseless (Hossain, 2020). Organizations provided financial aid for flood insurance and temporary shelter (Hossain, 2020). Civil society actors, especially local flood organizations and wardens, urged residents to move valuables to safe areas before floods (Forrest et al., 2019). Respondents stated that local flood organizations and flood wardens urged residents to relocate their belongings to secure locations away from the floodwater (Forrest et al., 2019). Adaptive capacity scored second lowest (0.25) after loss minimization. Mental and physical readiness for disaster response was also low, constrained by socioeconomic factors. Mental health support is essential throughout disaster phases (Choudhury et al., 2006; Glauberman and Qureshi, 2018). The overall HIP score was 0.40, indicating low preparedness. Loss minimization and adaptive capacity had the lowest scores, while knowledge had the highest. Spearman's rank correlation confirmed the interdependence of the six HIPM dimensions, emphasizing the need for holistic interventions to improve flood preparedness in vulnerable communities.

4.4 Factors influencing preparedness

In multiple regression analysis (Table 5), males, older participants, those with moderate income, and pucca or semi-pucca homeowners showed higher knowledge levels. Cultural norms and economic factors limit women's access to preparedness information. A study in Bangladesh showed that female participants recognized the role of flood volunteers, while another study found males more informed overall (Chisty et al., 2023). According to another study, males were more informed than females (Munthali et al., 2024). However, in that earlier study, no significant correlation was found between knowledge and either married status or gender (Munthali et al., 2024). According to another study, females are less resilient and more vulnerable than males since they are typically not permitted to work outside of their homes or the Haor villages in Bangladesh for cultural and religious reasons (Kamal et al., 2018). Participants in kacha houses, younger individuals, and those with vulnerable family members were less prepared for subsistence, reflecting financial limitations. Fishermen, farmers, and those with vulnerable members showed low loss mitigation due to economic constraints. Cost impedes the use of simple strategies, like dikes or dry food storage, that reduce flood impacts. Males, higher-income

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TABLE 3 Information regarding floods.

Features	Frequency	Percentage
1. What is the safety classification of the present residence in terms of flood resistance?		
Very Safe	0	0
Safe	0	0
Moderately Safe	2	0.39
Unsafe	45	8.82
Very Unsafe	463	90.78
2. If there is a flooding event in your locality, how far away from your home do you expect the water to reach?		
Water is likely to reach my house or property	441	86.47
Water is likely to reach my neighbor's property or street but not my house	47	9.22
Water is likely to reach 1–2 blocks (170 meters) away from my house or property	22	4.31
3. What is the main source of getting information on floods in your area?		
Electronic media	33	6.47
Individuals (Family) and the Community	317	62.16
Local and National Authorities	1	0.20
Internet	9	1.76
Lack of media coverage regarding the flooding	150	29.41
4. Major impact experienced due to the flood		
Loss or Damage of property and Valuable Asset	458	89.80
Loss or change in livelihood Pattern	110	21.57
Disruption of movements	356	69.80
Disruption of services	210	41.18
Illnesses	428	83.92
Loss of Family Members	3	0.59
5. How would you assess the level of flood forecasting and warning by the authorities?		
Very Adequate	0	0.00
Adequate	0	0.00
Neutral	21	4.12
Inadequate	46	9.02
Very Inadequate	443	86.86
6. Did you go to the Shelter Center during the flood?		
No	430	84.31
Yes	80	15.69
7. Major reason for not going to shelter (For those who did not go to the shelter during the last flood)		
Long Distance	23	5.35
No Shelter Nearby	221	51.40
Weak Shelter	57	13.26
Insecurity in Shelter	27	6.28
Unfriendly Environment for Women	49	11.40
Negative Attitude	17	3.95
Others	36	8.37

individuals, and those without vulnerable family members demonstrated better social integration. In technological integration, female agri-farmers earning over 30,000 BDT monthly were less satisfied with the flood warning system, and pucca homeowners were more technologically adept than kacha residents. Households with vulnerable family members were less

TABLE 4 Responses for the HIPM dimension.

No.	Dimensions	Survey question with sources	Agree		Neutral		Disagree	
			N	%	N	%	N	%
01	Knowledge	I have experienced floods before (Diakakis et al., 2018; Gomez-Cunya et al., 2022).	510	100	0	0	0	0
02		I know what actions (such as calling the authorities, moving to the shelter, etc.) should be followed during a flood emergency (Diakakis et al., 2018).	194	38.04	41	8.04	275	53.92
03		All adult family members know how to swim (Mondal et al., 2020).	409	80.20	42	8.24	59	11.57
04		During floods, special assistance is necessary for vulnerable individuals (Old People, Children, Disabled; Chakraborty et al., 2019; Mason et al., 2021).	501	98.24	3	0.59	6	1.18
05		I have the information to carry out precautionary flood prevention and implement the necessary measures (Becker et al., 2014).	18	3.53	42	8.24	450	88.24
06	Subsistence	I have emergency savings money for any future flood situation (Mondal et al., 2020).	122	23.92	44	8.63	344	67.45
07		I store foods (Rice, pulses, dry food, special food for babies, etc.) for the family members before the flood season (Chanda Shimi et al., 2010).	289	56.67	81	15.88	140	27.45
08	Loss Minimization	I have reinforced my house or raised elevations to obstruct the entry of floodwaters (Yin et al., 2021).	52	10.20	12	2.35	446	87.45
09		I have saved for the recovery of any damages on my property and valuable assets due to the flood (Gomez-Cunya et al., 2022).	32	6.27	103	20.20	375	73.53
10		My house can withstand flooding (Gomez-Cunya et al., 2022).	0	0.00	02	0.39	508	99.61
11		My community and I have taken adaptive and mitigation measures for flooding, such as building dikes, improved drainage, etc.; Becker et al., 2014; Marfai et al., 2015; Gomez-Cunya et al., 2022).	22	4.31	0	0.00	488	95.69
12		I have shelter available in the case of flooding (Atreya et al., 2017).	181	35.49	41	8.04	288	56.47
13	Social Integration	I have emergency contact numbers and contact information of my relatives to get help during the flood (Gomez-Cunya et al., 2022).	237	46.47	29	5.69	244	47.84
14		My community people offer help and exchange services or goods with their neighbors during or after the flood (Atreya et al., 2017; Mondal et al., 2020).	386	75.69	52	10.20	72	14.12
15		Governments or organizations have taken initiatives for community flood preparedness, such as preparatory meetings, Training Programs, Preparing Shelters, and medical preparation (Hossain, 2020).	03	0.59	75	14.71	432	84.71
16	Technological Integration	I receive timely notification of flood warnings and community alerts (Gomez-Cunya et al., 2022).	05	0.98	35	6.86	470	92.16
17		I have an emergency plan for a flood in my family (Atreya et al., 2017).	130	25.49	41	8.04	339	66.47
18		I have an electronic device (TV/ Radio / Mobile; Nojang and Jensen, 2020).	480	94.12	0	0	30	5.88
19	Mental and Physical Adaptive Capacity	We have sufficient financial resources to cope with future flood risks (Becker et al., 2014).	0	0	56	10.98	454	89.02
20		I can evacuate my home or move valuable assets and equipment to a higher place before flooding begins (Gomez-Cunya et al., 2022; Marfai et al., 2015).	92	18.04	71	13.92	347	68.04
21		I think I am physically and mentally able to take decision in different situation during flood to help myself and my family (Foudi et al., 2017).	192	37.65	74	14.51	244	47.84

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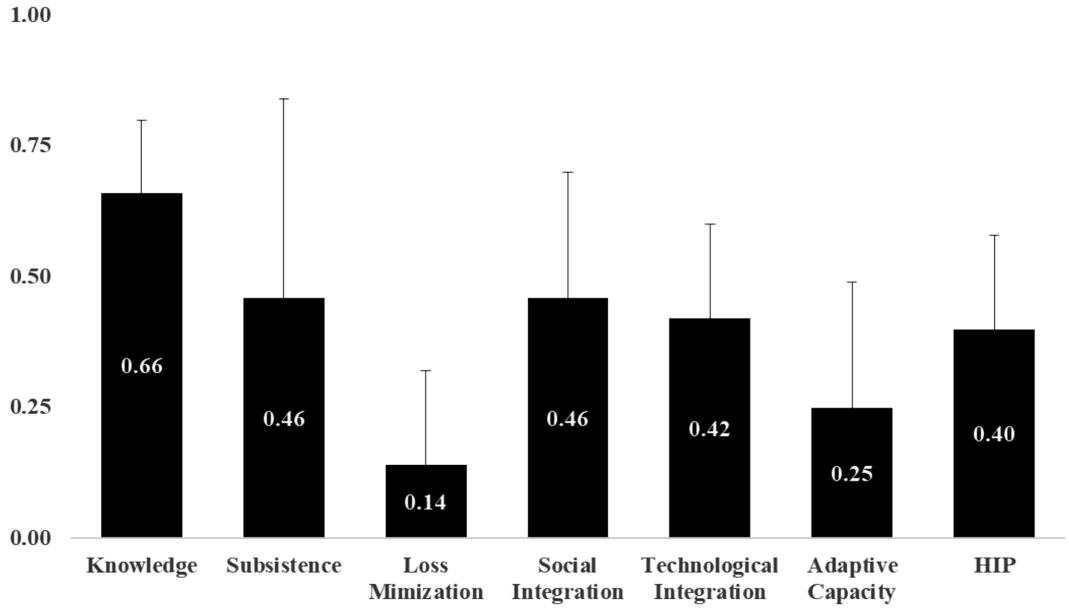

FIGURE 4
Six dimensions' overall mean score along with HIP.

prepared for subsistence and loss mitigation. Adaptive capacity was lower among females but higher among unmarried, mid-income participants, and pucca homeowners. Those aged 26–35, unmarried, unemployed, mid-income, and living in pucca houses showed the highest HIP (Table 5). Socioeconomic factors like gender, age, income, housing type, and family composition influence flood preparedness in rural Bangladesh. Males were more prepared, reflecting rural cultural norms that limit women's community involvement. Older participants and those with moderate income also had higher preparedness due to life experience and financial means. Socially integrated participants, often male and wealthier, had better community support and technological access during floods. Stronger, pucca homes contributed to better preparedness than kacha dwellings.

5 Limitations

The current study has some limitations. The selection of participants was conducted through non-probability sampling, thereby limiting the study's generalizability. Furthermore, an in-person interview was conducted at a designated time. Therefore, the findings may exhibit a social desirability bias and suggest a progressive decline in the level of preparedness as time passes. Despite being formulated on the foundation of literature reviews, expert opinions, pilot surveys, and Cronbach's alpha value calculation, our questionnaire might still have inherent limitations. We have ultimately put into practice an innovative, mostly untested model that may have several drawbacks. Nevertheless, the HIPM model has been implemented from the standpoint of Bangladesh, and it may be relevant to various disasters at various community levels. A widespread validation of this model is lacking. It may thus possess some limitations. Although individual flood protection is invaluable, it just scratches the surface of what might be achieved to ensure absolute flood prevention. According to many, an overwhelming emphasis on individual preparedness is detrimental to the institutional structures and rules that oversee it. Victims may attribute blame, while the most prominent actors, such as the government, are held liable due to the influence of the sociological and political settings in which these institutions function. However, this study approaches the examination of individual responsibility, accountability, and flood safety from a systematic standpoint.

6 Recommendations and conclusion

This study explores the six dimensions of HIPM and HIP level in relation to inundation. In a crisis, women are more susceptible than men (Rahman et al., 2015b). Our results suggest that women could need help in an emergency, especially regarding their ability to adjust mentally and physically. According to research, when a crisis struck, women were psychologically more impacted than males (Choudhury et al., 2006). Education is A major component of disaster preparedness (Hoffmann and Muttarak, 2017). Nevertheless, research indicates that the fundamental processes elucidating the impacts of schooling are very context-specific (Hoffmann and Muttarak, 2017). In our study, individual flood preparedness was not shown to be significantly influenced by education level. Furthermore, compared to those who live in kacha houses, residents in pucca and semi-pucca houses are better equipped for flooding, according to our research. It is important to remember that people from higher socioeconomic classes usually live in pucca and semi-pucca dwellings. It is conceivable that they possess greater access to dependable resources and information than their fellow residents. The administration of Bangladesh has already taken

TABLE 5 Variables associated with the six HIPM and HIP dimensions.

Features	β#						
	Model 1 Knowledge	Model 2 Subsistence	Model 3 Loss Minimization	Model 4 Social Integration	Model 5 Technological Integration	Model 6 Adaptive Capacity	Model 7 HIP
1. Gender							
Male							
Female	−0.10***	−0.37***	−0.16***	−0.27***	−0.14***	−0.26***	−0.22***
2. Age group (year)							
18–25							
26–35	0.11**	0.15*	0.04	0.15*		0.05	0.07*
36–45	0.07*	−0.00	0.0	0.07		0.01	0.01
46–55	0.11**	−0.00	0.02	0.06		0.05	0.03
More than 55	0.08*	0.06	0.01	0.05		−0.02	0.01
3. Marital status							
Married							
Unmarried	0.19***		0.10**	0.32***		0.24***	0.11**
4. Education							
Illiterate							
Primary school	0.01	0.01	−0.01	−0.05**	−0.01	−0.03	−0.02
Secondary school or more	0.04	−0.01	−0.04	−0.04	−0.06	−0.01	−0.01
5. Occupation							
Unemployed							
Business	0.02	−0.01	0.02	−0.05	0.01	−0.00	0.00
Employee in gov or non-gov organization	0.07	−0.01	0.08	−0.08	0.10	0.05	0.04
Agri Farmer	0.03	−0.04	−0.12***	−0.03	−0.09*	−0.09	−0.06*
Fisher	0.01	−0.14	−0.08**	−0.07	−0.08	−0.09	−0.07*
Wage Labor	0.02	0.01	−0.02	0.01	−0.04	0.00	−0.00
Others	−0.00	−0.02	−0.05	0.04	0.04	0.04	0.01
6. Monthly Income							
15,000–29,999							
Less than 15,000	−0.06***	−0.15***	−0.05***	−0.08***	0.02	−0.07**	−0.06***

(Continued)

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TABLE 5 (Continued)

Features	β#						
	Model 1 Knowledge	Model 2 Subsistence	Model 3 Loss Minimization	Model 4 Social Integration	Model 5 Technological Integration	Model 6 Adaptive Capacity	Model 7 HIP
>30,000	−0.11	−0.33	−0.38***	0.10	−0.44***	−0.07	−0.21*
No income	−0.01	−0.16*	−0.02	−0.05	−0.05	−0.07	−0.06
7. Housing type							
Kacha							
Pucca	0.31***	0.70***	0.74***	0.21	0.68***	0.36**	0.50***
Semi-pucca	0.04***	0.09**	0.04***	0.09***	0.04**	0.02	0.06***
8. Family with vulnerable member (children, pregnant woman, older person, etc.)							
No							
Yes	−0.04*	−0.17**	−0.12***	−0.07*		−0.06	−0.07**
9. What is the safety rating of the current living place?							
Moderately Safe							
Unsafe	−0.03	0.30	0.14	−0.05	−0.08	0.02	0.04
Very Unsafe	0.02	0.24	0.13	−0.14	−0.10	−0.02	0.01
10. How would you assess the level of flood forecasting and flood warning by the authorities?							
Neutral							
Inadequate	−0.05	−0.06	−0.08**	−0.12*	−0.11**	−0.02	−0.07*
Very Inadequate	−0.04	−0.04	−0.08***	−0.13**	−0.08*	−0.04	−0.07**
11. Did you go to the Shelter Center during the flood?							
No							
Yes	0.04***	0.04	0.10***	0.11***			0.05***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; $\beta^{\#}$ = Beta (Coefficient).

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several measures to reduce the probability of inundation (FFWC, 2024). However, as knowledge is still lacking and knowledge growth is essential to bolstering improvements in other preparation dimensions, more work must be directed here. In order to educate and instruct their residents about flood safety, authorities should start campaigns, gather social support, connect with them, and give them access to the most recent flood education and training. Incorporating flood preparedness topics into schools, colleges, and university curricula can also be a successful strategy for increasing people's level of preparedness, as can holding workshops, seminars, and training sessions. Considering the educational attainment and cognitive capacity of the populace, community-level education initiatives concerning flood preparedness may also be distributed through social media, mobile and web-based applications, and television. Information sources that have become indispensable and frequently utilized by the people of Bangladesh are these platforms. In the future, disaster management authorities and organizations may utilize these platforms to disseminate information regarding HIP. It is imperative that the authorities engage in collaborative efforts to disseminate information. In addition to governmental entities, various sectors and organizations can contribute to the dissemination of information pertaining to flood preparedness, efficient response, and recovery. Businesses, healthcare organizations, academic institutions, educational institutions, the media, and community leaders are among these. As a result, improved communication among government agencies, increased community involvement, needs assessments, and coordination between government agencies and non-governmental organizations could all contribute to enhanced governance of flood and disaster risk (Letsch et al., 2023).

Knowledge dissemination will be important, but it will not be sufficient. Across the country, not every area has equal access to other technology and internet connectivity. To effectively engage with all demographic segments, providing internet and technological access will be imperative. Furthermore, it is imperative that authorities establish stringent construction regulations, ensure greater accessibility to emergency resources, and mandate the storage of emergency supplies in every residential unit in order to enhance public preparedness. The authorities should also spend money on technology that can identify floods. Flood warnings must be distributed so that individuals not only comprehend the information but are encouraged to take steps to lower their risk of flooding. Given that Bangladesh is a developing country, outside funding could be needed to assist the government in carrying out these initiatives. Though knowledge can only go so far, these steps will be crucial because a large portion of the population can still not acquire products for loss minimization and subsistence.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Khulna University in Bangladesh (Reference number: KUECC-2022/02/07). The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because Most of the participants were illiterate. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MRI: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. IS: Conceptualization, Data curation, Formal analysis, Investigation, Software, Visualization, Writing – original draft, Writing – review & editing. MH: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. MA: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. EA: Conceptualization, Writing – original draft, Writing – review & editing. KA: Conceptualization, Writing – original draft, Writing – review & editing. MKI: Conceptualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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