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Waterlogging, health and healthcare access in southwest Bangladesh

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Abstract

Waterlogging, a type of stagnant flooding, is becoming more prevalent in southwest Bangladesh. It is expected to worsen due to the expansion of shrimp farming and climate change, which will contribute to environmental degradation. However, the impact of waterlogging on health, health service utilisation and household health expenditure remains poorly understood. We conducted a quantitative study between August and September 2022 in Tala, a disaster-prone sub-district in southwest Satkhira. Data were collected from 596 randomly selected households. A total of 1266 adults were surveyed, of whom 768 reported a recent illness. Of these adults, 213 reported seeking formal healthcare for their initial visit. Information about households' exposure to waterlogging in the past 12 months was also collected. Bivariate analyses were used to test the association between the outcome variables (reporting illness, utilisation of formal healthcare, and out-of-pocket expenditure) and the following other variables: age, gender, education, whether the respondent was the head of the household, type of illness, household wealth index, household size, and experience of waterlogging in the past 12 months. Two probit models were fitted for illness reporting and formal healthcare utilisation. Waterlogging experience was significantly associated with illness reporting [Coef: 0.47; CI 0.14,0.80], p = 0.006). However, it was not significantly associated with healthcare utilisation among the 768 adults who reported any illness [Coef: -0.11; CI -0.51,0.029], p = 0.600). Bivariate analyses of the association between healthcare expenditure and waterlogging revealed no significant association (p = 0.635). Significant associations were found between illness reporting and household wealth (wealthiest/poorest) and age (older/younger). In contrast, gender (male/female) and household size (larger/smaller) were negatively associated

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with illness reporting. Of the 768 adults who reported illness, a negative association was observed for education (compared to higher education) and a positive association was observed for wealth (average wealthy and poorest) and chronic illness (compared to acute illness). These findings highlight the need to consider the detrimental health impacts of waterlogging when improving Bangladesh's healthcare system.

Introduction

Climate change is not only causing a rise in global temperature. The warming of the planet also bears important repercussions on rainfall, with unpreceded rainfall patterns, resulting in both droughts and extreme rainfall, becoming more common [1]. As a consequence of disrupted rainfall patterns, both rural and urban settings around the globe are increasingly experiencing flooding and waterlogging. Nonetheless, waterlogging in particular, defined as the submergence or inundation of areas for a long time without adequate drainage, does not appear prominently in the climate change and health agenda, if not in emergency cases, when cities are affected by waterlogging following extreme rainfall [2,3].

Yet, agricultural experts warn us that waterlogging represents a major constant problem [4] both for rural communities, affecting 15–20% of all global wheat cropping regions each year [5], and for some cities, which are now affected by the problem year after year [6]. Likewise, some authors have argued that under the current climate crisis, the effects of waterlogging could be catastrophic, with the strongest effects being observed in Southern Asia [7,8].

Bangladesh is known for continuous exposure to waterlogging, both in its cities [9], especially during the monsoon season, and in the coastal South-West regions, given the combination of riverbed siltation and back water effect due to sea-level rise, low flow upstream and high tide [10–12]. Reflecting a global pattern, the literature examining the impact of waterlogging in Bangladesh focuses primarily on adverse effects on livelihood, infrastructure, economy, and the environment. For instance, Rahaman and colleagues report disruptions to infrastructure, such as damages to roads and houses and routine economic activities [13]. Similarly, other authors have reported that waterlogging results in crop damage, ultimately affecting a household economic's well-being [14]. This emerging literature on the effects of waterlogging is complemented by a richer literature examining risk factors associated with waterlogging to identify high-vulnerability areas, using also geospatial analysis [9,15].

What is surprising is the limited number of studies that have specifically examined the relationship between waterlogging and health. Rahaman and colleagues report that in their study in Noakhali Pourashava, respondents to their survey recognised the existence of a close link between polluted stagnant water due to waterlogging and often to disruption in the sewage system and water-borne diseases [13]. An earlier study conducted among youth in southwest Bangladesh also detected poorer health and educational outcomes among orphans in facilities exposed to waterlogging [16]. Kabir and colleagues report a decline in psychological health following the

Monsoon season among communities exposed to sea-level rise in southwest Bangladesh, suggesting an association between waterlogging and mental health [17]. More in general, the literature recognises that due to its specific geographical location, its landscape, and human-built environment, Bangladesh is one of the most climate-vulnerable countries, with water systems being most affected, increasing waterborne and vector-borne diseases [18].

Interestingly, however, the scientific literature, both globally and specific to Bangladesh, has paid limited attention to how waterlogging affects health service utilisation and household expenditures on health. Across contexts, the scientific literature on access has addressed the effects of floods [19–21], but has not examined what the effect of prolonged exposure to excess surface water can be on health service utilisation and household expenditures on health. Evidence on how waterlogging affects health service utilisation and household expenditure on health is needed to inform the planning and development of adequate adaptation strategies, especially in a country like Bangladesh, which struggles on its path to Universal Health Coverage.

Our study sets to fill the abovementioned gap in knowledge by examining the effect of exposure to waterlogging on health service utilisation and related household out-of-pocket expenditure using population-level data collected in the Tala upazila, in the district of Satkhira, southwest Bangladesh, where waterlogging has been expanding for the past decades [12]. We modelled health service utilisation and out-of-pocket expenditure conditional on illness reporting to discern the effect that exposure to waterlogging bears on service utilisation and expenditure from the effect that waterlogging bears on illness reporting.

Methods

Ethics approval and consent to participate

Ethics approval was granted from the Institutional Review Board (IRB) of the BRAC James P Grant School of Public Health, BRAC University (ref: IRB-19 November'20–050) in Bangladesh. Respondents were provided information about the study prior to data collection and their written informed consent was sought before each interview.

Inclusivity in global research

Additional information regarding the ethical, cultural, and scientific considerations specific to inclusivity in global research is included in the supporting information (S1 Checklist).

Data sources & study setting

This study was conducted as part of the ClimHB project, an exploratory research project aimed at understanding the links between climate change, migration and health system resilience, with specific emphasis on access to formal healthcare services [22]. We used data from a cross-sectional household survey conducted among households in Tala upazila, Bangladesh, during the monsoon season in August and September 2022. Tala upazila is a rural disaster-prone sub-district of Satkhira on the interior coast of southwestern Bangladesh, relying mostly on agriculture and with a high prevalence of out-migration. Respondents were interviewed about their illness status, utilisation of health care services conditional on their illness reporting and related out-of-pocket expenditures. Preliminary qualitative work indicated that waterlogging alongside the Covid-19 pandemic and cyclones were the most cited recent events impacting the Tala population.

Conceptual approach and data structure

Waterlogging is a recurrent problem in Tala that lasts several weeks or months. It usually occurs during the monsoon and sometimes continues for a long time afterwards [12,23]. In affected areas, waterlogging impacts several dimensions of livelihood, and has direct and indirect impact on health [23,24]. We explored the relationship between waterlogging which is handled as exposure, illness reporting, formal health service utilisation, and related out-of-pocket expenditures, all

defined as outcomes. We approached the question in a three-step process. First, respondents recognise that they have an illness; upon reporting ill, they decide whether or not to seek formal health care; and finally, they report an expenditure (Fig 1). Our analysis does not attempt to make any epidemiological inferences about waterlogging and health; our focus is on the health care service utilisation from a behavioural perspective. And for this, from a conceptual standpoint, we have to recognise that waterlogging could play a role at each step. First, waterlogging is expected to be associated with a greater probability of reporting an illness since we expect people exposed to waterlogging to experience challenges in accessing clean water and/or to be more exposed to waterborne diseases. First, waterlogging is expected to be associated with a greater probability of reporting an illness since we expect people exposed to waterlogging to experience direct or indirect impacts on health (i.e., challenges in accessing clean water and/or to be more exposed to waterborne diseases, increased socio-economic vulnerabilities etc.). Second, given this higher disease burden, we could expect people exposed to waterlogging to present a greater probability of using healthcare services. At the same time, we recognise that waterlogging could also reduce access to care by acting both on demand, limiting communities' mobility due to flooding, and supply, limiting health service provisions due to negative consequences of flooding. Last, due to both an expected increase in service use and an increased use of resources needed to produce health services in an unfavourable (flooded) setting, waterlogging is expected to result in higher expenditure on health.

Sampling

Household selection. Households were selected for inclusion in the survey if they included 1) any member who had suffered or was suffering from any illness over the last 30 days, or (2) a pregnant woman, or (3) a mother of any child under two years of age. A listing survey identified 2919 households meeting the inclusion criteria. 596 households were selected randomly from this list, divided over 10 clusters, five in clusters vulnerable to flooding and five in clusters less vulnerable to flooding [22]. All clusters were centred around a randomly selected health service provider and had a 2–3 km radius (depending on estimated population density).

Respondent selection. Within a household, we did not interview all members. Whenever possible, we interviewed an adult male and an adult female from 1) the 18–59 age group and 2) the 60-year-old or above age group. Moreover, there were a few specific questions for all under-5 children and pregnant women. If the questions were related to a minor (i.e., less than 18 years old), we interviewed their parents or immediate caregivers.

Data

This study includes only data related to adult healthcare access. We interviewed a total of 1268 adult individuals from 596 households about their illness reporting, health service utilisation, and OOPE. Information was also collected on individual socio-demographic and economic characteristics as well as on the overall household economic profile. Only

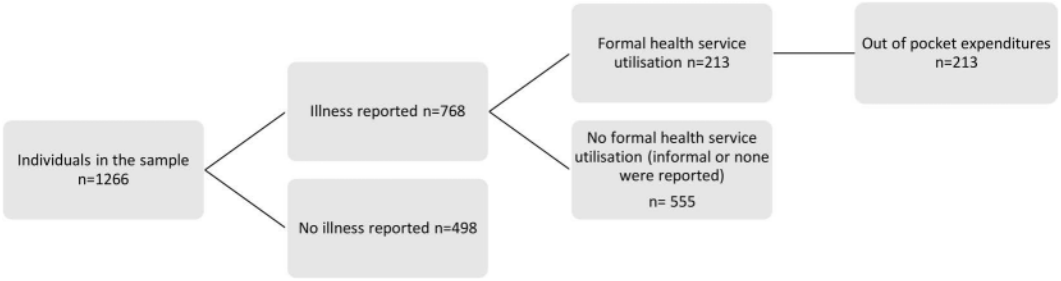

Fig 1. Data structure for illness reporting, formal health service utilisation and out-of-pocket expenditures.

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questionnaires with full information for the variables of interest were included; we excluded two individuals due to missing data. The final sample size includes 1266 adult respondents from 596 households (Fig 1). Data and script are available in supporting information (S1 Data, S2 and S3 Datas).

Variable description

Outcome variables. Three outcome variables are considered for this study: 1- illness reporting, 2-utilisation of formal health services (given illness reporting), and 3- out-of-pocket expenditure on medical care. In this study, utilisation of formal health services does not include maternal health care, it includes only health services utilisation for the chronic and acute conditions reported. Fig 1 illustrates the logic flow of individuals through the different outcomes considered for our analysis while Table 1 reports measurements for both outcome and exposure variables. An individual was classified as having reported an illness if they had reported either an acute illness in the past 30 days or a chronic illness, i.e., a condition lasting more than three consecutive months. Among those who reported an illness, we distinguished individuals who sought formal care from a health professional (=1) from those who did not (=0). The latter group may have relied on informal healthcare, visited a pharmacist, used self-treatment, consulted traditional healers, or taken no action. Finally, for those individuals who sought formal medical care, we measured out-of-pocket expenditure on formal medical care. To ensure data quality, out-of-pocket expenditure was measured as the sum of the following four variables, which allow for better recall: 1) consultation with a doctor, 2) lab tests, 3) medications, and 4) any other medical expenses (e.g., physiotherapy, healthcare instruments, blood, oxygen, etc.). Trained public health interviewers relied on digitalised data collection tools, whereby answers could be automatically checked for basic consistency and plausible values. This amount was measured in Bangladeshi Taka.

Exposure variables. In line with our research question and conceptual model, the main exposure of interest was waterlogging, measured as household having experienced waterlogging at least once in the past 12 months, based on respondents' recalling. First, we asked whether the household had experienced any of the 17 events on the list of events, including waterlogging. The year 2017 was used for recall purposes because it was the year of a destructive flood that impacted south-west Bangladesh. Follow-up questions were then asked to allow verification and discussion of the event with the respondent, such as the year and month of the last occurrence. Other questions covered the following topics, which will be used in other studies: a) The impact on household life, b) The intensity of this impact, c) Worries about the event happening again within the next 12 months. We traced waterlogging exposure back 12 months, a prolonged period, because we assumed that exposure to waterlogging can accrue over time and possibly have consequences for healthcare seeking over an extensive period. This was a trade-off between going back in time and maintaining a reasonable recall period. Moreover, we considered that communities are often exposed to waterlogging for months at a time and not just for a few days, with important effects on their socioeconomic well-being as well as on their health [10,23,25].

Our models included an additional number of individual and household-level characteristics as co-variates, both to control for confounding and to examine their effect on the outcomes of interest. These additional variables were selected based on variables identified in prior literature as relevant to influence health service utilisation and OOPE. Age was categorised as younger than 50 years old (incl.) or older than 50 years old, to reflect a categorisation of younger vs. elder individuals. Household size was categorised as fewer than 4 persons or more than 4 persons to reflect the median household size of 4. Household wealth was calculated using an asset-based measure, reflecting the standard asset composition and computational method using Principal Component Analysis indicated by the DHS. Based on the index, we further classified households into quintiles.

Data collection and management

Data were collected by a team of 20 trained field assistants using SurveyCTO software, version 2.70.

Table 1. Univariate distribution in the three samples used in the study: the sample, sample of individuals reporting any illness, sample of individuals reporting use of formal healthcare services given illness reporting.

Background factors and Outcomes	Measurement	Full sample, n (%)	Sample of individuals reporting any illness, n (%)	Sample of individuals reporting use of formal healthcare services given illness reporting (%)
Sample size		1266	768	213
Outcome variables				
Illness declaration				
Yes	Yes = 1	768 (60.7%)	768	213
No	No = 0	498 (39.3%)	–	–
Formal health service use				
Yes	Yes = 1	–	213 (27.7%)	213
No	No = 0	–	555 (72.3%)	–
Medical costs	Continuous Variable (takas)			
Zero cost		–	–	9
Min-max		–	–	0-31200
Mean(median)		–	–	4718(2900)
SD		–	–	5612.49
Individual factors				
Age group				
Younger than 50	Younger than 50 = 0	935 (73.9%)	541 (70.4%)	154 (72.3%)
Older than 50	Older than 50 = 1	331 (26.1%)	227 (29.6%)	59 (27.7%)
Gender				
Male	Male = 0	611 (48.3%)	333 (43.4%)	78 (36.6%)
Female	Female = 1	655 (51.7%)	435 (56.6%)	135 (63.4%)
Education status				
No education	No education = 0	241 (19.1%)	156 (20.3%)	41 (19.2%)
Primary	Primary = 1	380 (30.0%)	228 (29.7%)	62 (29.1%)
Secondary	Secondary = 2	599 (47.3%)	354 (46.1%)	96 (45.1%)
Higher	Higher = 3	46 (3.6%)	30 (3.9%)	14 (6.6%)
Head of household				
Yes	Yes = 1	560 (44.2%)	313 (40.8%)	77 (36.2%)
No	No = 0	706 (55.8%)	455 (59.2%)	136 (63.8%)
Household factors				
Household size				
Up to four persons	Up to 4 persons = 0	808 (63.8%)	504 (65.6%)	145 (68.1%)
More than four persons	More than 4 persons = 1	458 (36.2%)	264 (34.4%)	68 (31.9%)
Wealth				

(Continued)

Table 1. (Continued)

Background factors and Outcomes	Measurement	Full sample, n (%)	Sample of individuals reporting any illness, n (%)	Sample of individuals reporting use of formal healthcare services given illness reporting (%)
Poorest	Poorest = 0	287 (22.7%)	167 (21.7%)	39 (18.3%)
Average poor	Average poor = 1	317 (25.0%)	192 (25%)	47 (22.1%)
Average wealthy	Average wealthy = 2	317 (25.0%)	183 (23.8%)	68 (31.9%)
Wealthiest	Wealthiest = 3	345 (27.3%)	226 (29.4%)	59 (27.7%)
Experienced Waterlogging in the past 12 months				
Waterlogged	Waterlogged = 1	71 (5.6%)	53 (6.9%)	13 (6.1%)
Not waterlogged	Not waterlogged = 0	1195 (94.4%)	715 (93.1%)	200 (93.9%)
Health factors				
Declared Illness types				
None	None = 0	498 (39.3%)	–	–
Acute	Acute = 1	365 (28.8%)	365 (47.5%)	72 (33.8%)
Chronic	Chronic = 2	249 (19.7%)	249 (32.4%)	72 (33.8%)
Both acute and chronic	Both acute and chronic = 3	154 (12.2%)	154 (20.1%)	69 (32.4%)

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Analysis

Our analysis proceeded in stages. First, we used univariate and bivariate descriptive statistics to examine the data distribution for illness reporting and health service utilisation samples. Chi-square tests were used to identify the association between the two first outcomes of interest and the exposure variables.

Second, we initially decided to model the decision to use health services conditional upon illness reporting using a Heckman selection model [26]. As displayed also graphically in Fig 1, we selected this modelling approach because we wished to correct for the sample selection bias arising from the fact that health service utilisation could only be observed for those individuals who had previously reported either a chronic or acute illness [27]. Based on the results of the descriptive statistics indicating that waterlogging was associated with illness reporting, but not with service use, we selected it as an independent variable in the selection model estimating the probability of illness reporting, but not in the main equation estimating health service utilisation. Once we run the model, however, the likelihood-ratio test of independent equations indicated that the measured correlation in the errors of the two equations was not significantly different from zero (LR chi2 (df)=2.18(1), p = 0.140). This suggested that case self-selection could not be ascertained in our specific and that the results of the Heckman model were effectively equivalent to those of simpler two-step models run on truncated samples.

Therefore, as a third step, we ran two separate probit models on two distinct, yet related samples. We first estimated the probability of an individual reporting any illness (n = 1266), either chronic or acute, and then conditional upon this reporting, we estimated the probability of the individual using modern health care services (n = 768). Both models include waterlogging as an exposure variable. In our results, we report the results of the two separate probit models as our primary results and report the results of the Heckman model only in the supporting information (S4 Data).

Finally, we examined the distribution of medical costs. Only nine individuals out of the 213 ones who had sought care reported not having incurred any health expenditures. Therefore, we retained all individuals in the analysis of out-of-pocket expenditures (OOPE) and performed Welch Two Sample t-tests and Kruskal-Wallis tests to examine differences in OOPE across categories. These tests were chosen given the uneven distribution in our samples.

Data management and software

Data management and preliminary descriptive statistics were conducted using Rstudio software (Version 2023.03.1 + 446 (2023.03.1 + 446). The Heckman and the probit models were run using Stata software (BE-Basic edition, version 18.0).

Results

Socio-economic and health profiles of the respondents

Table 1 presents the socio-economic and health profiles of the respondents and their households. 73.9% of the respondents were up to 50 years of age, 51.7% were women, 19.1% received no education, 3.6% received a higher education, and 44.2% were head of household. 63.8% of the respondents came from households with up to four persons, 22.7% were classified as coming from the poorest households, while 27.3% belonged to the wealthiest households. 5.6% of the respondents were from households that had experienced waterlogging in the past 12 months. Of all respondents, 39.3% reported no illness, 28.8% reported an acute illness only, 19.7% a chronic illness only, and 12.2% reported both chronic and acute illnesses.

Bivariate analyses for illness reporting

Table 2 presents bivariate analyses for respondents reporting an illness. Our analysis suggests that important differences existed between individuals who reported and individuals who did not report an illness. In comparison to respondents who did not report illness, respondents who reported any illness were more likely to be older than 50 (29.6% vs 20.9%, $p < 0.001$), female (56.6% vs. 44.2%, $p < 0.001$), not being the head of the household (59.2% vs. 50.4%, $p = 0.002$) and coming from the household that had experienced waterlogging in the past year (6.9% vs. 3.6%, $p = 0.018$).

Bivariate analyses for formal health service utilisation

Table 3 presents bivariate analyses for respondents reporting formal health service utilisation compared to those who did not use it, conditional upon illness reporting. Respondents reporting formal health service utilisation compared to those who did not were more likely to be female (63.4% vs. 54.1%, $p = 0.024$), to come from the highest two quintiles of the wealth index (31.9 and 27.7% vs 20.7 and 30.1%, $p = 0.012$) and to have reported more often both chronic and acute illnesses (32.4% vs. 15.3%, $p < 0.001$). Waterlogging exposure was not significantly associated with health service utilisation.

Probit model estimates for illness declaration

Given the Heckman model's non-superiority, we decided to focus the analysis on the two independent probit models run on the truncated samples. We report findings accordingly and start by examining factors associated with illness reporting first and service use second. Results from the Heckman selection model are reported in the supporting information (S4 Data).

Confirming results from bivariate analysis, our probit model indicated that respondents from households experiencing waterlogging [Coef: 0.47; CI 0.14,0.80], $p = 0.006$) were more likely to report an illness compared to respondents from households not experiencing one. Moreover, respondents older than 50 [Coef: 0.35; CI 0.16,0.54], $p < 0.001$) and from wealthier quintiles [Coef: 0.26; CI 0.04,-0.48], $p = 0.018$) were also more likely to report an illness compared to other

Table 2. Bivariate analyses of illness reporting (n = 1266).

Outcomes and background factors	Have reported any illness in the full sample		Have not reported any illness in the full sample		Pearson Chi2	
	n (768)	%	n (498)	%	Chi2	p-value
Age group (*)					11.326	0.000
Younger than 50 (incl.)	541	70.4	394	79.1		
Older than 50	227	29.6	104	20.9		
Gender (*)					18.300	0.000
Male	333	43.4	278	55.8		
Female	435	56.6	220	44.2		
Education status					2.755	0.431
No education	156	20.3	85	17.1		
Primary	228	29.7	152	30.5		
Secondary	354	46.1	245	49.2		
Higher	30	3.9	16	3.2		
Head of household (*)					9.222	0.002
Yes	313	40.8	247	49.6		
No	455	59.2	251	50.4		
Household size (*)					2.551	0.110
Up to four persons	504	65.6	304	61.0		
More than four persons	264	34.4	194	39.0		
Wealth					5.274	0.153
Poorest	167	21.7	120	24.1		
Average poor	192	25.0	125	25.1		
Average wealthy	183	23.8	134	26.9		
Wealthiest	226	29.4	119	23.9		
Experienced Waterlogging in the past 12 months (*)					5.559	0.018
Waterlogged	53	6.9	18	3.6		
Not waterlogged	715	93.1	480	96.4		

Notes: (*) Dummy variable- Chi2 with Yates's continuity correction.

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respondents while males were less likely than females to do so [Coef: -0.38; CI -0.62,-0.15], p = 0.001) as well as respondents coming from larger household [Coef: -0.20; CI -0.36,-0.04], p = 0.013).

Probit model estimates for formal health service utilisation

213 out of the 768 respondents having reported an illness declared using health services in the prior month (27.7%). Table 4 presents the results of a probit for formal health service utilisation. Confirming results from the bivariate analysis, the model detected no significant association between waterlogging and service use. Health service use was found to be associated with higher education (no education compared to higher [Coef: -0.70; CI -1.24,-0.16], p = 0.011, primary compared to higher education: [Coef: -0.63; CI -1.14, -0.13], p = 0.014 and secondary compared to higher education [Coef: -0.67; CI -1.16,0.18], p = 0.007); household wealth, with the poorest experiencing the lowest utilisation, and illness type with respondents reporting chronic and both chronic and acute illnesses being more likely to seek formal care than those reporting only an acute condition (chronic: [Coef: 0.28; CI 0.52,0.52], p = 0.017, chronic and acute: [Coef: 0.71; CI 0.46,0.97], p < 0.001).

Table 3. Bivariate analyses of health service utilisation conditional upon illness reporting.

Outcomes and background factors	Used formal care		Did not use formal care		Pearson Chi2	
	n (213)	%	n (555)	%	Chi2	p-value
Age group (*)					0.373	0.541
Younger than 50 (incl.)	154	72.3	387	69.7		
Older than 50	59	27.7	168	30.3		
Gender (*)					5.078	0.024
Male	78	36.6	255	45.9		
Female	135	63.4	300	54.1		
Education status					5.630	0.131
No education	41	19.2	115	20.7		
Primary	62	29.1	166	29.9		
Secondary	96	45.1	258	46.5		
Higher	14	6.6	16	2.9		
Head of household (*)					2.331	0.127
Yes	77	36.2	236	42.5		
No	136	63.8	319	57.5		
Household size (*)					0.641	0.423
Up to four persons	145	68.1	359	64.7		
More than four persons	68	31.9	196	35.3		
Wealth					11.023	0.012
Poorest	39	18.3	128	23.1		
Average poor	47	22.1	145	26.1		
Average wealthy	68	31.9	115	20.7		
Wealthiest	59	27.7	167	30.1		
Experienced Waterlogging in the past 12 months (*)					0.145	0.703
Waterlogged	13	6.1	40	7.2		
Not waterlogged	200	93.9	515	92.8		
Illness type					34.244	0.000
Acute	72	33.8	293	52.8		
Chronic	72	33.8	177	31.9		
Both	69	32.4	85	15.3		

Notes: (*) Dummy variable- Chi2 with Yates's continuity correction.

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Mean medical costs for formal healthcare

Only 9 individuals out of a total of 213 reported no medical healthcare costs, which means that 95.8% of respondents reported out-of-pocket expenditures for medical costs (mean:4718 takas, SD:5612.49, median:2900 takas, with 1 USD being equivalent to approximately 121 takas - Table 1). Table 5 shows that respondents from average wealthy and wealthiest households reported significantly higher costs (mean = 5345 takas, mean = 5933 takas) compared to respondents from poorest households (mean = 3309 takas) and average poor (mean 3453 takas), $p = 0.029$. Respondents reporting acute illness had significantly lower costs (mean = 2555 takas) compared to respondents reporting chronic (median = 5817 takas) or both types of illnesses (mean = 5827 takas), $p < 0.001$. Having experienced waterlogging was not found to be associated with higher medical costs in formal healthcare ($p = 0.635$).

Table 4. Probit for illness declaration and health service utilisation.

	Model 1		Model 2	
	Illness reporting		Formal health service utilisation	
Background characteristics	**Coef. (C.I.)**	**P-value**	**Coef. (C.I.)**	**P-value**
Age group				
Younger than 50	Ref.		Ref.	
Elders (50 + years old)	0.35(0.16,0.54)	0.000***	-0.05(-0.30,0.19)	0.668
Gender				
Female	Ref.		Ref.	
Male	-0.38(-0.62,-0.15)	0.001***	-0.23(-0.55,0.08)	0.150
Education status				
Higher education	Ref.		Ref.	
No education	-0.23(-0.66,0.20)	0.288	-0.70(-1.24,-0.16)	0.011*
Primary	-0.19(-0.59,0.22)	0.360	-0.63(-1.14,-0.13)	0.014*
Secondary	-0.27(-0.67,0.12)	0.169	-0.67(-1.16,0.18)	0.007*
Head of household				
Yes	Ref.		Ref.	
No	-0.01(-0.24,0.23)	0.963	0.01(-0.30,0.32)	0.940
Household size				
4 pers. or less	Ref.		Ref.	
5 or more pers.	-0.20(-0.36,-0.04)	0.013*	-0.08(-0.30,0.14)	0.489
Wealth				
Poorest	Ref.		Ref.	
Average poor	0.01(-0.08,0.34)	0.224	0.05(-0.25,0.35)	0.755
Average wealthy	0.02(-0,19,0.23)	0.829	0.41(0.12,0.70)	0.006**
Wealthiest	0.26(0.04,0.48)	0.018*	0.09(-0.22,0.39)	0.575
Waterloggging				
No	Ref.		Ref.	
Yes	0.47(0.14,0.80)	0.006**	-0.11(-0.51,0.29)	0.600
Illness reporting				
Acute illness	–	–	Ref.	
Chronic illness	–	–	0.28(0.52,0.52)	0.017*
Acute and chronic	–	–	0.71(0.46,0.97)	0.000***
Constant	0.55(0.07,1.02)	0.024*	-0.21(-.83,0.40)	0.497
Model statistics				
/athrho	–	–	–	–
Rho	–	–	–	–
Wald chi2 (df)				
LR chi2(df)	56.73(11)	0.000***	56.09(13)	0.000***
LR chi2 (df) test of indpt eqns. (Rho = 0)	–	–	–	–
Selected observations	–	–	–	–
Non selected observations	–	–	–	–
Total observations	1266		768	
Pseudo R2	0.033		0.062	–

Notes: Coef. (C.I.): coefficient (Confidence Intervals). *0.05, **0.01***0.001.

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Table 5. Bivariate analyses for the mean medical costs for respondents reporting formal healthcare access (n = 213).

Background factors and outcomes	Mean medical costs for health service utilisation (Takas)	
	Mean	P-value
N Total	213	
Age group		0.473
Younger than 50	4556.75	
Older than 50	5137.63	
Gender		0.813
Male	4818.53	
Female	4659.36	
Education status		0.622
No education	5187 (median = 3550)	
Primary	4171 (median = 2553)	
Secondary	4306 (median = 2500)	
Higher	8584 (median = 5730)	
Head of household		0.3709
Yes	4298.69	
No	4954.85	
Household size		0.2701
Up to 4 persons	4447.22	
More than 4 persons	5294.29	
Wealth		0.029*
Poorest	3309 (median = 1700)	
Average poor	3453 (median = 1650)	
Average wealthy	5345 (median = 3854)	
Wealthiest	5933 (median = 3400)	
Experienced Waterlogging in the past 12 months		0.6354
Yes	5444.23	
No	4670.42	
Illness reporting		0.000***
Acute	2555 (median = 800)	
Chronic	5817 (median = 5010)	
Both acute and chronic	5827 (median = 3700)	

Notes: Welch Two Sample t-test were performed when two categories and Kruskal-Wallis test for three or more categories.

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Discussion

This article presents the results of an original study aimed at understanding the association between waterlogging, the health of populations and their use of healthcare in a region of a country facing numerous events linked to climate [22,28]. The results confirm our conceptual standpoint on the association between waterlogging during the last 12 months of the survey and the declaration of episodes of illness, whether chronic or acute. Moreover, and thanks to a rigorous analytical approach, the study does not confirm the hypothesis of an association between waterlogging and the use of health services. The same applies to healthcare expenditure, the association with waterlogging is not verified. People exposed to waterlogging reported feeling sicker but did not appear to face greater barriers in access to care nor greater expenditure. This study provides relatively original insights into the role of waterlogging but also confirms more general trends.

First we note that research into health services utilisation has not yet given much thought to the role of waterlogging and its possible impacts [28,29]. While the link between waterlogging and people's lives is much analysed in agricultural or climate research, limited if any attention has been paid to its effects on health, particularly in relation to health systems [4,8,9,14]. This is one of the first studies to look at human health and, above all, access to care and financial protection, essential elements of health systems which together with others are often overlooked in climate research in Bangladesh [14]. As one of the determinants of population health, the health system is also often overlooked in climate research [22,30]. For One Health experts, the association between waterlogging and the occurrence of episodes of illness is not surprising, given that we know to what extent environmental health and human health are intertwined [31], particularly in Bangladesh [18,28,32,33]. Despite few studies, soil contamination by saltwater intrusion impacts the agricultural system and human health [29]. Studies in Bangladesh all confirm the effects of the environment on human health and the onset of disease, such as water salinity on hypertension, pre-eclampsia [34,35] and mental health [17]. In the Khulna district, close to our study area, a qualitative study shows that the population is well aware that the lack of "*pure drinking water aggravated the spread of waterborne diseases*" [36] after the cyclones.

Perhaps more surprising is that, conditional on illness reporting, we did not detect higher health service utilisation, and subsequently also higher healthcare expenditure, among individuals exposed to waterlogging. At the same time, we note that waterlogging was also not associated with reduced utilisation of formal healthcare services. Therefore, both hypotheses we advanced ex-ante were disattended by our findings, suggesting that in spite of higher health needs, people exposed to waterlogging do not tend to seek more care, yet they do not necessarily face greater barriers to access than those not exposed to waterlogging. This finding partially contradicts evidence emerging from the literature on floods, suggesting that health service use is affected negatively for up to three subsequent years [19]. To this respect, our study highlights the importance of investigating waterlogging as a distinct phenomenon from floods. We note, however, that the conceptual underpinning of the Universal Health Coverage (UHC) concept is that the more health needs people have, the more they should be able to be treated without becoming impoverished [37]. Our study clearly indicates that many people are still forgoing care and when receiving care, they pay a very high price for it. In Bangladesh, studies have long shown that while the country is well ahead in preventive services such as (free) vaccinations [38], barriers to accessing curative services (not free) are very high, as shown by the two recent national surveys [39,40]. The spatial distribution of curative services and payment arrangements can partly explain those barriers [28,41]. The latest DHS for Bangladesh in 2022 shows that 84%, 75% and 66% of children who reported an episode of ARI, fever or diarrhoea, respectively, sought advice or treatment. However, this relatively high figure does not apply to traditional practitioners and includes all forms of recourse (public and private sectors, NGOs) [39]. Most of them went to a pharmacy/drug store, confirming the challenges of providing a quality service at a lower cost. Moreover, the Bangladeshi healthcare system is highly fragmented and not always well adapted to dealing with environmental crises [42]. In the Khulna division, where our study area is located (Satkhira district), there is a low level of training and supervision of routine staff compared with the rest of the country, and this is the division where the percentage of facilities offering curative services is the lowest. It is the 3rd lowest for all essential services, including standard deliveries [40].

Moreover, the people of Bangladesh, as elsewhere in Southeast Asia, are paying a heavy financial price in a context where user fees continue to be the norm due to low effective implementation of social health protection systems [41,43,44]. Our study in Tala confirms that out-of-pocket payments remain considerably high, with the average value being equivalent to USD 38, and that the ability to pay for care influences healthcare spending, posing a challenge to the equity of the healthcare system [45,46]. Over 70% of healthcare payments in Bangladesh are made directly by households, far more than India and Pakistan, and this proportion has been rising steadily over the last 20 years [47]. Only 0.3% of women aged between 15 and 49 have health insurance in Bangladesh, and the two main problems preventing them from using health services are the lack of money to pay for treatment and the distance from the facility [39]. So, in waterlogging areas exacerbated by climate change,

people have more significant needs (both physical and mental) but are faced with a health system that does not have the resources to cope. Yet the responsiveness of healthcare systems is one of the essential characteristics of their performance [48]. In addition, studies on the resilience of healthcare systems show that it is necessary to anticipate these chronic or acute shocks to better plan adaptation strategies to meet the needs of populations [49,50]. The status quo is not an option, and the shortage of rural health workers and the continuation of user fees without the organisation of health insurance systems will continue to fail to meet people's needs. However these needs are bound to increase in the context of climate change, with waterlogging being only one of the many consequences, not even the primary one [29]. So, experts in Bangladesh argue that "*A climate change resilient health care system needs to be developed*" [28]. The political will announced for UHC in Bangladesh [42] must now take concrete form, especially in the current context where the public calls for significant changes to be organised in favour of social protection.

More generally, our study confirms the burden of chronic disease in this part of the world, including in Bangladesh's relatively rural and isolated area. On a national scale, managing chronic diseases (and non-communicable diseases) is becoming a priority, given the extent of their burden in the context of the epidemiological transition [39,51]. This poses another major challenge in terms of adapting the healthcare system, especially as the Tala study confirms that people living with a chronic illness incur higher healthcare costs than others. In addition, the results confirm the influence of age, gender and socio-economic status on illness reporting, confirming what Sen [52] already postulated a long time ago. This question poses another challenge, given that the expression of a health need significantly influences the use of healthcare beyond the issues linked to the healthcare system [53].

While this study is original, it is important to note certain limitations. Firstly, we emphasise the relatively small sample size and the fact that few people in our sample recalled exposure to waterlogging. Data were collected at the end of the monsoon season, but it was a year of drought. The drought might explain the small number of respondents from households that experienced waterlogging in the past year, reflecting perhaps an intense vulnerability to waterlogging in standard years. Secondly, the structure of our data only allows us to explore associations and not to detect causality. Third, all measures used in the study are self-reported, with all associated limitations that must be acknowledged. Yet, we recognise that no better data are currently available in the country to examine this association between waterlogging, service use, and expenditure. Fourthly, this study is part of a larger project and the data collection protocol, including the selection criteria, is intended for use in several studies. Households were selected for inclusion in the survey if they included 1) any member who had suffered or was suffering from any illness over the last 30 days, or (2) a pregnant woman, or (3) a mother of any child under two years of age. These criteria are the point of entry into the household. Then an adult male and an adult female from 1) the 18–59 age group and 2) the 60-year-old or above age group were interviewed. Only adult respondents were included in this study.

Last, we note that we could not integrate into the model supply-side factors, such as actual service availability and quality of care indicators, due to a lack of pertinent data. Furthermore, we chose to operationalise the research question concerning the use of formal healthcare services, but this does not mean that informal care is not being used either.

Conclusion

This study demonstrates that waterlogging, defined as persistent stagnant water on land, is associated with a higher probability of reporting illness but not with a higher probability of seeking formal care or reporting higher health expenditure. While the country has improved dramatically in terms of health in the past 50 years [54], Bangladesh is facing a serious threat to its development: deteriorating environmental conditions related to land and water management choices, exacerbated by climate change [10,12,23]. This study shows that new efforts are needed to strengthen health systems and meet increasing health needs in time of climate change, so that the financial burden is not left to the people living in affected areas.

Supporting information

S1 Data. Script and data information.
(DOCX)

S2 Data. Probit data.
(DTA)

S3 Data. OOPE data.
(DTA)

S4 Data. Heckprobit results.
(DOCX)

S1 Checklist. Inclusivity.
(DOCX)

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References

1. Masson-Delmotte V, Zhai P, Pirani S, Connors C, Péan S, Berger N, et al. Summary for Policymakers. Climate Change 2021: The Physical Science Basis. IPCC; 2021.
2. Ding Y, Wang H, Liu Y, Lei X. Urban waterlogging structure risk assessment and enhancement. J Environ Manage. 2024;352:120074. https://doi.org/10.1016/j.jenvman.2024.120074 PMID: 38266521
3. Zhang Q, Wu Z, Zhang H, Dalla Fontana G, Tarolli P. Identifying dominant factors of waterlogging events in metropolitan coastal cities: the case study of Guangzhou, China. J Environ Manage. 2020;271:110951. https://doi.org/10.1016/j.jenvman.2020.110951 PMID: 32579518

4. Tian L-X, Zhang Y-C, Chen P-L, Zhang F-F, Li J, Yan F, et al. How does the waterlogging regime affect crop yield? A global meta-analysis. Front Plant Sci. 2021;12:634898. https://doi.org/10.3389/fpls.2021.634898 PMID: 33679848
5. Kaur G, Singh G, Motavalli PP, Nelson KA, Orlowski JM, Golden BR. Impacts and management strategies for crop production in waterlogged or flooded soils: a review. Agronomy J. 2020;112(3):1475–501. https://doi.org/10.1002/agj2.20093
6. Hossain M. Water logging problems in urban areas of Bangladesh and solution with analytical approach. BRAC J. 2013;01:1–7.
7. Liu K, Harrison MT, Yan H, Liu DL, Meinke H, Hoogenboom G, et al. Silver lining to a climate crisis in multiple prospects for alleviating crop waterlogging under future climates. Nat Commun. 2023;14(1):765. https://doi.org/10.1038/s41467-023-36129-4 PMID: 36765112
8. Nóia Júnior R de S, Asseng S, García-Vila M, Liu K, Stocca V, dos Santos Vianna M, et al. A call to action for global research on the implications of waterlogging for wheat growth and yield. Agric Water Manag. 2023;284:108334. https://doi.org/10.1016/j.agwat.2023.108334
9. Alam R, Quayyum Z, Moulds S, Radia MA, Sara HH, Hasan MT, et al. Dhaka city water logging hazards: area identification and vulnerability assessment through GIS-remote sensing techniques. Environ Monit Assess. 2023;195(5):543. https://doi.org/10.1007/s10661-023-11106-y PMID: 37017822
10. Dewan C. Misreading the Bengal Delta: climate change, development, and livelihoods in coastal Bangladesh. Seattle: University of Washington Press; 2021.
11. Awal MA, Islam AFMT. Water logging in South-Western coastal region of Bangladesh: causes and consequences and people's response. AJGR. 2020;9–28.
12. Tareq SM, Tauhid Ur Rahman M, Zahedul Islam AZM, Baddruzzaman ABM, Ashraf Ali M. Evaluation of climate-induced waterlogging hazards in the south-west coast of Bangladesh using geoinformatics. Environ Monit Assess. 2018;190(4):230. https://doi.org/10.1007/s10661-018-6591-9 PMID: 29556796
13. Rahaman MdS, Hossain N, Nurain A, Sarker P, Ichihara S. Investigation on causes and effects of waterlogging in the southern part of Bangladesh. MSD. 2020;12(2):4–11. https://doi.org/10.54989/msd-2020-0006
14. Alam MdS, Sasaki N, Datta A. Waterlogging, crop damage and adaptation interventions in the coastal region of Bangladesh: a perception analysis of local people. Environ Dev. 2017;23:22–32. https://doi.org/10.1016/j.envdev.2017.02.009
15. Islam MdR, Raja DR. Waterlogging risk assessment: an undervalued disaster risk in coastal urban community of Chattogram, Bangladesh. Earth. 2021;2(1):151–73. https://doi.org/10.3390/earth2010010
16. Masud MdM. The impact of waterlogging on health and education of orphans in the Southwest Region of Bangladesh. 2018.
17. Kabir S, Newnham E, Dewan A, Islam MdM, Hamamura T. Psychological health declined during the post-monsoon season in communities impacted by sea-level rise in Bangladesh. Commun Earth Environ. 2024;5(1). https://doi.org/10.1038/s43247-024-01862-1
18. Anik AH, Sultan MB, Alam M, Parvin F, Ali MM, Tareq SM. The impact of climate change on water resources and associated health risks in Bangladesh: a review. Water Sec. 2023;18:100133. https://doi.org/10.1016/j.wasec.2023.100133
19. Baten A, Wallemacq P, van Loenhout JAF, Guha-Sapir D. Impact of recurrent floods on the utilization of maternal and newborn healthcare in Bangladesh. Matern Child Health J. 2020;24(6):748–58. https://doi.org/10.1007/s10995-020-02917-3 PMID: 32285334
20. Petricola S, Reinmuth M, Lautenbach S, Hatfield C, Zipf A. Assessing road criticality and loss of healthcare accessibility during floods: the case of Cyclone Idai, Mozambique 2019. Int J Health Geogr. 2022;21:14.
21. Wiesehahn LT, Kaifie A. The impact of the 2021 flood on the outpatient care in the North Rhine region, Germany: a cross-sectional study. BMC Public Health. 2024;24(1):250. https://doi.org/10.1186/s12889-023-17279-y PMID: 38254123
22. Clech L, Meister S, Belloiseau M, Benmarhnia T, Bonnet E, Casseus A, et al. Healthcare system resilience in Bangladesh and Haiti in times of global changes (climate-related events, migration and Covid-19): an interdisciplinary mixed method research protocol. BMC Health Serv Res. 2022;22.
23. Clech L, Sierra JP, Mannan MA, Kabir MMS, Barua M, Espinoza J-C, et al. Local social-ecological context explains seasonal rural-rural migration of the poorest in south-west Bangladesh. PLOS Clim. 2024;3(3):e0000239. https://doi.org/10.1371/journal.pclm.0000239
24. Talukder B, Schubert JE, Tofighi M, Likongwe PJ, Choi EY, Mphepo GY, et al. Complex adaptive systems-based framework for modeling the health impacts of climate change. J Clim Chang Health. 2024;15:100292. https://doi.org/10.1016/j.joclim.2023.100292 PMID: 38425789
25. Neelormi S, adri N, Ahmed AU. Gender dimensions of differential health effects of climate change induced water-logging: a case study from coastal Bangladesh. IOP Conf Ser: Earth Environ Sci. 2009;6(14):142026. https://doi.org/10.1088/1755-1307/6/14/142026
26. Van de Ven WPMM, Van Praag BMS. The demand for deductibles in private health insurance. J Econometrics. 1981;17(2):229–52. https://doi.org/10.1016/0304-4076(81)90028-2
27. Pokhrel S, De Allegri M, Gbangou A, Sauerborn R. Illness reporting and demand for medical care in rural Burkina Faso. Soc Sci Med. 2010;70(11):1693–700. https://doi.org/10.1016/j.socscimed.2010.02.002 PMID: 20299143
28. Chowdhury MdA, Hasan MdK, Islam SLU. Climate change adaptation in Bangladesh: current practices, challenges and the way forward. J Clim Change Health. 2022;6:100108. https://doi.org/10.1016/j.joclim.2021.100108
29. Palmeiro-Silva Y, Rivera F, Hartinger S. Climate change and health within the sendai framework for disaster risk reduction: opportunities and challenges. Int J Disaster Risk Sci. 2025;16(1):33–43. https://doi.org/10.1007/s13753-024-00610-5

30. Ridde V, Benmarhnia T, Bonnet E, Bottger C, Cloos P, Dagenais C, et al. Climate change, migration and health systems resilience: need for interdisciplinary research. F1000Res. 2019;8:22. https://doi.org/10.12688/f1000research.17559.2 PMID: 32983410
31. McKenzie JS, Dahal R, Kakkar M, Debnath N, Rahman M, Dorjee S, et al. One Health research and training and government support for One Health in South Asia. Infect Ecol Epidemiol. 2016;6:33842. https://doi.org/10.3402/iee.v6.33842 PMID: 27906123
32. Hasan MK, Shahriar A, Jim KU. Water pollution in Bangladesh and its impact on public health. Heliyon. 2019;5(8):e02145. https://doi.org/10.1016/j.heliyon.2019.e02145 PMID: 31406938
33. Masud MA. The impact of waterlogging on health and education of orphans in the southwest region of Bangladesh. Department of Social Services (DSS), Ministry of Social Welfare, Government of Bangladesh; 2018. https://www.researchgate.net/publication/353427696_The_Impact_of_Waterlogging_on_Health_and_Education_of_Orphans_in_the_Southwest_Region_of_Bangladesh
34. Khan AE, Scheelbeek PFD, Shilpi AB, Chan Q, Mojumder SK, Rahman A, et al. Salinity in drinking water and the risk of (pre)eclampsia and gestational hypertension in coastal Bangladesh: a case-control study. PLoS One. 2014;9(9):e108715. https://doi.org/10.1371/journal.pone.0108715 PMID: 25268785
35. Shammi M, Rahman MM, Bondad SE, Bodrud-Doza M. Impacts of salinity intrusion in community health: a review of experiences on drinking water sodium from coastal areas of Bangladesh. Healthcare (Basel). 2019;7(1):50. https://doi.org/10.3390/healthcare7010050 PMID: 30909429
36. Kabir R, Khan HTA, Ball E, Caldwell K. Climate change impact: the experience of the coastal areas of Bangladesh affected by cyclones Sidr and Aila. J Environ Public Health. 2016;2016:9654753. https://doi.org/10.1155/2016/9654753 PMID: 27867400
37. Abiiro GA, De Allegri M. Universal health coverage from multiple perspectives: a synthesis of conceptual literature and global debates. BMC Int Health Hum Rights. 2015;15:17. https://doi.org/10.1186/s12914-015-0056-9 PMID: 26141806
38. Sarkar PK, Sarker NK, Doulah S, Bari TIA. Expanded programme on immunization in Bangladesh: a success story. Bangladesh J Child Health. 2017;39(2):93–8. https://doi.org/10.3329/bjch.v39i2.31540
39. DHS. Bangladesh Demographic and Health Survey 2022. Final Report. Rockville, Maryland, USA: National Institute of Population Research and Training Medical Education and Family Welfare Division Ministry of Health and Family Welfare; 2024.
40. icddr,b. Bangladesh Health Facility Survey 2022. Bangladesh: NIPORT and icddr,b; 2024.
41. Joarder T, Chaudhury TZ, Mannan I. Universal health coverage in Bangladesh: activities, challenges, and suggestions. Psyche (Camb Mass). 2019;2019:4954095. https://doi.org/10.1155/2019/4954095 PMID: 33281233
42. Sarker M, Hossain P, Ahmed ST, Barua M, Sutradhar I, Ahmed SM. A critical look at synergies and fragmentations of universal health coverage, global health security, and health promotion in delivery of frontline health care services: a case study of Bangladesh. Lancet Reg Health Southeast Asia. 2022;7:100087. https://doi.org/10.1016/j.lansea.2022.100087 PMID: 37383936
43. Fahim SM, Bhuayan TA, Hassan MZ, Abid Zafr AH, Begum F, Rahman MM, et al. Financing health care in Bangladesh: policy responses and challenges towards achieving universal health coverage. Int J Health Plann Manage. 2019;34(1):e11–20. https://doi.org/10.1002/hpm.2666 PMID: 30238490
44. International Labour Organisation ILO. Extending social health protection: Accelerating progress towards universal health coverage in Asia and the Pacific. 22. Genève: International Labour Organisation (ILO); 2021.
45. Mitra DK, Mridha MK. Sustaining progress in the health landscape of Bangladesh. Lancet Glob Health. 2023;11(12):e1838–9. https://doi.org/10.1016/S2214-109X(23)00494-1 PMID: 37973328
46. Sarker AR, Sultana M, Alam K, Ali N, Sheikh N, Akram R, et al. Households' out-of-pocket expenditure for healthcare in Bangladesh: A health financing incidence analysis. Int J Health Plann Manage. 2021;36(6):2106–17. https://doi.org/10.1002/hpm.3275 PMID: 34218437
47. WHO. World Health Organization Global Health Expenditure Database. 2025.
48. WHO. The world health report. 2000.
49. Blanchet K. Health system resilience. Understanding complex adaptive systems. Cambridge, Massachusetts: The MIT Press; 2025.
50. Gilson L, Barasa E, Nxumalo N, Cleary S, Goudge J, Molyneux S, et al. Everyday resilience in district health systems: emerging insights from the front lines in Kenya and South Africa. BMJ Glob Health. 2017;2(2):e000224. https://doi.org/10.1136/bmjgh-2016-000224 PMID: 29081995
51. Islam SMS, Uddin R, Das S, Ahmed SI, Zaman SB, Alif SM, et al. The burden of diseases and risk factors in Bangladesh, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Glob Health. 2023;11(12):e1931–42. https://doi.org/10.1016/S2214-109X(23)00432-1 PMID: 37973341
52. Sen A. Health: perception versus observation. BMJ. 2002;324(7342):860–1. https://doi.org/10.1136/bmj.324.7342.860 PMID: 11950717
53. Levesque J-F, Harris MF, Russell G. Patient-centred access to health care: conceptualising access at the interface of health systems and populations. Int J Equity Health. 2013;12:18. https://doi.org/10.1186/1475-9276-12-18 PMID: 23496984
54. Perry HB, Chowdhury AMR. Bangladesh: 50 years of advances in health and challenges ahead. Glob Health Sci Pract. 2024;12:e2300419.