The Self-Reported Human Health Impacts of Disaster on People in India: A Cross-Sectional Analysis of the Longitudinal Aging Study India

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Abbreviations:
AOR: adjusted odds ratio
CAPI: Computer Assisted Personal Interview
CEB: Census Enumeration Block
CI: confidence interval
ICMR: Indian Council of Medical Research
LASI: Longitudinal Aging Study India
PSU: Primary Sampling Units
RR: relative risk

Abstract

Introduction: The human health impacts of disaster are predicted to increase in frequency and severity due to the effects of climate change. This has impacts on all nations, but understanding disaster-related health impacts in highly populous nations, such as India, will help to inform risk preparedness and reduction measures for large proportions of the global population.

Problem: Disaster-related human health impacts in India were examined via the use of survey data to inform risk reduction.

Methods: A cross-sectional analysis of Wave 1 (2017-2018) data from the Longitudinal Aging Study India (LASI) was conducted to explore the impact of both natural and human-induced disasters on the self-reported health of people 45 years and above, as well as their partners (irrespective of age). Descriptive statistics, chi square tests of association, odds ratio, and logistic regression were used to analyze the data by socio-demographics, geographic location, and health concern type.

Results: Out of a total 72,250 respondents, 2,301 (3.5%) reported disaster-related health impacts, of which 90.1% were significant. Rural residents and those with no education were more likely to be affected. Droughts were most commonly responsible for affecting human health (41.7%), followed by floods (24.0%). Two-thirds of the sample reported psychological trauma and one-in-five experienced chronic illness.

Discussion: The LASI study presents an important first understanding of the self-reported human health impacts of disasters, both natural and human-induced in India. Findings indicate social determinants such as education level and rurality impact risk of disaster-related health impacts, while mental health concerns represent the biggest disaster-related health concern.

Conclusion: Future waves of LASI should be examined to determine if human health impacts are increasing due to the effects of climate change, as well as the vulnerability of an aging cohort.

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Introduction

Disaster events such as floods, earthquakes, and heatwaves have been shown to have significant physical health consequences.[1–4] Direct injuries and trauma resulting from these events can lead to disabilities, fractures, wounds, and acute health conditions. Moreover, the disruption of health care systems during and after disasters further exacerbates the challenges faced in managing physical health outcomes.[5]

The toll of disasters on mental health is equally substantial.[6] Survivors often experience psychological distress, posttraumatic stress disorder (PTSD), anxiety, and depression. Disasters, with their associated loss of lives, displacement, property damage, and social

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disruption, can have long-lasting psychological effects on individuals and communities, including first responders.[7]

Disasters also contribute to the spread of infectious diseases.[8] Poor sanitation and hygiene, overcrowding in temporary shelters, and disruptions to health care services create conditions favorable for the transmission of water-borne and vector-borne diseases. Contaminated water sources and inadequate access to medical care significantly increase the risk of disease outbreaks in the aftermath of disasters.

In addition to direct health impacts due to disaster, disasters also affect social well-being, which is closely intertwined with overall health outcomes.[9,10] Displacement, loss of livelihoods, and damage to infrastructure disrupt communities and social networks. This often results in social isolation, loss of social support systems, and increased vulnerability, particularly among marginalized populations.

Individuals with pre-existing chronic health conditions face heightened vulnerabilities during and after disasters.[11,12] Disruptions to health care facilities and limited access to medications further compromise the management of chronic diseases, such as diabetes, hypertension, and respiratory disorders. The stress experienced during and after disasters can exacerbate these conditions, leading to adverse health outcomes. With older people more likely to have pre-existing medical conditions, they represent a particularly vulnerable group in disaster events.[13]

As a county, India has the world's second largest population of people aged 60 years and over and the growth of the aging population in India is significant: three-times that of the average annual all-age population growth rate.[14] Alongside other countries struggling with issues due to aging populations, such as Japan, China, and the United States,[15] there is a growing elderly population in India facing health-related risks due to disasters.[16,17] This is concerning, given India as a country is susceptible to a variety of disasters due to its geographical location, diverse climate patterns, and high population density.[17,18]

Long-term assessment of extreme weather events in India has found that floods and tropical cyclones account for the largest proportion of disaster-related mortality between 1970 and 2019.[19] More recently, from 1995 through 2020, India was hit by 1,058 disaster events, with floods the most common (33%), followed by heatwaves (24%), droughts (22%), cold waves (16%), and cyclones (5%).[20] These events result in significant mortality and morbidity.[21,22] In some of the most disaster-prone states of India,[23] significant mental health challenges are experienced in the face of economic disadvantage and, at times, migration.[24] Despite the Indian subcontinent's risk from disasters, mortality rates due to extreme weather events are reported to be decreasing, even in the face of increasing frequency of such events.[19] Research has also highlighted community resilience in the face of disasters, including among at-risk groups such as fishers.[25]

At the same time, India has a health care system which is in transition.[26] Currently, India adopts a pluralistic approach with a combination of public and government-regulated (through the Insurance Regulatory and Development Authority; Hyderabad, India) private health insurances, as well as a largely no-cost public hospital system for Indian residents, aside from small, often symbolic, co-payments for some services.[27] The public health care system comprises three tiers. At the primary care level, care includes family planning, maternal and child-health-related services, immunization, prevention of locally endemic diseases, treatment of common diseases or injuries, and health education.[28] At the secondary level, cases referred from the primary level are treated by specialists at the district hospital at the district level and the Community Health Centre (CHC) at the block level. Finally, at the tertiary level, specialized consultative and intensive care is provided, usually on referral from the primary or secondary level. Moving forward, cross-sectoral approaches to reform India's health system, which almost collapsed during the COVID-19 pandemic,[29] are exploring ways to address the achievement of universal health coverage across all health services.[29]

With the increased frequency and severity of disasters attributed to climate change,[30] it becomes crucial to understand the extensive impact of these events on human health in India. This is particularly relevant for older people as an at-risk cohort. As such, this study aimed to examine the self-reported human health impacts of disasters (both natural and human-induced) on people aged 45 years and over in India using survey data.

Materials and Methods

Data Source

The Longitudinal Aging Study India (LASI) is an on-going, nationally representative longitudinal study involving people aged 45 and over (and their spouse, regardless of age) in India that gathers information on their health, economic, psychological, and social well-being.[31] Age 45 was chosen to harmonize the LASI with health and retirement surveys in Asia and to allow measurement of pre-retirement behavior.[31] Due to its sample size, it has been described as the largest national health and retirement study in the world.[14]

The LASI study comprises both household and individual modules. Household modules cover a range of topics including housing and the built environment, assets, income, and insurance, among others. Within the individual modules, demographics, health status, health behaviors, family and social network, work, and retirement, among others.[14]

Sample Design

The target sample for LASI is non-institutionalized Indian residents aged 45 and older and their spouses (irrespective of age). The LASI study adopts a multi-stage clustering sampling design: a three-stage sample design in rural areas and a four-stage sample design in urban areas. In each state, the first stage involved selection of Primary Sampling Units (PSUs), or sub-districts (Tehsils/Talukas); the second stage involved the selection of Secondary Sampling Units (SSUs), such as villages from rural areas and wards from urban areas of the selected PSUs. In rural areas, at the third stage, households were chosen from selected villages. However, sampling in urban areas involved one more stage. From each selected urban ward, one Census Enumeration Block (CEB) was randomly selected in the third stage. At the fourth stage, households from this CEB were selected. The main reason for adopting a four-stage sample design in urban areas is that urban wards are quite large, making it difficult to list all the households in a ward (Figure 1).

Geographic Coverage and Sampling Design

Wave 1 of LASI covers all states and union territories of India with a panel sample of 72,250 older adults aged 45 years and above, derived from an eligible sample of 82,650 individuals (a collection rate of 87.4%). More broadly, India as of 2024 has a population of 1.409 billion, of which females account for 48.5%. The median age of the population is 29.8 years, with 36.4% of the population

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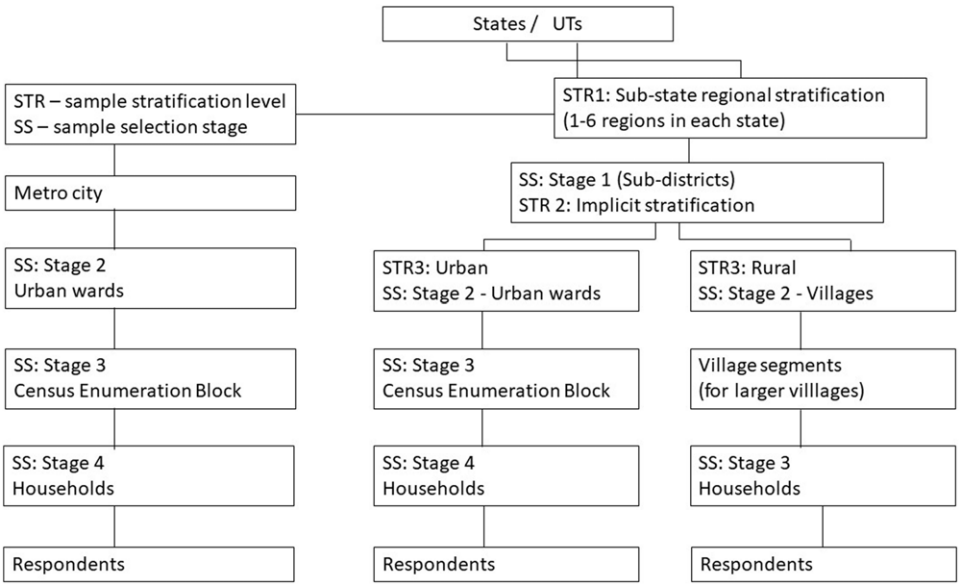

Figure 1. Sampling Design Framework Flowchart. Note: Source - LASI Wave-1 Report.[31]

residing in urban areas.[32] Life expectancy at birth for females is 70.1 years and for males is 66.5 years.[32]

The long-term goal of LASI is to continue this survey for the next 25 years with the first wave undertaken in 2017-2018 and released for use by researchers in 2021.[14] The second wave was planned for 2022-2023. The aim of LASI is to obtain all the indicators for the states and union territories. Being Wave 1, these data represent a valuable baseline of disaster-related health effects for comparison.

Data Collection

For LASI, a Computer Assisted Personal Interview (CAPI) technology was used to collect data in the field. The CAPI technology directly recorded the responses of survey participants. This method required field teams to be outfitted with laptop computers pre-loaded with survey questions asked of respondents in a face-to-face interview. Field teams inputted responses directly into a laptop computer, thereby limiting data entry processes as well as minimizing data recording and entry errors. In addition to the use of CAPI in data collection, LASI utilized interviewer training, pilot testing, quality control measures including random spot checks and systematic review of data entered, as well as data validation checks comprising range, logic, and consistency checks to validate the accuracy of entered data. Post data collection, verification and validation procedures were conducted, including cross-referencing of interview data with external sources, follow-up interviews for validation, and statistical checks for data consistency and reliability.[31]

Study Design and Outcome Variables

This study is a cross-sectional analysis of LASI data. Several outcome variables were chosen from LASI to form the basis of this study: natural disasters which affect human health, human-induced disasters which affect human health, and the health consequences of disasters. Each are detailed below and the full question set can be found in Supplementary File 1 (available online only).

Natural Disasters which Affect Human Health—There are two questions in the LASI about natural disasters. First, the survey asks if the respondent's health has been affected by a disaster such as a flood, landslide, cyclone/typhoon, drought, earthquake, tsunami, or any other natural calamity in the last five years (including extreme cold and hot weather). Response options are Yes or No. For those who indicated yes, they are asked to select which of the following natural disasters affected their health: flood, landslide, cyclone/typhoon, earthquake/tremor, tsunami, drought, or other, which provides an option to specify another type of natural disaster.

Human-Induced Disasters which Affect Human Health—The LASI also asks two questions about human-induced disasters, specifically if in the last five years the respondents health has been affected by human-induced incidents such as riots, terrorism, building collapses, fires, traffic accidents, or any other human-induced incident, with response options being Yes and No. If the respondent says yes, they are asked which of these human-induced disasters affected their health, and they are able to list as many as relevant: riots, terrorism, building collapse, fires, traffic accidents, and other, where the respondent can specify which other type of human-induced disaster had affected their health.

Health Consequences due to Disasters—Finally, for any respondents who answered yes to either or both of the questions about natural or human-induced disasters impacting health, they were asked to indicate if the type of health consequences they suffered as a result of these disasters were significant. Respondents could choose as many of the following options as were relevant: permanent physical disability; psychological trauma and mental health problems; chronic illness; and other, whereby respondents could specify additional health consequences not already listed.

Predictor Variables

Respondent data were collected from LASI across a range of socio-economic and demographic variables, such as age, sex, education, caste (social group), religion, income quintile, place of residence, and region of residence. In line with previous research,[33] and

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availability of variables in the data set,[14] these were used as predictor variables to identify those more at risk of experiencing disaster-related health impacts in India. Supplementary File 2 (available online only) shows a full list and the explanation of the variables used in analysis.

Data Analysis

Descriptive statistics and multi-variate analysis were used to meet the research objectives. Descriptive analysis was used to analyze the socio-demographic profile of the respondents, as well as the types of disasters impacting health. Chi square analysis was conducted to identify: (1) any statistically significant differences between those who have and haven't reported health impacts due to disaster by socio-demographic characteristics; (2) socio-demographic differences in the types of health impacts reported; and (3) socio-demographic differences in those who reported health impacts due to a single or multiple disaster exposures. Effect size is depicted via Cramer's V and φ. Adjusted Odds Ratio (AOR) was calculated comparing those who said yes to disaster-related health impacts to those who said no by different socioeconomic characteristics. Measures of association between two nominal variables are Cramér's V and Phi; larger contingency tables use Cramér's V, while 2x2 tables use Phi. Both indicate the strength of the link and vary from zero to one. These assessments are essential for comprehending the links between categorical data.[34]

Multi-variable logistic regression was performed to understand the factor associated with disaster. The first group within each category was used as the reference group. Alongside the logistic regression, the statistical significance P value (*** P <.01, ** P <.05) and upper and lower 95% confidence intervals (CI) were calculated. The SVY command was used[35] in STATA 18.0[36] (StataCorp; College Station, Texas USA) for descriptive and multi-variable analysis.

Further, multi-level analysis was performed. A multi-level approach divides geographical space into discrete areas disconnected from one another and provides an accurate estimate of the risk factors while analyzing data collected adopting a multi-stage sampling technique. The three levels were individual (Level 1), nested within the place of residence - Rural/Urban - (Level 2), and nested within states (Level 3). The outcome variable was whether the respondent experienced disaster-related health impacts. The multi-level models[37] were fitted to assess the influences of measured socio-economic factors as fixed effect whereas place of residence (Rural/Urban) and states.

Ethics Statement

Wave 1 of the LASI received ethical approval from the Indian Council of Medical Research (ICMR; New Delhi, India) Ethics Committee on September 5, 2013 (approval number LASI/12/1054). Before participation in the survey, informed written consent was received from the respondents. More details on the ethics approval processes can be found in the Wave 1 LASI report.[31]

Results

In the first wave of LASI (2017-2018), a total of 72,250 respondents were included in the survey. The study population had a higher proportion of females (58.0%) than males (42.0%), and the largest proportion of respondents were aged 45-59 years (41.4%). Almost one-half of the survey population (49.5%) reported no education and 62.4% were middle-income earners or lower. Over two-thirds (68.2%) were rural dwelling and the highest proportion of study subjects were from the central region (24.4%), followed by the east (23.4%) and northeast region (21.0%) of the country (Table 1).

Of the 72,250 respondents, 2,301 (3.5%) reported a disaster-related health impact (Supplementary File 3 shows a breakdown of the different samples reporting disaster-related health impacts; available online only). Those aged 18-44 years were less likely (P <.05) to be impacted by disasters (Table 1). There were statistically significant differences by age group, with respondents aged 45-59 years and 60-69 years significantly more likely than respondents of other age groups to report disaster-related health impacts (P <.001). A higher proportion of males reported a health impact of a disaster (47.7% impacted compared to 41.8% who reported no disaster-related health impacts - Table 1).

Similarly, respondents who reported no education were significantly more likely to report health impacts due to disasters (58.5%). Rural residents were also more likely to report health impacts due to disaster (85.1%; P <.001; Table 1).

Of the 2,301 respondents who indicated they had experienced health impacts due to disaster, 1,478 (64.2%) were due to natural disasters. As a rate per 100,000 population, the rate of those people who experienced significant health impacts due to disaster was 3,530.00 people per 100,000. Respondents aged 45 to 59 years reported the highest rates of disaster-related health impacts of any age group, for overall disasters (2,820.00 per 100,000 population), for natural disasters (2,580.00 per 100,000 population), and for human-induced disasters (1,250.00 per 100,000 population) - Table 2.

Figure 2 geographically displays the differences in types of disaster which affected health across the states of India. Disasters (both natural and human-induced) significantly impacted the health of people in Jammu, Kashmir, and Ladakh states. The Indian states of Uttar Pradesh, Bihar, and Madhya Pradesh reported a higher rate per 100,000 of health effects due to natural disasters.

Within the sample, a small proportion of respondents had experienced multiple disasters impacting their health. Supplementary File 4 (available online only) depicts the characteristics of the 286 people who reported experiencing multiple natural disasters. There were statistically significant differences in those who experienced single versus multiple natural disasters impacting health, by age group, wealth quintile, caste, religion, and region. Similarly, Supplementary File 5 (available online only) indicates statistical differences in the respondents with health impacts due to single and multiple human-induced disasters with differences based on education status (P = .003) and wealth quintile (P = .003).

Supplementary File 6 (available online only) depicts the background characteristics of those who reported health impacts due to exposure to only natural, only human-induced, and both types of disasters. In total, 153 respondents indicated having experienced health impacts due to both types of disasters, with females accounting for 59.3%. Droughts were the most common type of natural disasters reported to have impacted human health (affecting 41.7% of those who reported health impacts due to natural disasters). This was followed by floods (24.0%). Just 0.7% of respondents reported landslide-related health impacts. For human-induced disasters, traffic accidents accounted for 65.1% of disaster-related health impacts of respondents, followed by other causes (21.6%) and building collapse (12.2%) - Table 3.

Table 4 shows the AOR for those who have experienced disaster-related health impacts overall, regardless of type of

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Background Characteristics	Distribution of Total Sample		Experience of Disaster Affecting Health					
			Yes		No		Association	
	n	%	n	%	n	%	Chi-Square χ^2 (P Value)	Cramer's V and φ
Total	**72,250**	**100**	**2,301**	**100**	**69,949**	**100**		
Age								
18-44	9,871	12.7	234	9.1	9,637	12.8	$\chi2 = 29.303$ (P <.001)	V = 0.021
45-59	30,915	41.4	1050	44.9	29,865	41.3		
60-69	18,974	26.8	641	27.8	18,333	26.8		
70-79	9,101	13.9	276	14.1	8,825	13.8		
80 or Above	3,389	5.2	100	4.1	3,289	5.2		
Sex								
Male	30,569	42.0	1120	47.7	29,449	41.8	$\chi2 = 39.441$ (P <.001)	$\varphi = 0.024$
Female	41,681	58.0	1181	52.3	40,500	58.2		
Education Status								
No Education	33,207	49.5	1246	58.5	31,961	49.2	$\chi2 = 69.812$ (P <.001)	V = 0.032
Primary	24,963	32.0	698	29.0	24,265	32.1		
Secondary	9,966	12.8	271	9.8	9,695	12.9		
Graduate & Above	4,110	5.7	86	2.7	4,024	5.9		
Wealth Quintile								
Poorest	14,158	20.7	405	17.8	13,753	20.8	$\chi2 = 15.775$ (P <.005)	V = 0.015
Poorer	14,530	21.2	452	21.7	14,078	21.2		
Middle	14,537	20.5	466	23.7	14,071	20.4		
Richer	14,686	19.6	454	17.8	14,232	19.7		
Richest	14,339	18.0	524	19.0	13,815	18.0		
Caste								
Scheduled Tribe	12,509	8.8	291	8.1	12,218	8.8	$\chi2 = 112.836$ (P <.001)	V = 0.041
Scheduled Caste	12,046	19.7	409	21.7	11,637	19.6		
Other Backward Caste	27,184	46.7	1088	51.4	26,096	46.5		
Others Caste	17,887	24.9	455	18.8	17,432	25.1		
Religion								
Hindu	52,973	81.9	1743	81.8	51,230	81.9	$\chi2 = 66.031$ (P <.001)	V = 0.031
Muslim	8,667	11.7	344	13.7	8,323	11.6		
Other	10,605	6.4	214	4.5	10,391	6.5		
Place of Residence								
Rural	46,534	68.2	1749	85.1	44,785	67.6	$\chi2 = 139.59$ (P <.001)	$\phi = 0.044$
Urban	25,716	31.8	552	14.9	25,164	32.4		
Region								
North	10,726	7.5	233	4.1	10,493	7.6	$\chi2 = 624.286$ (P <.001)	V = 0.093
Central	17,412	24.4	451	14.7	16,961	24.7		
East	12,834	23.4	593	30.2	12,241	23.2		
Northeast	12,066	21.0	198	8.2	11,868	21.5		
West	9,536	20.1	625	40.9	8,911	19.3		
South	9,676	3.6	201	1.9	9,475	3.7		

Table 1. Socio-Economic Distribution of Sample Profile of Survey Individuals and Who Reported Disaster-Related Health Impacts in India, LASI, 2017-2018

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Background Characteristics	Types of Disaster Affected Health					
	Natural Disasters		Human-Induced Disasters		Total (Natural or Human-Induced)	
	N	Rate/100,000 Population	N	Rate/100,000 Population	N	Rate/100,000 Population
Total	**1631[a]**	**2680**	**823[b]**	**1100**	**2301**	**3530**
Age						
18-44	176	2070	84	790	234	2530
45- 59	709	2810	407	1240	1050	3820
60-69	465	2730	212	1150	641	3660
70-79	206	2840	86	1060	276	3600
80 or Above	75	2380	34	700	100	2820
Sex						
Male	729	2870	455	1400	1120	4010
Female	902	2540	368	890	1181	3180
Education Status						
No Education	947	3290	392	1190	1246	4170
Primary	467	2340	270	1050	698	3200
Secondary	166	1820	120	1120	271	2700
Graduate & Above	51	1130	41	640	86	1690
Wealth Quintile						
Poorest	292	2220	128	930	405	3040
Poorer	328	2760	160	1150	452	3610
Middle	349	3360	142	920	466	4090
Richer	318	2410	169	1110	454	3210
Richest	344	2600	224	1450	524	3720
Caste						
Scheduled Tribe	217	2590	91	820	291	3310
Scheduled Caste	301	3070	134	1120	409	3950
Other Backward Caste	776	3010	377	1200	1088	3940
Others Caste	300	1920	196	1050	455	2710
Religion						
Hindu	1,240	2670	602	1070	1743	3520
Muslim	249	3230	133	1440	344	4150
Other	142	1710	88	910	214	2460
Place of Residence						
Rural	1,281	3440	601	1300	1749	4400
Urban	350	1020	222	680	552	1650
Region						
North	142	1240	129	1080	233	1920
Central	277	1360	182	820	451	2130
East	483	3740	150	1150	593	4560
Northeast	107	690	100	740	198	1380
West	488	5890	183	1860	625	7190
South	134	1180	79	730	201	1880

Table 2. Types of Disaster Affected Health (Expressed as Rates per 100,000 Population) by Socioeconomic Characteristics LASI, 2017-2018

[a] This figure (1631) shows the number of people who reported being affected by natural disasters, but they may also have been affected by human-induced disasters as well (see also Supplementary File 3).

[b] This figure (823) shows the number of people who reported being affected by human-induced disasters, but they may also have been affected by natural disasters as well (see also Supplementary File 3).

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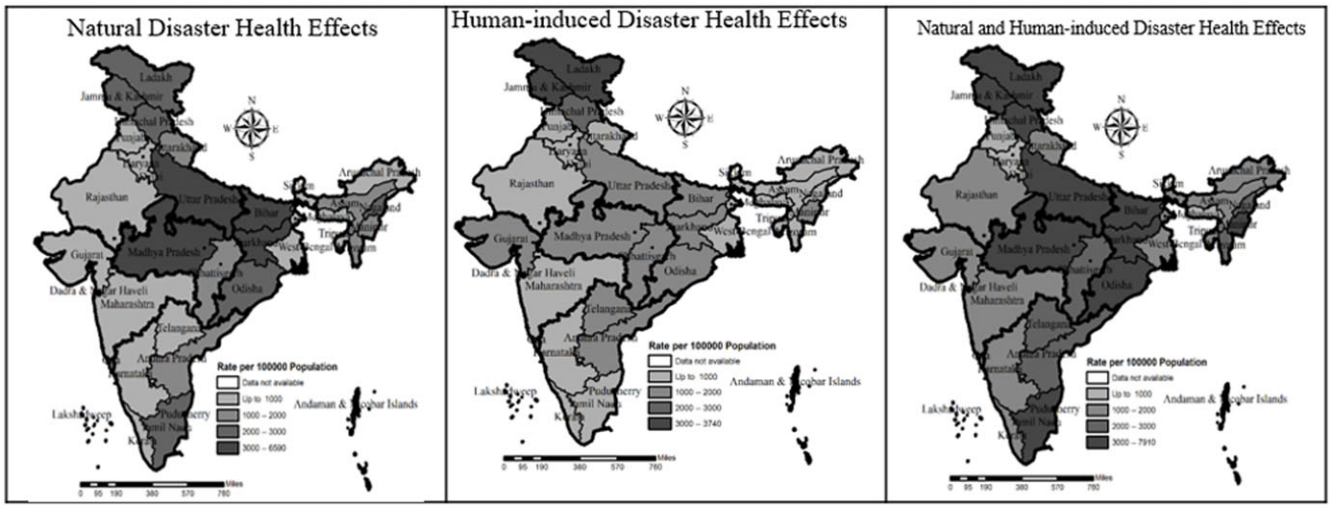

Figure 2. Geographical Differences in Types of Disaster Affecting Human Health by Indian State.

disaster. When compared to those aged 18-44 years, people aged 45-59 years had the highest probability of being affected by disaster (AOR = 1.224; 95%CI, 1.053-1.422; P <.001). Females had a lower probability of being affected by disaster compared to males (AOR = 0.729; 95%CI, 0.664-0.800; Table 4).

The results of the multi-variate logistic regression indicate those who belonged to the Muslim religion were at higher risk of disaster-related health impacts as compared to Hindus (AOR = 1.369; 95%CI, 1.203-1.558). Those who resided in urban areas (AOR = 0.739; 95%CI, 0.664-0.824) were at lower risk of disaster-related health impacts as compared to those who resided in rural areas. Those who resided in the west region (AOR = 3.181; 95%CI, 2.689-3.764) and the east region (AOR = 2.379; 95%CI, 2.015-2.809) were at higher risk of disaster-related health impacts as compared to those who resided in the north (Table 4). Supplementary File 7 (available online only) displays logistic regression by socio-demographic variables for natural disasters and human-induced disasters. Results show significant differences by sex, with females significantly (P <.001) less likely to be impacted by both natural disasters and human-induced disasters than males. For natural disasters, there were significant differences by education statues and wealth quintile, such as that those with any education were significantly less likely to report health effects than those without education (P <.001), and quintiles higher than the poorest also significantly less likely to report health effects than the respondents in the poorest quintile (P <.001). For human-induced disasters, the richest quintile reported the highest AOR for health effects (1.9-times higher than the poorest wealth quintile; P <.001).

Psychological trauma and mental health problems were the most common types of health concerns, representing 57.1% of all health conditions reported (n = 1,379). A further 23.3% (n = 564) of reported health concerns were chronic illness, followed by other types of health impacts (n = 244; 10.1% of all reported conditions) and permanent physical disability (n = 229; 9.5%).

When examining the type of disaster-related health consequences, there were no differences by age group; however, there were differences by sex, whereby males were significantly more likely to report suffering permanent physical disability (P = .002), whereas females were more likely to report and psychological trauma and mental health problems (P <.001) - Table 5.

There were significant differences by education status, whereby those with graduate and above education were more likely to self-report psychological trauma and mental health problems due to disaster (P <.001), while those with secondary education were more likely to report chronic illness (P <.001). There were significant differences by wealth quintile for all types of health consequence aside from permanent physical disability (Table 5).

Rural dwelling respondents were significantly more likely to report experiencing psychological trauma and mental health problems due to disaster (P <.001), whereas urban dwelling respondents were more likely to report experiencing chronic illness (P = .001) - Table 5.

Two multi-level logistic regression models were fitted to investigate the factors associated with disaster-related health impacts. The first model was a null/empty model without any predictor variables. The second model adjusted for socio-economic factors. A multi-level logistic regression model was used to investigate the factors associated with disaster-related health impacts. Results of the multi-level logistic regression model, AORs, and the corresponding 95% CI are presented in Supplementary File 8 (available online only). Results largely confirm preceding findings, with significant increased AOR of disaster-related health impacts for 45-59-year-olds, those from all wealth quintiles except for the poorest quintile, people belonging to the other backwards caste group, Muslim religion, and from the eastern and western regions of India. Females and those with some level of education were found to be significantly less likely to report disaster-related health impacts.

To account for clustering in the model, place of residence was incorporated (rural/urban) and state as a random effect in the multi-level models. In the full model, which controlled for explanatory variables, the increased the variation in self-reported disaster from 16.007 to 21.040 and 7.327 to 9.060 suggested that the place of residence (rural/urban) and state, respectively, contribute to the increase in variance in self-reported disaster health impacts. Additionally, the increase in Variance Partition Coefficient (VPC) after adding the explanatory variables indicated

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Natural Disaster		Human-Induced Disaster	
Type	**Yes (%)**	**Type**	**Yes (%)**
Cyclone/Typhoon	16.8	Building Collapse	12.2
Droughts	41.7	Fire	8.9
Earthquakes/Tremors	21.3	Riots	11.7
Flood	24.0	Terrorism	3.6
Landslides	0.7	Traffic Accidents	65.1
Tsunami	1.2	Other	21.6
Other	20.3		

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Table 3. Type of Disasters Causing Self-Reported Disaster-Related Human Health Impacts

Background Characteristics	Adjusted Odds Ratio	[95% Confidence Interval]		Significance
		Lower	Upper	
Age				
18-44	Ref			
45-59	1.224	1.053	1.422	***
60-69	1.174	1.001	1.377	**
70-79	1.038	0.862	1.250	
80 or Above	0.969	0.757	1.240	
Sex				
Male	Ref	.	.	
Female	0.729	0.664	0.800	***
Education Status				
No Education	Ref	.	.	
Primary	0.756	0.682	0.839	***
Secondary	0.745	0.64	0.867	***
Graduate & Above	0.547	0.427	0.701	***
Wealth Quintile				
Poorest	Ref	.	.	
Poorer	1.162	1.012	1.335	**
Middle	1.349	1.174	1.549	***
Richer	1.355	1.175	1.563	***
Richest	1.844	1.599	2.127	***
Caste				
Scheduled Tribe	Ref	.	.	
Scheduled Caste	1.257	1.063	1.486	***
Other Backward Caste	1.478	1.271	1.719	***
Others Caste	1.057	0.890	1.255	
Religion				
Hindu	Ref	.	.	
Muslim	1.369	1.203	1.558	***
Other	0.952	0.800	1.132	
Place of Residence				
Rural	Ref	.	.	
Urban	0.739	0.664	0.824	***

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Table 4. Multivariate Logistic Regression of Disaster Related Health Impacts in India, LASI, 2017-2018 (*continued*)

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Background Characteristics	Adjusted Odds Ratio	[95% Confidence Interval]		Significance
		Lower	Upper	
Region				
North	Ref	.	.	
Central	1.223	1.028	1.455	**
East	2.379	2.015	2.809	***
Northeast	0.869	0.710	1.063	
West	3.181	2.689	3.764	***
South	1.147	0.921	1.429	

Table 4. *(continued)*. Multivariate Logistic Regression of Disaster Related Health Impacts in India, LASI, 2017-2018

*** $P < .001$.

** $P < .05$.

a strengthening of the clustering effect compared to the null model (Supplementary File 8).

Discussion

Disasters, be it human-induced or natural, can cause significant destruction and upheaval, as well as having negative impacts on the health of the affected population. To the best of the authors knowledge, this study is the first to examine disaster-related health impacts on residents of India. Using Wave 1 (baseline) LASI data, this study identified that 3.5% of the population reported that disasters, either human-induced or natural, affected their health. Also at a population level, reported was a rate of 2430.00 per 100,000 population reporting health impacts due to natural disasters. Although challenging to find directly comparable data, the Our World in Data (Global Change Data Lab; United Kingdom) initiative reports all-age global rates of injury per 100,000 population due to natural disasters ranged from a low of 0.35 to a high of 1.73 between 2012 and 2016, broadly comparable with the five-year recall period in the LASI methodology.[38]

Ninety percent of those impacted reported significant health impacts, most notably psychological trauma and mental health problems, and chronic illness among other causes of ill-health. In addition to physical health impacts, the role of disasters in contributing to mental ill-health is well-documented.[6,39] The current analysis identified important differences between males and females with respect to the health impacts of disaster. Notably, findings suggest males are more susceptible to lifetime disability and chronic diseases while females are more susceptible to psychological and mental health problems. Further research is required to examine if this may be linked to the traditional work roles of males and females. Further, these finding indicates an increasing need for mental health services, especially for women, in light of the escalating impacts of climate change and population aging.

The disruption to mental health treatment during times of disaster is also significant.[40] With India's Mental Healthcare Act 2017, granting legally binding rights to mental health care for 1.3 billion people,[41] the treatment burden associated with disasters could put pressure on a system that varies widely in terms of mental health resources state-by-state.[42] Ensuring mental health is at the forefront of disaster resilience is vitally important. However, while LASI provides population-level insights into the impact of disasters on human health, there is a need for future iterations of LASI to delve deeper into the types of psychological trauma and mental health problems respondents are experiencing, as well as which disasters cause such conditions, to better tailor treatment options. Additionally, future rounds of data collection could delve into whether reported health impacts are due to the direct effects of the disaster or due to secondary effects such as socio-economic or psychological changes. While ultimately both are likely to be important, better data will inform whether the focus should solely be on primary prevention of disaster-related impacts on health, or whether significant attention and resourcing should be paid to preparing communities to deal with the secondary impacts post-disaster, particularly in the context of a changing climate.

Social determinants, such as income level, education level, and remoteness of residential location, have been shown to have significant impacts on health, including injury among all ages.[43,44] This is also true for disasters, with a range of social determinants shown to impact fatalities due to extreme weather events,[45] as well as health impacts due to disasters in the medium and long term.[46] These findings indicate that the relative risk (RR) of health being affected by disasters declined as education rates increased, indicating education has a protective effect on health impacts due to disaster. Similarly, rural dwelling respondents were more likely to be negatively affected. Such findings support the need to apply a social determinants of health lens when developing disaster risk reduction and resilience approaches to ensure those in the community who most need support receive it. Conversely, the RR of experiencing health impacts due to disaster increased as wealth increased, which appears to be a counter-intuitive finding. It may be that urban areas have higher income level residents and the interplay of these two factors correlates to lower likelihood of reporting disaster-related health impacts. However, this is merely speculation and further research is needed to understand this somewhat unexpected result.

As a longitudinal study of aging, it will be vitally important for future iterations of the LASI to continue to measure the health impacts of disaster, with Wave 1 representing a baseline measure against which to measure future change. This is important both to determine if the proportion of the population impacted increases in the wake of more frequent and severe disasters due to a changing climate,[30] but also to understand health impacts of disaster on an aging cohort. The latter will be particularly important in coming years, as the proportion of India's population aged 60 and above is estimated to more than double, reaching 19% by 2050.[14] Surprisingly, despite the vulnerability of older people to disasters,[13] it was respondents aged 45-59 years reporting the highest RR of

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disaster-related health impacts, with those among the oldest cohort age of 80+ being less likely to report health impacts due to disaster than the youngest cohort (18-44 years). Further research is needed to understand why elderly LASI participants were less likely to report disaster-related health impacts than those of middle age and what this means for countries with rapidly aging populations.

Geographically, LASI was able to shed light on the Indian states more impacted by disasters affecting health. These LASI data suggest that the Indian states of Uttar Pradesh, Bihar, and Madhya Pradesh had higher proportions of respondents indicating natural disasters had impacted human health. Bihar is known to be significantly flood affected, recording the highest number of floods between 1995 and 2020.[47] Given the proportionately higher RR of disaster-related human health impacts reported in the west and the east of India, specific attention should be paid to these locations when it comes to early warning systems and infrastructure to respond in times of disaster,[48] as well as ensuring health systems are equipped to respond both in the short term, but also for longer term health-related effects of disaster.[49]

In the context of a changing climate, future LASI rounds should track changes, if any, in the types of natural disasters impacting human health. Despite reports indicating India was most commonly afflicted by floods from 1995 through 2020,[47] it was drought that was reported among LASI respondents as being the type of natural disaster most commonly impacting human health. Findings indicate drought preparedness must be a core component of disaster risk reduction approaches in India.

Limitations

Despite LASI being a longitudinal study of aging, it gathers data on partners of those aged 45 years and over, which is evident in 12.7% of the overall sample being aged 18-44 years. As such, the 18-44 years age group will not be representative of the general population and rates per 100,000 calculated for this age group likely under-estimate the impact of disaster-related health impacts. It should also be noted that other at-risk groups from disasters, such as infants, young children, and adolescents, are not included in these data. From the data available, it is unable to be determined if the health impacts of disasters are due to the disaster itself or due to secondary impacts post-disaster. This topic warrants further examination. Additionally, in time, LASI will be a longitudinal study of aging, but currently only one wave of data are available. Disaster-related health impacts, including type of disaster and health consequences, are self-reported. As such, these data may be subject to recall bias, selection bias, or social desirability bias in responses.[50,51] There may also be missing data and health changes for individuals due to disaster which are not reported in the interview process. With respect to the health consequences suffered, there was an inability to further unpack what types of permanent physical disability, psychological trauma, and mental health problems or chronic illness have been experienced by respondents. Finally, the LASI questionnaire included traffic accidents as a human-induced disaster. The scale of such traffic accidents was not determined in order to establish if these are merely individual incidents or population-level disasters. Their inclusion as a "disaster" may be reconsidered in LASI Wave 2 data collection.

Conclusion

Disasters represent a significant cause of mortality and morbidity. Data from the first round of LASI provide an opportunity to understand disaster-related health impacts at a population level in India. A small proportion of the population was found to be impacted, but the vast majority of those face significant health impacts, most commonly mental health impacts and chronic illness. Social determinants such as education level and rurality impact risk of disaster-related health impacts, indicating a need to apply a determinant of health lens over disaster risk reduction and resilience approaches. Given an increasingly aging population in India, future waves of the LASI should continue to examine disaster-related human health impacts, including changes over time in the context of a changing climate, as well as identifying any increased vulnerability among an aging cohort.

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Supplementary Materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X25000020

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Background Characteristics	Permanent Physical Disability				Psychological Trauma and Mental Health Problems				Chronic Illness				Others			
	Yes		No		Yes		No		Yes		No		Yes		No	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Total	229	100.0	2077	100.0	1,379	100.0	927	100.0	564	100.0	1,742	100.0	244	100.0	2,121	100.0
Age	$\chi2 = 5.932$ P = .204				$\chi2 = 6.947$ P = .139				$\chi2 = 7.064$ P = .133				$\chi2 = 1.753$ P = .781			
18-45	21	9.2	212	10.2	155	11.2	78	8.4	48	8.5	185	10.6	23	9.4	219	10.3
45- 59	91	39.7	953	45.9	602	43.7	442	47.7	281	49.8	763	43.8	117	48.0	953	44.9
60-69	68	29.7	577	27.8	393	28.5	252	27.2	149	26.4	496	28.5	62	25.4	597	28.1
70-79	35	15.3	250	12.0	172	12.5	113	12.2	62	11.0	223	12.8	33	13.5	259	12.2
80 or Above	14	6.1	85	4.1	57	4.1	42	4.5	24	4.3	75	4.3	9	3.7	93	4.4
Sex	$\chi2 = 9.374$ P = .002				$\chi2 = 16.343$ P <.001				$\chi2 = 3.972$ P = .046				$\chi2 = 1.372$ P = .241			
Male	133	58.1	985	47.4	621	45.0	497	53.6	294	52.1	824	47.3	127	52.0	1,020	48.1
Female	96	41.9	1,092	52.6	758	55.0	430	46.4	270	47.9	918	52.7	117	48.0	1,101	51.9
Education Status	$\chi2 = 1.684$ P = .640				$\chi2 = 35.203$ P <.001				$\chi2 = 39.211$ P <.001				$\chi2 = 8.072$ P = .045			
No Education	126	55.0	1,129	54.4	820	59.5	435	46.9	243	43.1	1,012	58.1	118	48.4	1,167	55.0
Primary	74	32.3	621	29.9	368	26.7	327	35.3	217	38.5	478	27.4	75	30.7	639	30.1
Secondary	22	9.6	249	12.0	146	10.6	125	13.5	79	14.0	192	11.0	36	14.8	241	11.4
Graduate & Above	7	3.1	78	3.8	45	3.3	40	4.3	25	4.4	60	3.4	15	6.1	74	3.5
Wealth Quintile	$\chi2 = 1.885$ P = .757				$\chi2 = 64.225$ P <.001				$\chi2 = 38.621$ P <.001				$\chi2 = 34.676$ P <.001			
Poorest	45	19.7	364	17.5	267	19.4	142	15.3	80	14.2	329	18.9	31	12.7	387	18.2
Poorer	48	21.0	399	19.2	291	21.1	156	16.8	91	16.1	356	20.4	43	17.6	420	19.8
Middle	40	17.5	428	20.6	318	23.1	150	16.2	93	16.5	375	21.5	36	14.8	440	20.7
Richer	45	19.7	419	20.2	263	19.1	201	21.7	128	22.7	336	19.3	43	17.6	429	20.2
Richest	51	22.3	467	22.5	240	17.4	278	30.0	172	30.5	346	19.9	91	37.3	445	21.0
Caste	$\chi2 = 2.467$ P = .481				$\chi2 = 16.067$ P = .001				$\chi2 = 37.007$ P <.001				$\chi2 = 2.969$ P = .396			
Scheduled Tribe	22	9.6	271	13.0	150	10.9	143	15.4	106	18.8	187	10.7	23	9.4	274	12.9
Scheduled Caste	42	18.3	371	17.9	264	19.1	149	16.1	85	15.1	328	18.8	47	19.3	376	17.7
Other Backward Caste	114	49.8	964	46.4	674	48.9	404	43.6	219	38.8	859	49.3	124	50.8	994	46.9
Others Caste	45	19.7	417	20.1	266	19.3	196	21.1	125	22.2	337	19.3	49	20.1	418	19.7

Table 5. Number and Proportion of Disaster-Related Significant Health Consequences due to Disasters Combined by Type of Health Consequence *(continued)*

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Religion	$\chi2 = 2.361$ P = .307				$\chi2 = 47.512$ P <.001				$\chi2 = 65.623$ P <.001				$\chi2 = 3.265$ P = .195			
Hindu	181	79.0	1,566	75.4	1,065	77.2	682	73.6	392	69.5	1,355	77.8	194	79.5	1,600	75.4
Muslim	33	14.4	314	15.1	232	16.8	115	12.4	72	12.8	275	15.8	27	11.1	327	15.4
Other	15	6.6	197	9.5	82	5.9	130	14.0	100	17.7	112	6.4	23	9.4	194	9.1
Place of Residence	$\chi2 = 2.592$ P = .107				$\chi2 = 28.669$ P <.001				$\chi2 = 9.542$ P = .001				$\chi2 = 5.937$ P = .015			
Rural	164	71.6	1,587	76.4	1,101	79.8	650	70.1	401	71.1	1,350	77.5	170	69.7	1,627	76.7
Urban	65	28.4	490	23.6	278	20.2	277	29.9	163	28.9	392	22.5	74	30.3	494	23.3
Region	$\chi2 = 16.475$ P = .006				$\chi2 = 444.212$ P <.001				$\chi2 = 435.528$ P <.001				$\chi2 = 57.410$ P <.001			
North	28	12.2	208	10.0	141	10.2	95	10.2	56	9.9	180	10.3	24	9.8	216	10.2
Central	52	22.7	402	19.4	193	14.0	261	28.2	164	29.1	290	16.6	73	29.9	400	18.9
East	35	15.3	564	27.2	494	35.8	105	11.3	62	11.0	537	30.8	21	8.6	581	27.4
Northeast	27	11.8	178	8.6	62	4.5	143	15.4	109	19.3	96	5.5	15	6.1	191	9.0
West	64	27.9	547	26.3	450	32.6	161	17.4	48	8.5	563	32.3	92	37.7	548	25.8
South	23	10.0	178	8.6	39	2.8	162	17.5	125	22.2	76	4.4	19	7.8	185	8.7

Table 5. *(continued).* Number and Proportion of Disaster-Related Significant Health Consequences due to Disasters Combined by Type of Health Consequence

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