Co-funded by the Erasmus+ Programme of the European Union

URGENT: Urban Resilience and Adaptation for India and Mongolia

Report on:

Lecture Material

Health and Disasters

Partner number: P11

Jawaharlal Nehru University, New Delhi

India

Co-funded by the Erasmus+ Programme of the European Union

Urban Resilience and Adaptation for India and Mongolia:
curricula, capacity, ICT and stakeholder collaboration to support green & blue infrastructure and nature-based solutions
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Disclaimer

Health and Disasters

Semester -I: July – December

Coordinator	Dr Nikunj Makwana
Credits	**4 Credits**
Lecturers	Dr Nikunj Makwana
Level	M.A.
Host institution	Special Centre for Disaster Research (SCDR), Jawaharlal Nehru University, New Delhi
Course duration	One Semester [July - December]

Summary

This one full semester elective course provides the Master level students of Disaster Studies the basic understanding of human life and human health in the event of any emergency or disaster. Besides, it will also introduce students to the new frameworks for research and operations across the world for health in emergencies and disasters. The course will touch upon the evidences developed in the recent to emphasize on human centric disaster management. The course includes individual assignments.

Target Student Audiences

Semester - I Students of M.A.

Prerequisites

- Nil

Aims and Objectives

This course has been designed with a view to help students in developing a comprehensive understanding and knowledge of importance of integrating human health and emergences and disasters. The main objectives of the course are: (i) to help students in understanding interactive impact of health on various aspects of disaster management; (ii) to comprehend role of health in emergencies and disasters; and (iii) to identify, formulate and handle questions relevant for disasters and health. The course provides health perspective, that will help the students to reduce disaster risks and contribute to better and more targeted health-based response following disasters.

General Learning Outcomes:

By the end of the course, students will successfully:

- Understand the disaster risk related health issues and their impacts,
- Learn and appreciate importance of human health and much needed disaster risk reduction and planning,
- Identify and visualize health-based response following variety of disaster scenarios.

Overview of Sessions and Teaching Methods

The course will be delivered through interactive approach of discussions and learning from text books and referring the original research papers as well as review papers to understand the subject, the way it is. The interactive sessions supported by case studies, videos, external links and exercises. It also refers to the latest publications for understanding the trend in the given discipline and its applications. Whenever possible other teaching methods will be adopted and practical sessions, field trips and other organizational visits will be arranged to enhance the learning experience.

Course Workload

The table below summarizes course workload distribution:

Activities	Learning outcomes	Assessment	Estimated workload (hours)	Self-Study (hours)
In-class activities				
Lectures and Presentations	Prioritizing health services; Supporting national and local health systems - Coordination; Primary Healthcare services; Clinical Services; Health Information System Human resources; Financial management for humanitarian response; Monitoring and evaluating the systems; Evaluation of disaster Programs and Projects in health system.	Mid Semester Examination	06	06
Lectures and Presentations	Resilient Health Systems and Infrastructure; Planning Emergency Health services; Triage; Mass casualty management; Emergency medical care; Mass event with long-term major implications; Mass event of immediate, limited implication; Intermediate events causing temporary displacement; Mass event long term displacement; Managing essential drug supplies; Post-emergency phase; Hospital Safety;	Mid Semester Examination	08	08

	Hospital Preparedness; Prehospital emergency management system.			
Lectures and Presentations	Stressors, protective factors, and mental health disorder in emergencies and disasters; General measures and psychosocial support; Risk factors and intervention strategies; Post Traumatic Stress Disorder; Psychological First Aid (PFA); Disaster Mental Health Counselling; Managing stress and well-being	Mid Semester Examination	06	06
Lectures and Presentations	Communicable diseases as public health threats; Principles of communicable disease control; General approach for setting up disease control programmes; Major disease in emergency and non-emergency settings; Diseases from the animal sector and other emerging diseases; Monitoring, evaluation and research for disease control programmes	End Semester Examination	08	08
Lectures and Presentations	Diseases related to water, sanitation and hygiene; Community involvement in disease prevention and mitigation; Improving environmental conditions; Excreta disposal; Water quantity and Water quality; Hygiene and Food safety; Vector borne diseases control; Solid waste management; Drainage Lineation; Water and sanitation in cholera outbreak response; Planning guidelines for institutions.		06	06
Lectures and Presentations	Understanding Disaster Health; Health consequences/implications of Disaster; Health Emergency and Disaster Risk Management Framework; Emergency Medical Preparedness and Response in Disasters - Delivery of emergency medical services in disasters and Hospital level disaster management;	End Semester Examination	06	06
Lectures and Presentations	Health in International DRR Frameworks, Health related vulnerability and rehabilitation,	End Semester Examination	08	08

	Human Resources for Health in Disasters, Health and Health-system related aspects of CBRNE disasters; Nutrition and food safety, Care of Road Traffic Injuries victims; The minimum initial services package (MISP) for SRH in Emergencies and Disasters; Maternal health and safe motherhood; Infant and young child feeding in emergencies.			
Independent work				
Individual Assignments	Field Trips and Skill development work	Individual Presentations	08	08
Total			***56***	***56***

Grading

The students' performance will be based on the following:

- Quizzes/Surprise Test – 10%
- Mid Semester Examination – 30%
- End Semester Examination – 50%
- Individual Assignments – 10%

Grade	Grade Point	FGPA	Class/Division
A+	9	8.5 and above	High First Class
A	8	7.5 and above but less than 8.5	Middle First Class
A-	7	6.5 and above but less than 7.5	Lower First Class
B+	6	5.5 and above but less than 6.5	High Second Class
B	5	4.5 and above but less than 5.5	Middle Second Class
B-	4	3.5 and above but less than 4.5	Lower Second Class
C+	3		
C	2		
C-	1		
F	0		

Course Schedule: **Semester-I: July - December**

Course Assignments

The Structure of Individual Assignments will be as follows:

- Field visit report.
- Review of research articles/working paper with given objectives.

Literature

- International Federation of Red Cross and Red Crescent Societies, 1997. Handbook for Delegates.
- UNICEF. Assisting in Emergencies: A resource handbook for UNICEF field staff. Prepared by Ron Ockwell, 1986.
- The Johns Hopkins, Red Cross and Red Crescent "Public Health Guide in Emergencies" Second Edition (2008), International Federation of Red Cross and Red Crescent Societies, Switzerland
- Clements, B. W., & Casani, J. (2016). Disasters and public health: planning and response. Butterworth-Heinemann. (Book)
- Noji, E. K. (Ed.). (1996). The public health consequences of disasters. Oxford University Press. (Book)
- Landesman, L. Y. (2005). Public health management of disasters: the practice guide. American public health association. (Book)
- Diaz, J. O. P., Murthy, R. S., & Lakshminarayana, R. (2006). Advances in disaster mental health and psychological support. Voluntary Health Association of India Press. New Delhi India.
- Park, K. (2019). Park's textbook of preventive and social medicine (Selected Chapters e.g. 1,2,3,15)
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- Mainstreaming Disaster Risk Reduction into Health: Strategies, Methodologies & Tools. NIDM and UNDP. Accessible at https://nidm.gov.in/pdf/pubs/DRR-health.pdf

NDMA (National Disaster Management Authority) (2007) National Disaster Management Guidelines Chemical Disasters (Industrial). Govt. of India.

- HOSPITAL DISASTER MANAGEMENT GUIDELINES DIRECTORATE OF HEALTH SERVICES, KERALA available at http://dhs.kerala.gov.in/pdf2018/hdmg_18082018.pdf
- Health Emergency and Disaster Risk Management Framework, ISBN 978-92-4-151618-1, World Health Organization 2019
- Book Chapter 'Public Health Aspects of Disaster Management' by Ashok K. Jindal, Puja Dudeja. Text Book of Public Health and Community Medicine, AFMC Pune 2009.
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- Khankeh, H. R., Khorasani-Zavareh, D., Johanson, E., Mohammadi, R., Ahmadi, F., & Mohammadi, R. (2011). Disaster health-related challenges and requirements: a grounded theory study in Iran. Prehospital and disaster medicine, 26(3), 151-158.
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Life Support Systems

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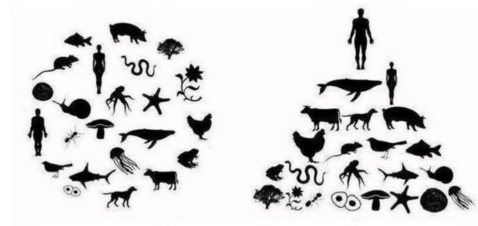
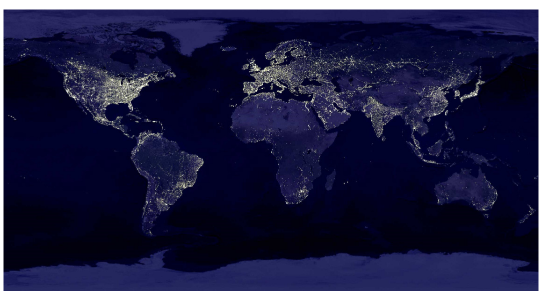
Environmental Degradation



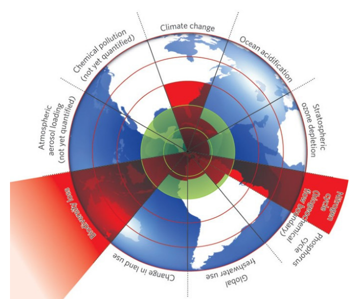
ECO-system EGO-system

Urbanizing Planet



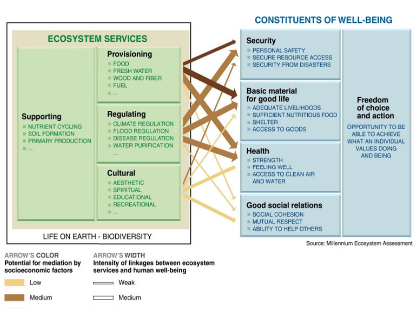
Source: NTLS/DMSP

Planetary Boundaries



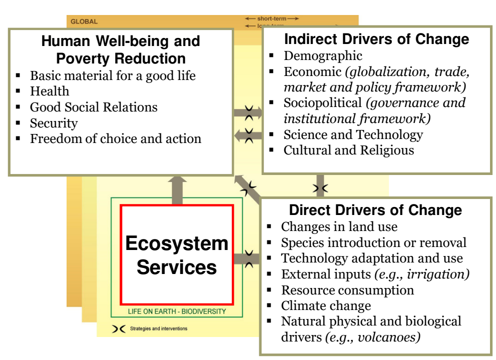
Source: Stockholm Resilience Center

Human Well-being



Source: MEA (2005)

Life Support Systems



Public health implications of multiple disaster exposures

Claire Leppold, Lisa Gibbs, Karen Block, Lennart Reifels*, Phoebe Quinn**

Disasters are an important public health issue; however, there is scarce evidence to date on what happens when communities and populations experience more than one disaster. This scoping review identifies literature on the effects of multiple disasters published until Aug 2, 2021, 1425 articles were identified, of which 150 articles were included. We analysed direct and indirect public health implications of multiple disasters. Our analysis suggests that exposure to multiple disasters can affect mental health, physical health, and wellbeing, with some evidence that the potential risks of multiple disaster exposure exceed those of single disaster exposure. We also identified indirect public health implications of multiple disaster exposure, related to changes in health-care facilities, changes in public risk perception, and governmental responses to multiple disasters. We present findings on community recovery and methodological challenges to the study of multiple disasters, and directions for future research.

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Introduction

Disasters can lead to short-term and long-term effects on physical and mental health, and can indirectly affect health and wellbeing as a result of evacuation, social disruption, financial loss, lifestyle change, damage to health-care facilities, and changes to the wider political and socioeconomic context.[1,2] Historically, disasters have been considered as rare, singular, discrete events. However, in the past 10 years, there has been increasing recognition of the ways in which disasters can overlap.[3,4] In March, 2011, the northeast region of Japan experienced the Great East Japan Earthquake, which led to a tsunami and subsequently to a nuclear disaster—an event that is often referred to as the 3.11 triple disaster.[3] In 2017, Hurricane Harvey resulted in a chemical plant explosion in Texas, USA, in addition to flooding and fires.[5] There are many examples of multiple disaster events occurring together, and the past year highlights overlaps between the COVID-19 pandemic and other types of disaster globally.[4,6] In the context of projected increases in disasters as a result of climate change,[7–9] and already high frequencies of exposure to overlapping disasters, there is a need to understand the ways in which multiple disasters can affect population health, wellbeing, and recovery processes, and the extent to which these effects might differ from those of single disasters.

In the past 5 years there has been a growing body of theoretical and conceptual work to understand so-called cascading disasters (disasters generating secondary disasters), compound disasters (combinations of simultaneous or successive extreme hazard events), and recurrent disasters (in which the same hazard repeats; table).[10–16] However, unclear and inconsistent terminology is often used to describe multidisaster scenarios,[5,14–16] and wider understanding of the public health effects of these events is poor. The literature on cascading or compound disasters is often primarily focused on modelling risks and hazards and on the role of critical infrastructure,[5] whereas empirical research, especially on community-level or population-level effects and on long-term recovery processes, has been scarce. The extent of the literature on the public health implications of multiple disasters has been unclear.

In this scoping review we aim to identify empirical research on the public health effects of the exposure of individuals or communities to multiple disasters, and recovery from these events. We draw on the definition from the United Nations Office for Disaster Risk Reduction of a disaster as a "serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts."[17] When examining the public health implications of multiple disasters, we take an inclusive view as to what qualifies as a disaster. We build from work in disaster studies identifying the importance of accounting for not only the commonly recognised 'natural' and technological disasters, but also slow-onset disasters such as drought,[18] chronic disasters,[19] and neglected disasters that have received less attention because they are misunderstood or they do not fit into the clear categories of 'natural' or technological.[20] We approach this Review with recognition that all these disasters have the potential to co-occur, occur sequentially, or repeat, and we seek to identify existing literature on cases in which people or communities have experienced more than one disaster. The focus of this Review is on public health effects and the recovery process from past events, while recognising that exposure to multiple disasters can involve overlapping periods of preparedness, response, and recovery.

Methods

Through this scoping review we examined the extent, range, and nature of research activity[21] on multiple disasters, public health, and recovery. We sought to include any empirical public health literature on previous cases of cascading, compound, or recurring disasters; however, considering the inconsistencies in terminology noted in previous papers, we also left scope to include multiple disaster scenarios that have been researched but not labelled in these ways. Our research questions, therefore, focus on multiple disasters rather than specifying disasters as cascading, compound, consecutive, or recurring. With a focus on identifying and

	Definition	Example
Consecutive disasters	"Two or more disasters that occur in succession, and whose direct impacts overlap spatially before recovery from a previous event is considered to be completed."[10] This definition includes successive compound disasters and cascading disasters.[10]	In 2008, Haiti was hit by multiple hurricanes. While still in the process of recovering from the hurricanes, Haiti then experienced a magnitude 7 earthquake in 2010 and a subsequent outbreak of cholera. These disasters have been labelled as consecutive disasters.[10]
Compound disasters	A term to describe natural hazards and the combination of two or more extreme events, which occur simultaneously or successively and have substantial effects.[11,15]	In 2012, Hurricane Sandy hit the New York metropolitan area. The unusual path of Hurricane Sandy was affected by multiple weather systems over the North American continent and the north Atlantic. This combination of multiple climate hazards, culminating in an unusual hurricane path and subsequent intense effects (widespread flooding), is referred to as a compound event.[15]
Cascading disasters	"Extreme events, in which cascading effects increase in progression over time and generate unexpected secondary events of strong impact. These tend to be at least as serious as the original event, and to contribute substantially to the overall duration of the disaster's effects."[13] A key element to cascading disasters is that they have a point of escalation, a crucial junction in a chain of reactions that leads to greater effects than the initial disaster would have done.[12] Cascading hazards, risks, and disasters have gained increasing attention since 2010.[3,12,15]	The 3.11 triple disaster in Japan in 2011 (earthquake that led to tsunami, which then led to nuclear disaster) is often described as a cascading disaster.[3]
Recurring or recurrent disasters	"The recurrence of a single natural hazard in the same geographic region over a one-year period."[16]	There was severe flooding in Pakistan in 2010, 2011, and 2012. Haiti experienced four hurricanes in 2008. These are two examples of recurring disasters.[16]

Table: **Terminology to describe multiple disasters**

collating learnings from past events, we constrained the focus of this Review to empirical studies from contexts in which people or communities had been previously exposed to more than one disaster. Specific inclusion terms are presented below. We followed the scoping review methodology outlined by Arksey and O'Malley,[21] and the principles for reporting in the PRISMA Extension for Scoping Reviews (appendix p 29).[22]

See Online for appendix

The following research questions were developed through preliminary literature searches and discussions with colleagues: what research has been done to examine the complexities of the public health effects of multiple disasters, and what research has been done to examine experiences of recovery from multiple disasters?

Data abstraction and content analysis

We abstracted data on publication information, study sites, multiple disaster constellation covered, methods, key findings, and any recommendations made in articles. We also noted if and how recovery was discussed, and detailed methodology information for studies on quantitative health outcomes.

We inductively created categories based on primary areas of focus (ie, mental health, physical health, etc). We then analytically grouped articles on the basis of their key themes into whether they covered direct or indirect implications for public health, informed by the framework outlined by Shoaf and Rottman.[1] Deaths, illnesses, and physical and psychological effects of multiple disasters were classified as direct implications, and any wider factors that could influence population health in multiple disasters were classified as indirect implications for public health.

Reflecting on the literature on methodological challenges to the study of (singular) disasters,[23] we also assessed articles for any methodological or conceptual challenges that were explicitly noted or implicitly apparent in relation to the study of multiple disasters.

Results

The 150 included articles (figure 1) were published between 1994 and 2021. Most of these articles (111; 74%) were published in or after 2014, highlighting that the public health implications of multiple disaster exposures is an emerging area of research. The articles covered a range of hazard constellations, and the lengths of time between each disaster ranged from minutes to years; the longest specified time between disasters was 25 years between the Good Friday earthquake and tsunami and the Exxon Valdez oil spill in southcentral Alaska, USA.[24] Some disasters were studied more frequently than others. One of the largest groups of articles focused on combinations of hurricanes—including some or all of Katrina in 2005, Rita in 2005, Gustav in 2008, Ike in 2008, and Isaac in 2012—and the Deepwater Horizon oil spill (2010) in the Gulf Coast of the USA (19 articles).[25–43] A further ten articles focused on some or all of these hurricanes but not on the oil spill.[44–53] Of all included articles, 71 (47%) covered cases of recurring disasters.[30,31,34,37,38,43–51,54–84] The full list of disaster cases covered in the included articles can be viewed in the appendix (p 1).

Most of the 150 included articles had a quantitative research design (98; 65%), with fewer qualitative (42; 28%) or mixed methods (10; 7%) studies. We present a detailed assessment of 67 quantitative health outcome studies in the appendix (p 18); the majority (53; 79%) were cross-sectional studies with no comparison groups and sample sizes ranging from 100 to 5000. There were ten major population studies with more than 10 000 participants and ten studies that included comparison groups, whereas five studies had fewer than 100 participants.

We categorised articles on the basis of their primary topic of focus by frequency (figure 2). The following sections outline the identified direct and indirect implications for public health and the recovery process, and methodological challenges.

Direct implications for public health

Mental health

More than a third of included articles (53; 35%) focused on mental health in the aftermath of multiple disasters,[25–30,32,35–37,41,46,48,51,54,56–58,63,64,71,72,84–114] representing the largest theme identified. Numerous articles observed high rates of psychological distress, acute stress disorder, post-traumatic stress disorder, depression, panic disorder, or risk of suicide attempts in populations that had experienced multiple disasters.[36,54,56,64,84,90,93,97,98,110,112,114]

There were different approaches to study multiple disasters and mental health. Some studies compared the mental health risks from multiple (more than one) disaster exposures with the risks from a single disaster exposure, and found that multiple exposures were associated with increased risks to mental health (a cumulative effect).[37,41,46,71,85,97,98,109] For example, in a nationally representative survey of Australians, those exposed to multiple disasters across their lifetime were at significantly greater risk of suicide attempts than were those exposed to a single disaster.[98] Although some researchers have questioned whether exposure to one disaster could have a positive effect of preparing people mentally for future disasters, we identified evidence against this notion.[37,46,98] For example, Harville and colleagues[46] found that exposure to both Hurricane Katrina and Hurricane Gustav was associated with poor mental health, and that even when individuals perceived benefit after the first disaster, this benefit was not protective against the mental health effects of experiencing both disasters. Conversely, one study after the 9/11 terrorism attack (2001) and Hurricane Sandy (2012) found that previous high exposure to the 9/11 terrorism attack was associated with a weaker effect of Hurricane Sandy on post-traumatic stress disorder for older adults, but the opposite result was found for younger adults.[89] These findings represent an area in need of further study; however, from the articles identified in this Review, there were no consistent findings to suggest that experiencing one disaster could be protective against the effects of the next.

A group of studies found that mental health outcomes differed according to the severity of multiple disaster exposures (defined by one or more of degree of losses, damage, difficulties in accessing resources, perceived

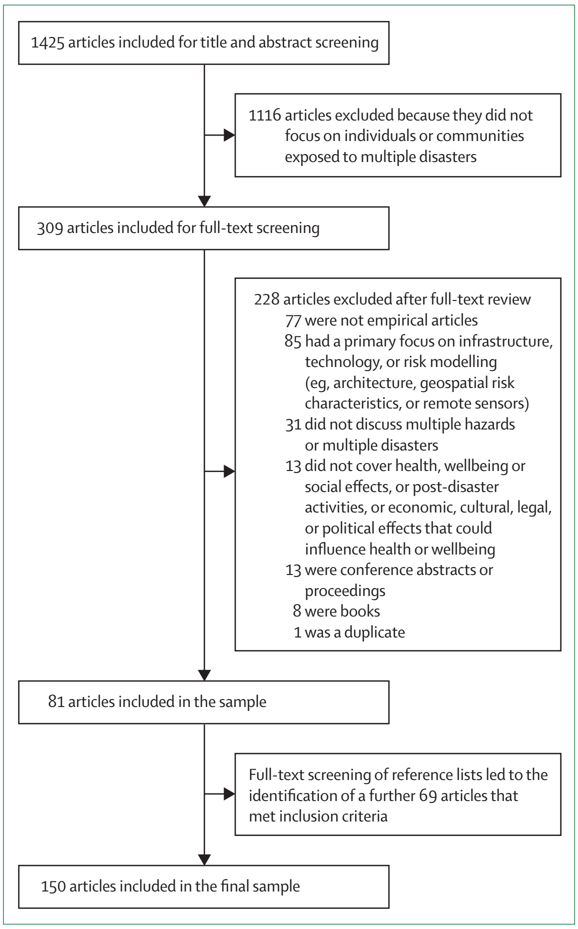

Figure 1: **Flow chart of included studies**

danger, or injuries experienced; appendix p 18).[46,64,100,105,106] Another subset of articles focused on the mental health of children who had experienced multiple disasters,[28,32,87,107,113] and found both cumulative effects and differences according to the severity of exposures. Another group of studies found that post-traumatic stress disorder from previous disasters can be exacerbated or reactivated after experiencing the next disaster, even if it is a different type of disaster. This occurrence was highlighted by studies that looked at populations exposed to both the 9/11 terrorism attacks and Hurricane Sandy in New York.[89,92,94,100,102,106]

Other articles on mental health included a group of studies that focused on the identification of socio-demographic characteristics associated with increased risk of adverse mental health outcomes following multiple disasters (eg, by age,[48,51] gender, educational attainment, financial hardship,[35,57] and temporary housing experiences[111]), with mixed results. Another group of articles focused on mental health risks faced by disaster responders[86,103,104] and public health workers[62,64] in the face of multiple disasters. There was also a group of studies that described alcohol-related and tobacco-related

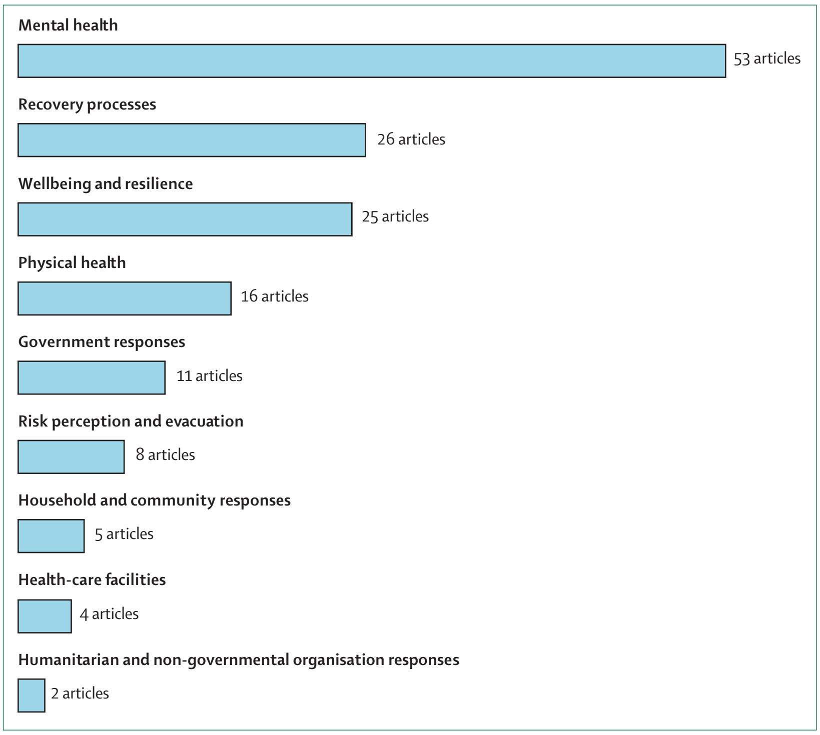

Figure 2: Included articles by primary topic of focus (n=150)

health behaviours and mental health in the aftermath of multiple disasters.[64,95,96,99,101]

Wellbeing and resilience

25 studies focused on factors influencing wellbeing and resilience in settings of multiple disasters,[31,33,34,38–40,42,44,45,47,49,50,55,62,68,77,82,83,115–121] including religiosity and the role of religion on coping,[38,40,45,47,49] social support,[45] the will to live,[116] gender,[45] perceived collective efficacy,[115,120] and perceived communal coping,[119] with mixed findings across different disaster contexts. One subset of articles focused on identifying patterns in positive emotions and post-traumatic growth following multiple disasters,[33,42,50,55,83,117,120] with some studies highlighting that hope and optimism[33] or psychological resilience[42] can be protective factors for mental health after multiple disasters or can facilitate coping and resilience after multiple disasters.[50] More widely, wellbeing and resilience have generally been insufficiently studied following multiple disasters. One systematic review that focused on the 3.11 triple disaster in Japan found numerous studies documenting mental health effects, although little research on the resilience of this population or on possible interventions to support wellbeing.[110]

Turning to barriers to wellbeing or resilience in settings of multiple disasters, one study found profound difficulties in balancing home and work responsibilities among workers in the Florida Department of Health who had to respond to four hurricanes in 2004, and who were, in many cases, affected by the hurricanes personally as well as professionally.[62] Cherry and colleagues[31] documented threats to cultural heritage, financial challenges, and lingering health concerns as major challenges faced by fishing communities in the Gulf Coast of the USA who were affected by Hurricane Katrina and the Deepwater Horizon oil spill. Two studies after the 2010 and 2011 Christchurch earthquakes in New Zealand found inequalities in trajectories of wellbeing and quality of life in the years following the earthquakes by income, ethnicity, and disability and physical health status.[118,121] Conceptualisations of resilience in multiple disaster contexts were also critiqued, with one study finding that people in poor neighbourhoods of Rio de Janeiro, Brazil, faced constantly recurring disasters and used resilience strategies as a necessity.[82]

Physical health

16 articles focused on physical health after multiple disasters.[75,76,79,80,122–133] One study, which looked at 500 communities across the USA, found that those who had experienced recurring disasters had increased incidences of asthma, high blood pressure, and self-reported poor mental health and poor physical health. Moreover, the incidence of all such outcomes increased with each additional year in which a community experienced a disaster.[128] After Hurricane Katrina and the Deepwater Horizon oil spill in the Gulf Coast of the USA, one study (focused primarily on mental health) found that people exposed to both of these disasters had more physical health symptoms than did populations exposed to only one of the disasters,[41] suggesting a cumulative effect. These studies highlight that exposure to multiple disasters can be associated with poorer self-rated health or increased physical health symptoms than exposure to one disaster.

Conversely, not all studies suggested a cumulative effect of multiple disaster exposures on physical health. One article on maternal and child health found that exposure to Hurricane Charley (2004) during pregnancy or shortly before conception was associated with increased risk of extremely preterm delivery; however, exposure to additional hurricanes did not seem to increase this risk further.[80]

There were also indications of a connection between mental health and physical health outcomes in settings affected by multiple disasters. One study in the Gulf Coast of the USA suggested that losses as a result of Hurricane Katrina were associated with subsequent distress related to the Deepwater Horizon oil spill, which in turn was associated with physical health symptoms—suggesting that mental health effects from disasters can be one pathway to physical health effects.[29] Hayashi and colleagues[127] similarly found that post-traumatic stress disorder and insomnia after the 3.11 triple disaster in Japan was associated with increased fracture risk among older adults. Several studies in this same context also found a substantial increase in diabetes,[129] bodyweight, body-mass index, waist circumference,[131–133] and polycythemia[130] among populations exposed to the 3.11 disasters, with studies finding that those forced to evacuate were at greater risk of these outcomes than were non-evacuees.[129–131]

Other studies found an effect of emotional repression on immune parameters in populations affected by multiple disasters,[122] potential effects of multiple disaster exposures on child growth,[126] and patterns of waterborne and foodborne diseases after meteorological disasters.[79] Four articles focused on mortality after multiple disasters, including issues with death recording,[76,125] and physical and social determinants of mortality.[75,124]

Indirect implications for public health

Effects on health-care facilities

Four articles focused on health-care facilities in settings of multiple disasters.[134–137] Three studies found staff shortages in the aftermath of the 3.11 triple disaster in Japan,[135] which persisted for up to 18 months after the disaster and affected local health-care facilities.[136,137] One study looked at Hurricane Stan (2005) and a subsequent landslide in Guatemala and documented the immediate effects on one hospital, finding major structural damage but also a rapid recovery driven by a common vision shared by workers.[134] Across all identified cases, the affected hospitals continued functioning despite major logistical difficulties. Further research on indirect effects on patient care or on the health and wellbeing of hospital staff in multidisaster settings is warranted.

Risk perception and evacuation

Eight studies focused on public perceptions of risk and related behaviours in settings of recurring disasters, with mixed findings.[43,52,59,60,65,78,138,139] Smith and McCarty[60] found that, during the four hurricanes in Florida, USA in 2004, hurricane strength was the primary predictor of evacuation behaviours during each hurricane; however, increases in the numbers of hurricanes experienced had no effect on the likelihood of evacuating. Similarly, one study of 19 large earthquakes in Sichuan province (China) found that the severity of past disaster experiences was strongly correlated with perceptions of disaster risk, but the number of past disaster experiences was not.[138] Wang and colleagues[59] looked at public complacency (defined as the public believing that the threat would not happen and ignoring it, or not preparing for it, even if the threat appeared imminent) during the 2004 hurricanes in Florida, and found that public complacency peaked after three hurricanes. Other studies across different settings have similarly suggested a need for further work to improve communication and knowledge exchange between residents and government actors in settings affected by recurring disasters,[139] with one study underscoring that multiple disasters could provide a window of opportunity for agencies to engage citizens in preparedness.[65] Other studies have identified additional factors that might influence risk perception, evacuation decisions, or both in settings of recurring disasters, including gender,[43] the extent of losses in previous disasters,[78] and persuasion by family and friends.[52]

There is a need for further research on how experiencing multiple disasters can influence risk perception and public responses to risk, and the indirect implications there might be for public health as a result (ie, from non-evacuation or delayed evacuation).

Household and community responses

Five articles focused on strategies for coping with multiple disasters at the household and community level.[81,140–143] Bacon and colleagues[140] reviewed cumulative disasters in Nicaragua (coffee leaf rust from 2011 to present, drought in 2009, and Hurricane Mitch in 1998) and found a correlation between the coping responses that households used in past events and their continued use in subsequent disasters. Conversely, one study in Nebraska, USA documented various coping mechanisms for handling recurring severe drought in 2002–04 and 2012–14, and found that previous experience with the earlier drought resulted in different actions, including new water-conservation and land-use practices, in the later drought, with support from the government.[141]

Two studies examined the role of traditional knowledge systems of recurring disasters. Ngwese and colleagues[81] studied communities affected by recurrent flooding and droughts in Ghana, and found that communities used traditional knowledge systems to prepare for disasters, while often viewing these practices as having low efficacy. In a study of climate-related hazards in Cambodia, Pauli and colleagues[142] found that combining traditional knowledge and biophysical data could lead to a better understanding of so-called pressure points, at which the effects of recurring flooding become most severe, and the authors advocate for the co-production of knowledge between scientists and local communities.

Government responses

11 articles focused on government responses, including tensions in balancing national disaster management and local governance in multiple disaster settings,[144,145] disruptions in communications to citizens caused by additional disasters occurring,[146] and organisational learning in government responses to multiple disasters.[61,67,73,74,144–150] Kapucu and colleagues[61] found no evidence for improvement in emergency management responses to each of the four hurricanes that hit Florida in 2004. Similarly, one study reviewed government responses to disasters that occurred over the course of two decades in the USA,[147] and another reviewed disasters that occurred between 1996 and 2005 in the Netherlands;[148] both studies found that the same problems were often

repeated in government responses to multiple disasters without improvement. Nohrstedt and colleagues[149] found that the frequency and severity of disasters experienced in 85 countries were not associated with improved disaster risk reduction policies in those countries, even after controlling for income levels, types of disaster and starting policies.

There is some evidence of government learning in different contexts. For example, Brody and colleagues[74] looked at floods in Florida from 1999 to 2005 and found evidence for policy learning over time in local government. One study of emergency response in China found that government-organised response and rescue operations improved after the Wenchuan earthquake of 2008 and were more efficient and effective during the Lushan earthquake of 2013.[150] In another study, Corbacioglu and Kapucu[73] found evidence for organisational learning, but only after multiple disasters that culminated in one of devastating scale. Little organisational learning was seen in Turkish disaster management after the Erzincan, Dinar, and Ceyhan earthquakes between 1992 and 1998; however, the devastating earthquake in Marmara in 1999 led to changes in disaster management in Turkey.

There is a need for further research on the public health implications of government responses and governmental learning versus non-learning in multiple disaster settings (and related policy changes or non-changes), as an upstream structural determinant of health.

Humanitarian and non-governmental organisation responses

One study assessed the occurrence and effects of disasters in the southern Africa region between 2000 and 2012, with a focus on humanitarian responses, and found that smaller, subnational disasters were reoccurring and compounding large-scale disaster events.[151] However, this study found that large datasets often mask the effects of local and small-scale disasters, leading to bias in humanitarian disaster-relief responses, which focus on larger events. On a more local level, one study after the Nepal earthquakes in 2015 found that the operational reliance of non-governmental organisations on social capital to distribute support after a disaster contributed to inequities in access to resources.[152]

Recovery processes

26 articles focused on elements of recovery from multiple disasters, including economic recovery,[153,154] government and political factors in the recovery stage,[53,66,155–160] community capitals,[24] schools as central hubs for recovery,[161] disaster recovery committees,[162] inequalities in recovery,[163–167] and reconstruction experiences.[150,168–170] This group also included articles on programmes undertaken in a recovery setting in low-income and middle-income countries, including a food security and relief programme,[171] a microcredit programme,[172] a recovery aid programme,[69] and a global water, sanitation, and hygiene (WASH) programme.[70]

Some studies looked at individual or household recovery experiences (eg, of reconstructing housing, or settling insurance claims);[158,160,166,167,169,173] however, most focused on recovery at the community level[24,69,70,154,172] or the country level.[153,171] This focus was in contrast to some of the included mental health studies, which conceptualised individual-level recovery as the absence of mental health conditions or return to pre-disaster psychosocial or cognitive functioning.[28,48,83]

Few of the 26 articles identified provided a definition of recovery, and those that did gave different definitions.[160,163,166,167,169] The majority (23; 88%) of articles discussed recovery as a generalised concept, rather than recovery from multiple disasters. We identified only three articles that directly focused on the complexities of recovery from multiple disasters. Sargeant and colleagues[169] looked at the aftermaths of Typhoon Haiyan (2013) and Typhoon Haima (2016) in the Philippines and the Nepal earthquakes (April and May, 2015), and found that individual recovery was constrained by the continued need to respond to new cases of flooding, landslides, and monsoons. Ray-Bennett[172] suggested that multiple disasters can produce complex crises that make recovery tenuous, and Himes-Cornell and colleagues[24] emphasised the need for further research into what happens to communities that experience a disaster while they are still recovering from a previous one.

Challenges to researching multiple disasters

Conceptual and methodological challenges were identified in the study of multiple disasters. Many studies noted issues in defining and measuring multiple exposures.[28,41,85] Among quantitative studies on health outcomes (appendix p 18), there was a wide range of ways in which disaster exposure was defined and measured, and in some cases exposure was not measured directly. There was also a wide range of time periods covered between different disasters. For example, there were only 30 min between the 2010 Biobío earthquake and tsunami in Chile,[87,88] but 11 years between the 9/11 terrorist attacks and Hurricane Sandy in New York City.[106] However, we could not identify any clear evidence for differences in the effects of multiple disasters depending on the timescale between exposures or on hazard type (ie, differences in multiple exposures to the same hazard type versus different hazard types), representing a need for further research. Some studies noted that they were affected by methodological constraints that are common across disaster research, including the limitations of naturalistic study designs and the inability to draw causal conclusions,[26,28,29,32,55] absence of control groups,[110] and difficulties in tracking and including disaster-affected individuals who relocated out of study areas.[56,84]

Panel: Recommendations for supporting public health in multiple disaster settings

Mental health

- Provision of mental health support services to populations affected by cumulative trauma such as multiple disasters.[25,31,35,84,90,96,112,127]
- In mental health support interventions, screen for previous disaster exposures and other past traumas to identify populations at risk.[37,41,87,98,102,106]
- In counselling protocols, account for history of post-traumatic stress disorder symptoms from past disasters.[94]
- Whereas post-traumatic stress disorder and depression are commonly considered in public health screenings after a disaster, alcohol misuse, panic disorder, obsessive compulsive disorder and suicide risk are also relevant to screen for.[97,98]
- Mental health services should be widely offered in communities affected by multiple disasters, rather than waiting for people to seek out support.[35]
- Explore support options for children, young people, and families.[28,87,113]

Wellbeing and resilience

- Psychosocial support programmes after multiple disasters.[40,45,63,83,105,115]

Physical health

- Clinicians should be aware that experiencing traumatic events during multiple disasters can affect physical health,[25,123,129–131,133] and should screen for exposure to past disasters.[89]

Government responses

- Identify ways to improve links between governments and affected communities to enable more effective communication.[59,67,68]
- Improve opportunities for local government officials to connect with decision makers in central government,[157] and strengthen subnational governance and integration of non-governmental organisations to improve responses to consecutive disasters.[144]
- Develop new public policy strategies to support families affected by multiple disasters.[126]

Risk perception and evacuation

- Strengthen community groups and support community leaders to increase localised communication about risks of multiple disasters.[138]
- Create spaces in which local residents of disaster-affected places and governments can exchange information and experiences.[139]

Recovery

- Consider the historical nature of trauma in an area and recollections of past disasters when examining effects of present disasters and working on recovery.[92]
- Develop inclusive recovery frameworks, committees, and support programmes that recognise the needs of diverse communities.[118,162,165,166,169]
- Develop policy and interventions to support people in preventing, preparing for, and recovering from ongoing or recurring disasters.[164] Ensure that any recovery interventions do not overlook crucial social, cultural, political, and environmental factors that can influence the recovery process.[159,163,167]

It was notable that some articles (16; 11%) focused on a single disaster within a multi-disaster setting.[31,32,36,86,90,112,113,116,117,124,135,137,154–157] There were also numerous quantitative studies in which the entire study population was affected by multiple disasters, without comparison to populations affected by no disasters or only one disaster (appendix p 18). We identified only one article that engaged with theoretical literature on compound or cascading disasters.[151]

Discussion

Our Review suggests that multiple disasters can have direct and indirect effects on physical health, mental health, and wellbeing, with evidence of cumulative effects. Moreover, multiple disasters can affect health-care facilities, population risk perception and evacuation decisions, household and community responses, government responses, humanitarian and non-governmental organisation responses, and recovery processes, in ways that go beyond what is seen from single disasters.

We could not identify consistent individual-level risk factors for adverse outcomes following multiple disasters, with mixed results by age and gender. However, we found an emerging body of literature on the inequitable effects of multiple disaster exposures on physical health, mental health, and recovery processes at the community level. Hahn and colleagues[128] found that communities in the USA that had medium or high ratings on the Centers for Disease Control and Prevention Social Vulnerability Index (built from data on poverty levels, employment, educational attainment, and more) had the highest incidences of self-reported poor mental health, poor physical health, asthma, and high blood pressure after exposure to multiple disasters. Morgan and colleagues[121] found uneven trajectories of wellbeing and quality-of-life scores in the aftermath of the 2010 and 2011 Christchurch earthquakes in New Zealand. Those who had low income, were Māori, or who lived with a physical health condition or disability were more likely to experience lower quality of life and wellbeing in the long term. A group of studies following the 2015 Nepal earthquakes emphasised inequalities in long-term recovery trajectories,[163,166,167] finding that marginalised groups were more likely to face long-term displacement[164] and to be excluded from

Search strategy and selection criteria

The search strategy was informed by preliminary searches, and aims to account for different terms that are used to discuss multiple disaster scenarios. We searched Scopus, Web of Science, and PubMed from database inception to August 2, 2021, using the following terms: "cascading disaster*" OR "overlapping disaster*" OR "multi* disaster*" OR "compound* disaster*" OR "intersect* disaster*" OR "cumulative disaster*" OR "simultaneous disaster*" OR "concurrent disaster*" OR "consecutive disaster*" OR "repeat* disaster*" OR "recur* disaster*" OR "reoccur* disaster*" OR (multi* hazard*) AND (disaster* OR crisis OR crises OR emergenc*) AND recovery. This search resulted in 529 hits from Scopus, 931 from Web of Science, and 332 from PubMed. After 367 duplicates were removed, 1425 articles were screened.

We included peer-reviewed empirical academic articles published in English. Inclusion criteria were that articles focus on individuals or communities exposed to multiple disasters, and include discussion of the health, wellbeing, or social effects of these disasters; post-disaster activities; or economic, cultural, legal, or political effects that could influence health or wellbeing. To identify exposure to multiple disasters, we screened articles and included them for full-text screening if they either named more than one disaster (eg, the Great East Japan Earthquake and Fukushima Daiichi nuclear power plant disaster) or described scenarios in which more than one disaster occurs (eg, reference to recurring disasters), and indicated a defined population or place that experienced these disasters. Because of our focus on peer-reviewed empirical evidence, we excluded conference abstracts, theses, books, and theoretical or conceptual or commentary papers. We also excluded papers with a primary focus on infrastructure, technology, or risk modelling (ie, architecture, geospatial risk characteristics, or remote sensors).

Of the 1425 articles, 1116 were excluded during initial title and abstract screening because they did not describe a case of multiple disasters, leaving 309 articles for full-text screening. After this screening, 228 articles were excluded (figure 1) and 81 were included. The reference lists of all 81 included articles (apart from that of one systematic review) were then examined, and a further 69 articles that met the inclusion criteria were identified after full-text screening. With these, we included a total of 150 articles in the Review.

community-led reconstruction initiatives.[165] Still further research, policy, and recovery services will need to address inequities when advancing efforts to prevent, prepare for, respond to, and recover from multiple disasters.

Given the gaps we have identified, several recommendations can be made for further research. There is a need for further studies to examine differences between the effects of recurring disasters (of the same hazard type), and cascading disasters and consecutive disasters with different hazard types. Equally, there is a need for further research to investigate whether effects might differ depending on the timing between disaster exposures. There is also a further need for research on the psychological effects of repeat disaster exposure,[57,101] how previous disaster exposure affects the experience of any subsequent disasters,[25] the effect of multiple disasters on preparedness and recovery,[43] and the physical health effects of multiple disasters.[41] There is also a clear need to better understand the long-term effects of multiple disaster exposures.[33] In addition, although this Review has looked back at previous cases of multiple disaster exposures in individuals and communities, there is also a future-facing body of work on risk assessments (eg, in urban planning) and the all-hazards approach to disaster preparedness that will be relevant for reducing the public health risks of multiple disaster exposures.[174] Linking studies on the documented effects of past disasters with future-facing studies on modelling and reducing multi-disaster risks will be important in future work.

Recommendations for practice

In addition to the research recommendations that we have discussed, there are also several recommendations for practice that can be taken from this Review. There is scarce evidence to date on how to best support the health and wellbeing of people and communities after multiple disaster exposures. There is a pressing need for work on intervention programmes that are tailored to multi-disaster scenarios, given the ways in which the effects of these scenarios might differ from those of single disasters and the potential need for overlapping preparedness, response, and recovery activities in relation to different hazards. The panel summarises a range of recommendations for practice made in the identified articles, covering mental health, wellbeing and resilience, physical health, government responses, and recovery, and we suggest a need for integrated action across these categories. Many of these recommendations were similar to those made in the context of single disasters, for example providing widespread mental health support services. However, some recommendations were specific to multiple disasters, such as screening for past disaster exposure in interventions responding to new disasters.

Limitations

First, a general limitation of scoping reviews is that they do not systematically appraise the quality of evidence.[21] This approach is suitable for the current topic, given the emerging nature of knowledge on multiple disaster exposures, and the fact that public health implications have been studied by diverse disciplines and methods. The current findings could inform a further systematic review or meta-analysis (eg, focused on quantitative studies of mental health outcomes). Second, only English-language articles were included. Third, we categorised articles on the basis of the primary focus we identified within them; however, there were cases in which the boundaries between categories (eg, between mental health and wellbeing) overlap. Fourth, because we were unable to include all potential combinations of hazard types in the search terms, this Review identified only cases that were described as multiple disasters; however, there are likely to be more cases than those actively described as such. For example, since completion of this Review, we have identified a relevant article on multiple disaster exposures that refers to people with multiple disaster exposures as exposure outliers.[175] Fifth, we recognise that the definition of where disasters begin and end can be unclear. There is increasing emphasis from some researchers that disasters should be thought of as processes, rather than events;[176] however, this framing was not present in most articles that we reviewed. Sixth, this Review focused on direct and indirect public health implications and the recovery stage of the disaster cycle, and did not include specified search terms on preparedness or resilience. Finally, we did not include grey literature in this review; however, the existence of increasing amounts of grey literature on multiple disasters should be noted.

This scoping review outlined existing research on the public health effects of multiple disasters and recovery from these disasters. We underscore the relevance of public health implications of multiple disaster exposures. Given the projected increases in extreme weather events owing to climate change, there is a pressing need to become better equipped to address public health in settings of multiple disasters.

Contributors

CL and LG conceived and designed the study. CL acquired and analysed the data. CL, LG, KB, LR, and PQ contributed to the interpretation of data. CL drafted the manuscript, and all authors revised it critically for important intellectual content. All authors give final approval to the version to be published, and agree to be accountable for all aspects of the work.

Declaration of interests

We declare no competing interests.

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ARTICLE

The Sendai Framework for Disaster Risk Reduction: Renewing the Global Commitment to People's Resilience, Health, and Well-being

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Abstract The Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) is the first global policy framework of the United Nations' post-2015 agenda. It represents a step in the direction of global policy coherence with explicit reference to health, development, and climate change. To develop SFDRR, the United Nations Office for Disaster Risk Reduction (UNISDR) organized and facilitated several global, regional, national, and intergovernmental negotiations and technical meetings in the period preceding the World Conference on Disaster Risk Reduction (WCDRR) 2015 where SFDRR was adopted. UNISDR also worked with representatives of governments, UN agencies, and scientists to develop targets and indicators for SFDRR and proposed them to member states for negotiation and adoption as measures of progress and achievement in protecting lives and livelihoods. The multiple efforts of the health community in the policy development process, including campaigning for safe schools and hospitals, helped to put people's mental and physical health, resilience, and well-being higher up the disaster risk reduction (DRR) agenda compared with the Hyogo Framework for Action 2005–2015. This article reviews the historical and contemporary policy development process that led to the SFDRR with particular reference to the development of the health theme.

Keywords Disaster risk reduction · Global health · Health policy · Public health · Safe hospitals

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1 Introduction

Disasters destroy lives and livelihoods around the world. Between the years 2000 and 2012, it is estimated that over 700,000 people lost their lives; more than 1.5 billion people were affected by disasters in various ways, with women, children, and several other groups impacted disproportionately. Disaster impacts also set back hard-won economic development gains and affect all socioeconomic strata, societal institutions, and sectors in one way or another. The total economic loss was estimated to have exceeded USD 1.3 trillion over the 2000–2012 period (UNISDR 2013a).

Disasters are not natural events. They are endogenous to society and disaster risk arises when hazards interact with the physical, social, economic, and environmental vulnerabilities and exposure of populations (UNISDR 2013b). Many of the destructive hazards are natural in origin and include earthquakes and extreme weather events resulting in floods and droughts, which has resulted in disaster risk management policy being largely event driven. Therefore, the attention of the policy community has naturally fallen on the hazards and the related physical processes that result in disasters.

Progress in disaster risk reduction (DRR) research has shown that it is often not the hazard that determines a disaster, but the vulnerability, exposure, and ability of the population to anticipate, respond to, and recover from its effects. A shift from pure hazard response to the identification, assessment, and ranking of vulnerabilities and risks (including their unequal distribution in populations) became critical (Department for International Development 2006). This shift in focus takes into account social factors shaping local populations' interpretation of risks and their thresholds for action (Eiser et al. 2012). The implication is that societal determinants of risk (through individual or collective agency and with the assistance of science and technology) can be identified and influenced to achieve better economic and social development trajectories (Scott et al. 2013).

The Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) was born from the need to ensure DRR policy reflects our evolved understanding of the complexity of disaster risk in the twenty-first century. Implementation calls for closer collaboration among all sectors including the health sector in order to prevent, prepare for, respond to, and recover from disasters that result from the highly interdependent and evolving risks to which we are exposed.

This article provides a brief summary of the history of UN-based frameworks for DRR, a reflection on the processes leading to these frameworks, and finally focuses on SFDRR. It discusses some of the reasons for and importance of having a strong health focus in SFDRR and the benefits of the close relationship that health has with the science and technology aspects in this framework. It offers ideas on how renewing the global commitment to people's resilience, health, and well-being can be enhanced by the implementation of SFDRR over the next 15 years.

2 Landmark Policy Developments Led by the United Nations in Disaster Risk Reduction

Providing assistance to disaster-affected populations is almost as old as international cooperation itself (Kamidohzono et al. 2015). A turning point came with the UN General Assembly (UN/GA)'s recognition of "the importance of reducing the impact of natural disasters for all people, and in particular for developing countries." This led to the designation of the 1990s as the International Decade for Natural Disaster Reduction (IDNDR 1994) in which "the international community, under the auspices of the United Nations, paid special attention to fostering international co-operation in the field of natural disaster reduction" (UNISDR 2012).

In 2000, the International Strategy for Disaster Reduction (UNISDR) was established following IDNDR of the 1990s. The UN/GA convened the second World Conference on DRR in Kobe, Hyogo, Japan 2005, which concluded the review of the Yokohama Strategy and its Plan of Action and the adoption of the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters (HFA) (UNISDR 2005) by 168 countries. The HFA outlined five priorities for action:

(1) Ensure that DRR is a national and a local priority with a strong institutional basis for implementation;
(2) Identify, assess, and monitor disaster risks and enhance early warning;
(3) Use knowledge, innovation, and education to build a culture of safety and resilience at all levels;
(4) Reduce the underlying risk factors;
(5) Strengthen disaster preparedness for effective response at all levels.

In the HFA, health was mentioned only three times in one paragraph (19) under Priority 4 (reduce the underlying risk factors) (UNISDR 2005, p. 11):

> Integrate DRR planning into the health sector; promote the goal of "hospitals safe from disaster" by ensuring that all new hospitals are built with a level of resilience that strengthens their capacity to remain functional in disaster situations and implement mitigation measures to reinforce existing health facilities, particularly those providing primary health care.

This text focuses narrowly on hospitals and health facilities, overlooking the wider societal determinants of human health and well-being.

Around the same time, two further global policy processes were initiated in parallel to the HFA process: the climate change agreements and Millennium Development Goals. The three policy areas were intricately related as they all draw on scientific knowledge and influence human well-being directly or indirectly. However, they were not linked together as clearly as they could have been in the HFA and the policy processes for each area developed as separate policy streams (Fig. 1). The economic development, emergency response, and climate change communities of research, policy, and practice are composed of different individuals and disciplines and managed by different organizations with different funding streams that deepen the siloes in theory and practice, albeit with some degree of overlap that is increasingly recognized and reflected in the UN post-2015 agenda.

Yet, there are obvious synergies between the three policy areas that can be emphasized and strengthened to promote policy coherence and facilitate convergence of objectives in implementation (ICSU and ISSC 2015). For

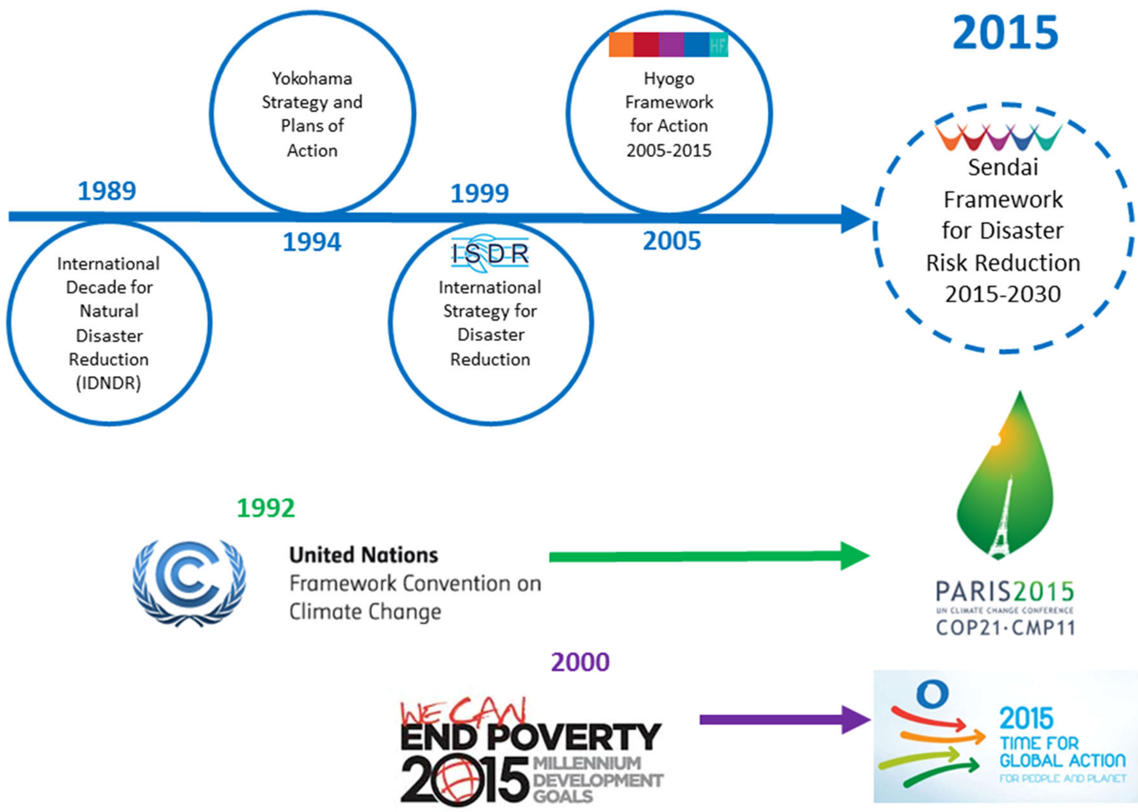

Fig. 1 Twenty five years of international commitments to disaster risk reduction [*Source* Adapted from presentation by Andrew Maskrey, Lead Author and Head of the Risk Knowledge (UNISDR 2015)]

example, important synergies that have not been realized exist between the proposed post-2015 sustainable development goals and the SFDRR targets and indicators: population health and well-being outcomes have been identified explicitly within the SDGs, but these cannot be achieved without managing those risks that are so closely associated with disasters such as weak critical infrastructure, for example, poorly built hospitals. The integration of climate change adaptation into planning and policy design, and decision making can promote support resilient economic development and prevention-orientated emergency planning.

Synergies with the climate change and sustainable development agenda should continue to be articulated and leveraged for more effective decision making and funding allocation. An all-hazard, risk-based, trans-disciplinary and multisectoral approach will help to identify and prioritize synergies, and this can help to formulate solutions to complex problems and the development of joint policy initiatives. This requires collaboration, communication, and capacity development across the scientific disciplines and technical fields, and with all stakeholders including representatives of governmental institutions, communities of policy making, scientific and technical specialists, the technology sector, and members of the communities at risk, in order to guide scientific research, set research agendas, and support education and training (Aitsi-Selmi et al. 2015).

This year—2015—presents an unparalleled opportunity to align landmark UN agreements through the convergence of three global policy frameworks: the Sendai Framework for DRR 2015–2030 (March 2015), the Sustainable Development Goals (September 2015; SDGs), and the Climate Change Agreements (December 2015; COP21). These major global policy instruments need to align urgently to facilitate and encourage better participation in DRR, sustainable development, and climate-change mitigation and adaptation from the science and technology communities.

3 Public Health Needs in Disasters

During recent decades, the world has faced a greater frequency and impact from disasters as well as a paradigm shift in the types of hazard and the possible risks that constitute a threat to human well-being, including climate change (see also Kelman 2015), rapid and unmanaged urbanization, lack of resources, poverty, and loss of biodiversity. The 2004 Indian Ocean earthquake and tsunami was historically exceptional in terms of its impact on lives and communities (Rodriguez et al. 2006). This disaster illustrated the vulnerability of multiple countries and communities to natural hazards that arise in distant locations. The event also encouraged the global community to adopt a comprehensive framework for action, and identify global priorities for work and practical steps that are required to achieve disaster resilience.

The implementation of the HFA over the past 10 years has been urged on by similar events, such as Hurricane Katrina, which served to remind society of the terrible consequences of limited planning and preparedness. Other examples include the 2011 East Japan Earthquake and Tsunami and Typhoon Haiyan in 2013, as well as the severe 2011 floods in Thailand that affected the Japanese car industry and the global computer industry for a significant period of time (Ye and Abe 2012).

The expansion of DRR to include risk assessments addressing vulnerability and exposure has been compared to the widening of health activities to include prevention which has traditionally been the preserve of public health. Public health is increasingly concerned with the total health system and not only the eradication of a particular disease affecting an individual patient (Murray et al. 2015). The consequences of disasters on human health and well-being are varied and include direct impacts on lives and livelihood sustainability and indirect impacts on macroeconomic growth and social support mechanisms (Schipper and Pelling 2006). The US Centers for Disease Control and Prevention link hazards to the transmission of infectious diseases, especially since water supplies and sewage systems may be disrupted and sanitation and hygiene may be compromised by population displacement and overcrowding that led to interrupted normal public health services (Malilay et al. 2013).

All three World conferences on DRR were held in Japan, which has been significantly affected by natural hazards but has also been at the forefront of disaster preparedness and recovery in many ways. The 1995 Hanshin-Awaji disaster, which killed more than 5500 immediately (Shinfuku 2002) and resulted in more than 40,000 injured, spurred building code reform and health system strengthening that are thought to have helped to reduce the impact of the 2011 earthquake and tsunami. In addition, the establishment of the Japanese Association for Disaster Medicine (JADM) in May 1995 as a professional association is believed to have had an important role in strengthening the health system's emergency preparedness and therefore resilience to disasters (Egawa 2014a, 2014b).

In Western Africa, the Ebola outbreak (2014–2015) devastated health facilities and people's trust in health care providers. The fragility of the health systems and the lack of resources to manage the isolation and treatment of patients overwhelmed the existing capacity of health care providers and local and national governments. The health disaster resulted in severe budget cuts to non-Ebola-related health services and a significant reduction in the use of health services owing to fears of cross-infection. As a result, more people are estimated to have died from childbirth, malaria, and AIDS, as well as other diseases (Walker et al. 2015).

Other than epidemics, disaster deaths are rarely due to infectious diseases, instead occurring due to a variety of causes that include blunt trauma, drowning, and air pollution, for instance, from forest fires or building collapses (Malilay et al. 2013). Aside from physical injury and infectious diseases, disasters can leave those affected with short- and long-term mental health consequences. Significant changes can occur rapidly in people's lives when they are exposed to extreme events and disasters. These can cause great stress to people, families, and communities because of their inherent effects, such as suffering short-term fear of death and other mental health disorders (Williams and Drury 2011). Post-traumatic stress disorder (PTSD) is the most often studied manifestation of the psychosocial stress caused by disasters, but mental health impacts also include general distress, anxiety, excessive alcohol consumption, and other psychiatric disorders (Neria and Shultz 2012).

Those with chronic diseases could have worse outcomes and many risk dying when their medication is not available or they lack access to health care. People with chronic diseases have ongoing medical needs that can easily be affected when health services are disrupted in disaster situations. While further understanding is required in this area, a recent systematic review (Ochi et al. 2014) revealed that a considerable number of patients lose their medication during evacuation, many lose essential medical aids such as insulin pens, and many do not even have a record of their prescriptions with them when evacuated. In the Philippines, during Typhoon Haiyan, the major medical and public health needs of the affected people were not injury-related, but the result of a lack of measures to prevent infectious diseases and the worsening of non-communicable diseases due to the lack of access to food, water, housing, and medicine (Egawa 2015).

4 Health After the Hyogo Framework: Changing Public Health Priorities for Action in Disaster Risk Reduction

In this section, the development of the health theme in the Annual Reports of the Secretary General (ARSG) on the implementation of the International Strategy for Disaster Reduction for the UN General Assembly (UN/GA) covering the 2005–2014 period is examined.

In 2005, the ARSG summarized the essential elements of the Hyogo Framework for Action, but health stakeholders were not highlighted (UN/GA 2005). In 2006, the ARSG stated that the World Health Assembly urged member states to engage actively in collective measures to establish global and regional preparedness plans that integrate risk reduction into the health sector and build capacity to respond to health-related crises (UN/GA 2006). In 2008, the Hospitals Safe from Disasters campaign, supported by the World Health Organization and the World Bank, attempted to better protect the lives of patients, health staff, and the public by reinforcing the structural resilience of health facilities; ensuring that health facilities continue to function in the aftermath of disasters; and upgrading preparation and training of health workers on preparedness plans (UN/GA 2008). In 2009, UNISDR ARSG encouraged national assessments of the safety of existing education and health facilities by 2011, and the development and implementation of concrete action plans for safer schools and hospitals by 2015 as was agreed at the Global Platform (GP) in May 2009 (UN/GA 2009).

In 2010, the UNISDR ARSG was particularly rich in capturing the impacts of disasters on health and hospitals. It stated that earthquakes in Haiti, Chile, and China have provided stark reminders of the increasing disaster risk in urban areas; and the same report predicted that it would take many decades for Haiti to recover and grow as a society and an economy because critical hospitals, other healthcare facilities, and schools were damaged or destroyed, and were consequently unable to continue service delivery to affected communities (UN/GA 2010). In 2011, the ARSG report noted that drought remains a hidden risk, poorly understood despite its impacts on human health, livelihoods, and multiple economic sectors as drought leads to stress and insecurity for rural and pastoralist populations (UN/GA 2011).

In 2012, the UNISDR ARSG mentioned the One Million Safe Schools and Hospitals initiative—through which the Secretariat works with communities, civil society organizations, governments, and the private sector to make schools and hospitals safe from disasters—and noted that the initiative had received over 200,000 pledges for safety (UN/GA 2012). Finally, in 2014, the ARSG stressed the urgent need to anticipate medium- and long-term risk scenarios and to identify concrete measures to minimize the creation of future risk, reduce existing levels of risk, and strengthen social, environmental, and economic resilience. The UN/GA observed that for the fourth consecutive year, economic losses from disasters had exceeded USD 100 billion (UN/GA 2014). These policy statements demonstrate how, over the years, UNISDR annual reports have had an increasing focus on health-related issues because of the growing concerns expressed by many stakeholders about the devastating effects of disasters on human health and well-being.

As part of the assessment of the impact and progress of the HFA, the *Mid-Term Review of the Hyogo Framework for Action* (UNISDR 2011) was published in 2011 and was facilitated by the UNISDR Secretariat through a participatory approach involving stakeholders at international, regional, and national levels. This report was guided by the advice of the 2009 GP for DRR, which requested a broad strategic review of the state of HFA implementation. The information that was collected was primarily of a qualitative nature, based on self-assessments and perceptions of the stakeholders involved via the HFA monitor reporting mechanism. In addition, a series of briefing papers was developed and the UNISDR Scientific and Technical Advisory Group was asked to contribute actively. In summary, this contribution stated that:

> […] recognising the importance of scientific and technical information for DRR UNISDR established a Scientific and Technical Committee in 2008 to address policy matters of a scientific and technical nature, where science is considered in its widest sense to include the natural, environmental, social, economic, health and engineering sciences, and the term 'technical' includes relevant matters of technology, engineering practice and implementation. In its report—Reducing Disaster Risks through Science—issues and actions, to the GP 2009, the committee concentrated on addressing: climate change; changing institutional and public behaviour to early warnings; incorporating knowledge of the wide health impacts of disasters; improving resilience to disasters through social and economic understanding. (UNISDR 2011, p. 35)

The Mid-Term Review concluded that the implementation of HFA over the 5 years prior had generated significant international and national political momentum and action around DRR. It also underscored areas where further work was necessary to build on the positive gains of the development of the HFA in order to achieve the expected outcome of "substantial reduction of disaster losses, in the lives and in the social, economic and environmental assets of communities and countries" (UNISDR 2011, p. 69).

Although there was little on health in the HFA Mid-Term Review, there was increasing interest in health-related issues in many discussions and debates around the GPs in 2011 and 2013. In part, this coincided with the Intergovernmental Panel on Climate Change (IPCC) in which UNISDR participated. In the Norway-UNISDR joint report in 2008 (Norway and UNISDR 2008), it was clearly demonstrated that there was a need for an IPCC report on disasters. This IPCC Special Report: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change*

Adaptation showed that much can be done to reduce the severity and frequency of extreme weather events influenced by anthropogenic climate change, through implementing sustainable development practices that aim to protect our environment and, concomitantly, improve human health and well-being (IPCC 2012). IPCC reported in 2014 that there is increased evidence that climate change is affecting many natural and human systems and poses significant risks to human health, ecosystems, infrastructure, and agricultural production (IPCC 2014). This led to a call for DRR to enable critical public policies that are informed by evidence from science and the use of tools from technology to address disaster risk (Aitsi-Selmi et al. 2015).

In summary, the Hyogo Framework for Action 2005–2015 helped to widen the remit of DRR activities beyond simply responding to disasters to include detailed risk assessment, improving early warning and response capacities, impact-based forecasting, better resource management, knowledge creation and sharing, building public commitment, and developing supportive institutional frameworks (HIS 2011). However, challenges remained in risk governance and assessment as well as monitoring, dissemination, capacity development, and shifting the culture from a hazard and response-driven culture to a risk-driven, integrated culture that encompasses the full DRR cycle from prevention to recovery and rehabilitation (IFRC 2014).

5 Developing the Hyogo Framework for Action Successor Through International Consensus Building

The HFA clearly suggested that successful disaster resilience requires scientific and technical capacities with inputs from physical, social, economic, health, and engineering disciplines. As the process of developing the HFA's successor began, the need for a more integrative DRR process that incorporated bottom–up and top–down actions, local scientific and technical knowledge, and a vast array of stakeholders became important (Gaillard and Mercer 2012). In this section, we review the policy development process and how the global and regional UNISDR platforms, the preparatory committees, and other international technical and policy negotiation meetings helped to shape SFDRR.

5.1 The Global and Regional Platforms

The GPs for DRR were held biennially from 2007 to 2013 and provided a forum for member states and other stakeholders including the scientific community and civil society organizations to assess progress on the implementation of the HFA by drawing on information from the relevant scientific and policy fora and the online Hyogo Framework Monitor (http://www.preventionweb.net/english/hyogo/hfa-monitoring/national/). Regional ministerial conferences and platforms were also organized by UNISDR and its regional offices as multistakeholder fora to support the delivery of government commitments by improving coordination and implementation of DRR activities while remaining linked to national and international efforts. Only the outcomes from two recent GPs of 2011 and 2013 are discussed below.

The 2011 GP gave greater attention to people's health than the previous two GPs due to a combination of factors, including a larger number of health delegates (>60) from many different countries and the establishment of a thematic platform devoted to DRR and health, which had been agreed at the 2009 GP (WHO 2009). Participants at the 2011 GP shared information on their projects and discussed a global plan of action to enhance multisectoral collaboration on DRR for health to protect lives and livelihoods (WHO 2011) and provided a launchpad for the discussions regarding the inclusion of DRR in the post-2015 development goals (WHO 2013). A joint statement on *Scaling-up the Community-Based Health Workforce for Emergencies* was developed by the Global Health Workforce Alliance (GHWA) together with the World Health Organization (WHO), the International Federation of Red Cross and Red Crescent Societies (IFRC), the United Nations Children's Fund (UNICEF), and the United Nations High Commissioner for Refugees (UNHCR) (GHWA et al. 2011). Speakers from WHO and partner organizations contributed to GP sessions that addressed the following issues (WHO 2011):

- Learning lessons for strengthening all-hazards preparedness arising from the global experience of a multisectoral approach to pandemic preparedness;
- Identifying the health aspects of preparedness and response to nuclear emergencies;
- Progressing the implementation of safer hospitals initiatives in more than 42 countries, which has resulted in the assessment of more than 630 health facilities assessed for their safety and ability to function in emergencies;
- Effectively restoring health services and health facilities in the recovery and reconstruction for disasters;
- Improving the flow of climate-related information between hydrometeorological services and the health sector for improved risk management and decision making in the context of the Global Framework for Climate Services;

- Developing programs to enhance risk assessment at all levels to inform on risk management programming by communities and countries.

In the Chair's summary of the GP of 2013 emphasis was placed on targeting the root causes of risk where participants raised the need to take concrete measures to tackle risk drivers including baseline levels of disease, inadequate health services and infrastructure before, during and after disaster events, and poor water and sanitation (GPDRR 2013). Several proposed actions for health were put forward (GPDRR 2013) including: full reporting of the health burden of disasters and the consequences for community development and the systematic application of the 2005 International Health Regulations (WHO 2005). Other important themes noted by the Chair were the emphasis placed on "integrated, multisectoral approaches to DRR, and to strengthening DRR in key sectors, such as education, agriculture and health" and that "development and resilience are unlikely to be sustained unless disaster risk is explicitly addressed in all development initiatives" (GPDRR 2013, p. 2).

In addition, "The global economy's transformation over the previous 40 years was recognized as leading to a growing accumulation of disaster risk and that countless everyday local events and chronic stresses involving multiple risks are an ongoing burden for many communities. Food security, livelihoods and people's health were noted as being directly at risk in drylands and drought-prone areas subject to desertification and in small island developing states. Finally, the private sector was seen as an important piece in the risk reduction puzzle and that "resilient business and investment go hand in hand with resilient societies, ecosystems and the health and safety of employees" (GPDRR 2013, p. 3).

Statements of support for public health, science, and technology from the UNISDR Regional DRR Platforms held in 2014 in Africa (UNISDR 2014a), the Americas (UNISDR 2014b), Asia (UNISDR 2014c), Europe (UNISDR 2014d), and in the Arab League (UNISDR 2014e) have been instrumental in shaping SFDRR's commitments for DRR in public health, science, and technology.

5.2 The Preparatory Committees

The Preparatory Committee meetings were open to governments and nongovernmental actors (scientists, the private sector, civil society, intergovernmental organizations) and facilitated formal member state negotiations on SFDRR. Three Preparatory Committee meetings were held between July 2014 and March 2015. An example of a successful policy process is captured in the strength of the call for science and greater evidence-informed DRR. The wider DRR community worked with member states to articulate specific science requests, where science in this context refers to knowledge obtained through systematic observation, recording, testing, evaluation, and dissemination. These data are generated by physical, geographical, engineering, environmental, social, health, psychological, management, and economic sciences to name but a few (Aitsi-Selmi et al. 2015).

The science, health, and technology call was maintained by the member states at negotiations held in Geneva in June 2014, November 2014, and in January and February 2015 and finally in Sendai, Japan in March 2015. Through the various national and international DRR meetings, the call for a stronger science element in policy also received support through the Major Group on Science and Technology, organized by the International Council of Science and included many of the major science institutions of the world.

5.3 Technical Meetings and Network Development

Networks and international collaboration have become essential to the creation and dissemination of new knowledge (Persson et al. 2004). Linking science and decision making requires a special effort. Science panels can be used to provide advice to decision-makers such as national-level research councils, boards, and committees to facilitate science communication alongside the creation of public participation processes and stakeholder panels and the development of special communication materials (von Wintderfeldt 2013).

As an example of such initiatives to close the science-policy gap and in an effort to promote the integration of science into the next DRR framework, Tohoku University established in 2012 the International Research Institute of Disaster Science (IRIDeS) to promote action-oriented research integrating and disseminating scientific discoveries. The institute includes a multidisciplinary disaster medical science division. In preparation for the 2015 World Conference on Disaster Risk Reduction (WCDRR) in Sendai, IRIDeS co-organized the International Symposium on Disaster Medical and Public Health Management: Review of Hyogo Framework for Action in Washington DC, May 2014. This symposium was officially supported by the Ministry of Health, Labour and Welfare of Japan. More than 120 health professionals, researchers from various organizations including UN agencies such as UNISDR, WHO, the Office for the Coordination of Humanitarian Affairs (OCHA), the World Bank, and the Pan American Health Organization (PAHO) participated.

A position paper (ISDMPHM 2014) proposed a set of recommendations reached by consensus including that the consideration of health in DRR should be imperative by promoting the mutual understanding of health and non-health sectors and capacity development through the education and training of health professionals regarding DRR to protect people's health and health infrastructure and reduce the vulnerability of communities to disasters (Egawa et al. 2014; Otomo and Burkle 2014; Sugawara and Yeskey 2014; Tomita and Ursano 2014; Pesigan and Cullison 2014; Radjak and Redmond 2014). These recommendations were disseminated through various fora including the 6th Asian Ministerial Conference on Disaster Risk Reduction (AMCDRR 2014; Chatterjee et al. 2015).

5.4 Advocacy from the Health Sector

WHO worked with a wide range of partners including member states through a multisectoral approach to improve health outcomes for people at risk of emergencies and disasters. WHO has been committed to providing guidance and assistance for developing country and community capacities in health and other sectors to manage the health risks associated with emergencies and disasters in an integrated manner that involves all partners and operates at all levels of research and decision making.

In the build up to WCDRR, WHO convened and participated in a number of fora to maintain the visibility of health, and influenced the policy and practice of emergency risk management for health broadly, and informed the health content of the post-2015 framework more specifically. As an example, at the 2011 GP, the issue of people's health was given greater attention due to a combination of factors, including a larger number of health delegates from many different countries and more presentations from the health sector than in previous sessions as well as two meetings of a thematic platform devoted to health (WHO 2011). In the same year, WHO also released a document that highlighted the vital role of community health workers, including volunteers, in DRR (GHWA et al. 2011), and called for governments and all partners to invest in strengthening their capacity. WHO also led the One Million Safe Hospitals and Safe Schools Campaign to make schools and hospitals safer from disasters (WHO n.d.).

WHO representatives have recognized that SFDRR is "[…]very different from what we saw in Hyogo because it's not just about protecting people's health but the recognition that health is at the very centre of DRR' and also that '[h]ealth and DRR are deeply connected; healthy people are resilient people and resilient people recover more quickly from disasters" (UN News Centre 2015).

6 SFDRR: An All-Hazards Approach

SFDRR is a voluntary agreement adopted on 18 March 2015 by 187 UN member states after extensive negotiations at the Third World Conference on Disaster Risk Reduction (UNISDR 2015), the successor to the HFA. It has a greater emphasis on health and gives a clearer mandate emphasizing the need for a more integrative DRR process that incorporates bottom-up as well as top-down actions, local scientific and technical knowledge, and draws attention to synergies with health, climate change, and sustainable development. This is a significant framework for health—for people's health involving all sectors and for the health sector itself—with more than 30 explicit references to health, which refer to implementation of an all-hazards approaches (Kelman 2015) and link to epidemics and pandemics in addition to the 2005 International Health Regulations (WHO 2005). This far-reaching new framework for DRR has a clear outcome, goal, seven global targets, and four priorities for action.

Five of the seven global targets are particularly relevant to health:

(a) Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020 and 2030 compared to 2005–2015;
(b) Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020 and 2030 compared to 2005–2015;
(d) Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;
(e) Substantially increase the number of countries with national and local DRR strategies by 2020; and
(g) Substantially increase the availability of and access to multi-hazard early warning (UNISDR 2015, pp. 7–8).

The following paragraphs from SFDRR include actions required by public health, which are agreed as priorities for WHO to act on in partnership with UNISDR and the UN system as well as local, national, regional, and global partners as relevant.

- *In Priority 3* At National and Local Level 30(i) "Enhance the resilience of national health systems, including by integrating disaster risk management into primary, secondary and tertiary health care, especially at the local level; developing the capacity of health workers in understanding disaster risk and applying and implementing DRR approaches in health work; and promoting and enhancing the training capacities in the field of disaster medicine; and supporting and training community health groups in DRR approaches in health programmes, in collaboration with other sectors, as well as in the implementation of the 2005 International Health Regulations of the World Health Organization" (UNISDR 2015, p. 16);

- *In Priority 3* At National and Local Level 30(j) "Strengthen the design and implementation of inclusive policies and social safety-net mechanisms, including through community involvement, integrated with livelihood enhancement programmes, and access to basic health care services, including maternal, newborn and child health, sexual and reproductive health, food security and nutrition, housing and education, towards the eradication of poverty, to find durable solutions in the post-disaster phase and to empower and assist people disproportionately affected by disasters" (UNISDR 2015, p. 16);
- *In Priority 3* At National and Local Level 30(k) "People with life threatening and chronic disease, due to their particular needs, should be included in the design of policies and plans to manage their risks before, during and after disasters, including having access to life-saving services" (UNISDR 2015, p. 16);
- *In Priority 3* At Global and Regional Level 31(e) "Enhance cooperation between health authorities and other relevant stakeholders to strengthen country capacity for disaster risk management for health, the implementation of the International Health Regulations (2005) and the building of resilient health systems" (UNISDR 2015, p. 17);
- *In Priority 4* At National and Local Level 33(c) "Promote the resilience of new and existing critical infrastructure, including water, transportation and telecommunications infrastructure, educational facilities, hospitals and other health facilities, to ensure that they remain safe, effective and operational during and after disasters in order to provide live-saving and essential services" (UNISDR 2015, p. 18);
- *In Priority 4* At National and Local Level 33(n) "Establish a mechanism of case registry and a database of mortality caused by disaster in order to improve the prevention of morbidity and mortality" (UNISDR 2015, p. 19);
- *In Priority 4* At National and Local Level 33(o) "Enhance recovery schemes to provide psychosocial support and mental health services for all people in need" (UNISDR 2015, p. 19).

SFDRR strongly endorses the role of science compared to other global policy frameworks and specifically delineates the role that the UNISDR's Scientific and Technical Advisory Group (STAG) will play in implementation. The framework reflects the understanding that policies that are formulated based on scientific evidence can play an essential role in these efforts by determining disaster risk and thereby uncovering improved ways to prevent, mitigate, prepare for, recover from, and respond to disasters and therefore save lives and reduce disease related to disasters (Carabine 2015).

7 Implementing SFDRR: The Impact on Health

Like other wide-reaching policy frameworks, the effective implementation of SFDRR, will require the integration of momentum for action across local, national, regional, and international levels and will need to build on synergies across DRR, the Sustainable Development Goals, and the climate change agreement in 2015. Mutually beneficial capacity development and joint policy initiatives across these policy areas could considerably enhance the mainstreaming of DRR in health (WHO 2014). This should improve alignment with shifts in the health sector from a health-care focused, vertical-systems approach to an approach that strengthens health systems, promotes equity, and collaborates closely with non-health sectors to influence the wider, societal determinant of health for the health benefit of people and communities. A large part of the responsibility for linking health to DRR and implementing SFDRR with partners across the DRR community will be borne by the health sector through the leadership of the Ministries of Health in countries and the World Health Organization (UN News Centre 2015).

Working in partnership with the UNISDR STAG and linking health to DRR to implement SFDRR will have significant impact particularly when it has the following mandate in Priority 1, Paragraph 25(g):

> Enhance the scientific and technical work on DRR and its mobilization through the coordination of existing networks and scientific research institutions at all levels and all regions with the support of the UNISDR Scientific and Technical Advisory Group in order to: strengthen the evidence-base in support of the implementation of this framework; promote scientific research of disaster risk patterns, causes and effects; disseminate risk information with the best use of geospatial information technology; provide guidance on methodologies and standards for risk assessments, disaster risk modelling and the use of data; identify research and technology gaps and set recommendations for research priority areas in DRR; promote and support the availability and application of science and technology to decision-making; contribute to the update of the 2009 UNISDR Terminology on DRR; use post-disaster reviews as opportunities to enhance learning and public policy; and disseminate studies (UNISDR 2015, p. 12).

The need to communicate and understand the value of SFDRR widely so that all sectors, including health actors, embrace and implement SFDRR to protect people's health from the risks of emergencies and disasters should be shared by all, if progress on the health priorities is to be made. The initial implementation efforts taken by stakeholders in the immediate wake of SFDRR include the following:

(1) IRIDeS committed to establishing a Global Center for Disaster Statistics in collaboration with the United Nations Development Programme (UNDP 2015). The result of a long partnership, the new centre will help deliver quality, accessible, and understandable disaster data, including health-related data, to member states as they endeavour to achieve the goals of SFDRR;
(2) A meeting organized by the Collaborating Centre for Oxford University and Chinese University of Hong Kong for Disaster and Medical Humanitarian Response (CCOUC) and the Chinese University of Hong Kong Centre for Global Health was held in Hong Kong on 23 March 2015. The purpose of the meeting was to bring together a group of local, national, and international experts on DRR representing a wide range of fields and disciplines to discuss how to consider taking forward DRR science, technology, and public health implementation in the Asia region and included a review of emergency preparedness in mainland China (CCOUC 2015); and
(3) The World Conference on Disaster and Emergency Medicine held in Cape Town, South Africa on 21–24 April 2015 whose closing statement concluded that the conference participants should endorse the precepts outlined in SFDRR, and support continuing and renewed initiatives to assist in meeting the health-related goals and priorities as outlined in SFDRR (WADEM 2015).

8 Conclusions

SFDRR includes health as an indivisible component of DRR. Its perspective is to mainstream and integrate DRR within and across all sectors, including health, and at the same time to evaluate health outcomes from DRR implementation and to align the implementation of DRR approaches with other relevant health frameworks such as the 2005 International Health Regulations (WHO 2005). This article reviewed the latest developments in DRR UN-based global policy and identifies how the public health theme has been articulated in the development of SFDRR. It also highlighted the wider role of science—a strong tradition underpinning public health—and activities that will be central to implementation. A big question remains regarding SFDRR implementation.

The means of implementation of SFDRR are outlined in its text, but need to be developed and then adapted to local requirements while simultaneously being tied to a global monitoring process that is yet to be defined. It should ideally link to the Sustainable Development Goals and climate change agreements due in 2015 (Kelman 2015; Tozier de la Poterie and Baudoin 2015). Terminology, targets, and indicators (UNISDR 2014e) and funding remain issues to be resolved.

A new phase in DRR policy and implementation is beginning and provides an opportunity to align the post-2015 DRR agenda with the global public health needs of the twenty-first century through evidence-based policy and scientific activity that reflects the mandate given to the scientific community in SFDRR (see paragraph 25(g) above). With efforts to build on synergies across health, sustainable development, and climate change, DRR can help to create convergence between global policy frameworks—a convergence that can be promoted and supported through better population health and well-being as a focal point and important outcome for the post-2015 UN agenda.

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Research Article

National Health-Oriented Hazard Assessment in Iran Based on the First Priority for Action in Sendai Framework for Disaster Risk Reduction 2015–2030

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Background. Understanding disaster risk is the first priority for action based on the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR), and hazard assessment is the first step in the assessment of disaster risks. Therefore, assessing health-oriented hazards is the first measure in disaster risk assessment in the medical universities area in Iran. This article introduces a national experience and results obtained from designing a national tool for defining and assessment of health-oriented hazards in Iran. *Methods*. In the present study, a National Health-Oriented Hazard Assessment tool (NHHAT) was developed by experts and implemented by the Iranian Ministry of Health for gathering data according to frequency, probability, magnitude, and vulnerability of the hazards to identify the first ten hazards of medical universities in the two decades ago (2000–2021). Finally, the top 20 health-oriented hazards were identified among the ten hazards reported by each university. *Results*. According to the findings, the four most important hazards were road traffic accidents, earthquakes, drought, and seasonal floods. Nevertheless, the hazards such as desertification, tunnel events, soil liquefaction, mass population movement, and sea progression were among the rarest ones reported in the medical universities in Iran. *Conclusion*. Many functional aspects of disaster risk management depend on the realistic and accurate information related to the main elements of risk, especially the probable hazards in the communities. The comprehensive hazard assessment can only provide such information using context-bond tools. This is an applied study and a national implementation to fulfill the priority of the Sendai framework (i.e., understanding disasters risk) in Iran. It is suggested that other countries should also compile standard tools to explore the hazards for designing up-to-date hazard maps.

1. Background

As mentioned in the Sendai Framework for Disaster Risk Reduction (2015–2030), all policies and plans for disaster risk management should be based on understanding disaster risk from all aspects, including the vulnerability of individuals and properties, capacities, exposures, and characteristics of the environment and specifically the hazard behavior. In the past 10 years to 2015, 700 thousand people have lost their lives, more than 1.4 million injured, and about 23 million become homeless because of disasters all over the world [1].

Evidence suggested that the exposure of individuals and properties to hazards had high and fast growth in all countries in comparison to reduce their vulnerability. Therefore, new risks and increased damages caused by disasters at local and national levels have been brought up [2]. Natural hazards in Asia caused 90% of the affected population, 50% of deaths, and economic damage in the world [3]. In 2014, 202 natural disasters were recorded in Asia alone, in which 10,107,000 people were injured and 87,760,054 were affected [4]. Meanwhile, more than 90% of all casualties from natural disasters happened in developing countries [5–7].

Iran is in a region prone to many natural and manmade hazards. Hazards such as earthquakes, drought, and floods are the most important causes of death and economic damages [8]. During the previous three decades, many disasters have taken place, such as Rudbar–Manjil earthquake (1990), Bam earthquake (2003), Golestan floods (2000 and 2005), Azerbaijan earthquake (2012), Bushehr earthquake (2013), and Kermanshah earthquake (2017) [9], in which more than 109,000 people died and 150,000 were injured [8]. The most important features that change a hazard into a disaster are its likelihood of occurrence, vulnerability, and the response capacity of the affected community. Not all hazards lead to a disaster but only those whose impacts and outcomes are beyond the capacity of the affected area are considered disasters [5].

Regarding the international documents (the Hyogo and Sendai frameworks), the new approach in world disaster management is to decrease the disaster risks. Then, it is necessary to pursue the following objectives: preventing new disaster events and reducing the impacts of the existing ones. This will be possible only through implementing integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technical, political, and organizational measures. This can lead to the prevention and reduce the exposure to the hazards and the damages caused by disasters. It also promotes the preparedness for responding and recovering, which may result in the enforcement of resilience. The most important prerequisite to achieve the above goals is to understand disaster risk at local, regional, national, and universal levels. Understanding the disaster risk and risk assessment process begins with the technical hazard assessment by analyzing the probable hazards of the region [10].

Hazard assessment is a process to understand the behavior of the hazard including its frequency, probability, severity, and impact that threatens the community [5]. Hazard assessment answers the following questions: Which hazards are plausible in the community? How probable are they? How much will be the damages and their losses? What will be their impact on the community? and How much the community is vulnerable to the hazards [11]? Hazard assessment is necessary according to the unique context of each community/country (climatic, cultural, social and economic, geographic, housing patterns, and political sustainability) [5]. Therefore, it is essential to design and develop a standard analysis tool compatible with cultural and contextual factors.

In a short review of the literature, there are different hazard assessment methods and tools. Each of them used a different method to identify and prioritize the hazards. The hazard assessment tools are generally divided into two major groups: quantitative and qualitative.

For example, Threat and Hazard Identification and Risk Assessment (THIRA) is a quantitative tool that was produced and suggested by the Federal Emergency Management Agency (FEMA) in the United States of America [12].

Based on our knowledge, there is no comprehensive hazard assessment tool in national and in the health area adapted to Iranian cultural and contextual conditions and no reliable studies related to hazard analysis of the country. The research team of Health in Emergency and Disaster at the University of Social Welfare and Rehabilitation Sciences conducted the present study with two goals. The first goal was to design and develop a national tool to assess the health-oriented hazards. The second goal was to explore and identify the country's hazard list based on the geographic areas managed by medical and healthcare universities, considering the indicators that have influenced the rating of the hazards. This article is intended to introduce the "context-bond HHAT" which has been produced based on the national and international experiences that resulted in identifying the probable hazards in the whole country.

2. Methods

The present study was conducted in Iran during the years 2017–2018. The data relating to possible hazards and their impacts (the items in Tables 1–4) were gathered from the medical universities area to identify the first ten hazards in each medical university during the years 2000–2017. Accordingly, an NHHAT was designed to extract and evaluate hazards based on their behavior (probability, frequency, vulnerability, and magnitude) and geographical characteristics. This tool was developed at the Health in Emergencies and Disaster Research Center, University of Social Welfare and Rehabilitation Sciences in Tehran, and then approved by the Iranian Ministry of Health and Medical Education. The criteria and thresholds in this tool were prepared according to the national and international experiences and developed based on the opinion of experts in the field of emergency and disaster, using valid literature and the available hazard assessment tools. The experts include 2 emergency medicine specialists, 3 health in emergency and disaster specialists, 1 disaster epidemiologist, 1 prehospital emergency specialist, 1 geologist and seismologist, and 1 meteorologist. After approval by the health system authorities, the tool was introduced by the Ministry of Health and Medical Education and administered by all parts of the health system around the country.

For designing this tool, first, a list of 53 different types of hazards (natural, technologic, biological, chemical, and radiological) was identified and placed in the first column of the checklist. This list was open-ended, so that more hazards could be added later. The information used to define this list was provided in the District Disaster Management Organization and the other related organizations such as Agriculture Jihad Organization, Meteorological Organization, University of Tehran Institute of Geophysics, Red Crescent Society, Fire Departments, local trustees, and reliable historical documents. In the next, the four essential criteria include probability, frequency, vulnerability, and magnitude (that each has different constant coefficients), and also, different items to determine and score them (Tables 1–4) were used for scoring and ranking the first ten hazards (Table 5) in each university during the years (2000–2017). It should be noted that the constant coefficients are determined based on expert opinion. This period

Table 1: Ranking the hazard according to its probability.

Probability	Definition
1	The occurrence probability of the hazard is very weak
2	The hazard is likely to occur over the next 20 years
3	The hazard is likely to occur in the next 10–19 years
4	The hazard is likely to occur in the next 5–9 years
5	The hazard is likely to occur in less than 5 years

Table 2: Ranking the hazard according to its frequency.

Rank of frequency	Definition
1	None in the last 20 years
2	Once in the last 20 years
3	Two or three times in the last 20 years
4	Four or five times in the last 20 years
5	More than five times in the last 20 years

Table 3: Ranking the hazards according to its magnitude.

Rank of magnitude	Definition
1	(i) No impact on human health (ii) Property damage less than 25000$ (iii) No homeless or displacement (iv) No impact on health services
2	(i) 1 or 2 killed (ii) 1–4 injured (iii) Property damage from 25000 to 250000$ (iv) 1–100 homeless/displaced (v) 0–2 hours disruption in health services
3	(i) 3–5 killed (ii) 5–9 injured (iii) Property damage from 250000$ to 2.5 million$ (iv) 101–1000 homeless/displaced (v) 2–12 hours disruption in health services
4	(i) 6–9 killed (ii) 10–99 injured (iii) Property damage from 2.5 million$ to 25 million$ (iv) 1001–10000 homeless (v) 12–24 hours disruption in health services
5	(i) More than 10 killed (ii) More than 100 injured (iii) Property damage more than 25 million$ (iv) More than 10000 homeless (v) More than 24 hours disruption in health services

was chosen based on the feasibility and availability of valid and reliable data. The reliability and availability of information are derived from the Iran Development Outlook Document (in 20 years). All Iranian organizations have defined their development strategies according to this 20-year timeline. Also, it should be noted that as access to the physical, economical, social, environmental, and other information of variables related to vulnerability was not possible, the variable of "exposure to damage" was used to determining the vulnerability. To the rank of the identified hazards (in each university), the score of each criterion (based on the guides in Tables 1–4) is multiplied by its constant coefficient by the stakeholders who were

Table 4: Ranking the level of vulnerability.

The rank of exposure to damage	Definition
1	Less than 20% of the population at risk of health, financial, and functional damage
2	20–40% of the population at risk of health, financial, and functional damage
3	40–60% of the population at risk of health, financial, and functional damage
4	60–80% of the population at risk of health, financial, and functional damage
5	80–100% of the population at risk of health, financial, and functional damage

supposed to complete the tool, and the sum of the obtained scores creates the final hazard score (i.e., the total hazard score = [frequencies (1–5) x 7] + [probability(1–2) x 2] + [magnitude(1–6) x 6] + [vulnerability(1–5) x 5]). Then, the hazards were arranged according to their highest scores, and the first ten hazards were determined in each university.

To complete the tool, guidance and a definition of the related terms were added as tool guidance and published in the book "national tools for assessing health in emergency and disaster" and later became available for all medical universities all over the country [13]. To increase the accuracy of data collection, the Secretariat of the National Working Group on Health in Emergency and Disasters in the Iranian Ministry of Health and Medical Education arranged some workshops and training courses to introduce the tool for all stakeholders to increase the accuracy of data collection.

The training included introducing the basic concepts related to disasters and the way to fill the tool. All the data (the first ten hazards identified in each university based on Table 5) were entered in Excel and analyzed. Finally, the first 20 hazards were selected and ranked according to the number of universities where each hazard was reported. For example, the first hazard (i.e., the road traffic accidents) is the hazard that was identified and reported by more universities.

3. Results

After designing the NHHAT and gathering data, the hazards and their occurrences (frequency), probability, magnitude, and impacts (number of injured or killed people, financial impact, and other data based on Tables 1–4) from 45 medical universities were analyzed to extract a list of the top 20 health-oriented hazards in Iran. Data analysis showed that "road traffic accidents" were the first priority for the Iranian Health System. Also, earthquakes, droughts, and floods are the three hazards that ranked second to fifth. The hazards 6–20 are shown in Figure 1. Except for the top 20 hazards which were very common, some rare hazards, such as desertification, tunnel events, soil liquefaction, mass population movement, and sea progression, were explored for the first time, which based on our knowledge was not ranked or reported before in the other studies. These hazards and their frequencies are given in Table 6.

Table 5: Table of identifying the top ten hazards in each medical university.

Hazard	Frequency (7)	Likelihood/probability (2)	Magnitude (6)	Vulnerability (5)	Hazard total score
Hazard 1, 2, 3, . . ., 10	. . . x 7 = . . .	. . . x 2 = . . .	. . . x 6 = . . .	. . . x 5 = . . .	—

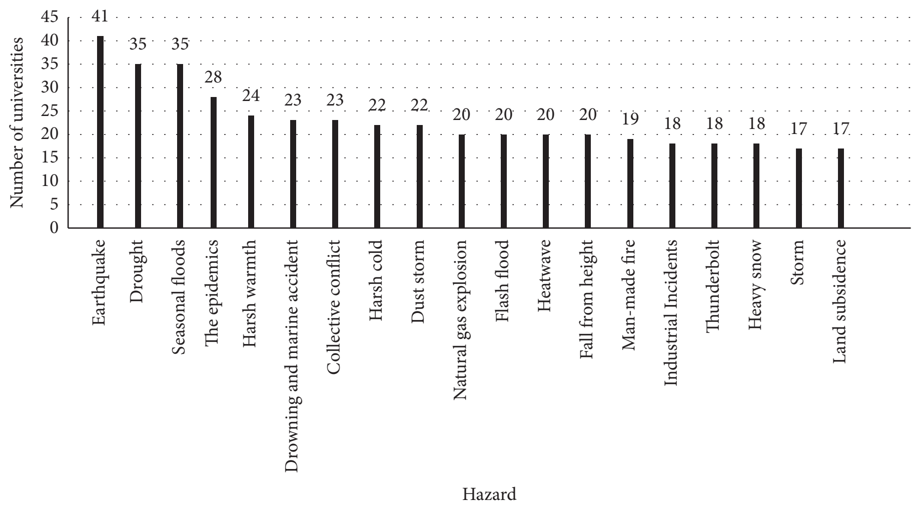

Figure 1: The top 20 health-oriented hazards in Iran based on data from years 2000–2017.

Table 6: The hazards that were explored for the first time in the medical universities area in Iran.

Row	Hazard	Number of universities
1	Water uplift	15
2	Falling	14
3	Soil liquefaction	13
4	Ice storm	11
5	Water pollution	9
6	Mass gathering	7
7	Insects and wild animals attack	6
8	Tunnel incident	5
9	Mountain incident	4
10	Events during project implementation	4
11	Sea level rise	4
12	Plant pests	3
13	Desertification	—
14	Sea oil pollution	3
15	Sea waves flows	2
16	Bridge collapse	2
17	Deforestation	1
18	Sea events	1

4. Discussion

Although gathering data with quantitative hazard assessment tools is more difficult in comparison to the qualitative tools, their precision is much higher [14]. In this study, the local hazard assessment tool with a quantitative approach has been used to determine and extract hazards using the data of the regions covered by the universities of medical sciences from all over the country. Also, in this study, similar to the health hazard assessment and prioritizing method (hHAP) which was used by the Los Angeles County Department of Public Health, an open-ended hazard checklist was used to determine the hazards. In this tool, a list containing 36 probable hazards out of 60 identified ones was chosen and reviewed [15]. However, in the Federal Emergency Management Agency (FEMA) and Coppola recommended method, the possible hazards are identified using different sources mentioned in the list. For example, in this way, a list of hazards of the examined area is extracted by using methods such as brainstorming, historical research studies in media archives, governmental documents, the collective memory of citizens, taking an overview of existing plans and programs, using maps, and follow-up interviews, and then choosing and listing hazards based on priorities [5, 12].

In this study, the criteria such as "frequency," "magnitude," "vulnerability," and "hazard probability" have been used to score and prioritize the hazards in about 20 years. However, this interval is not the same for all tools and methods. In a few cases, no time interval is considered at all. For example, in the hazard assessment tool by the Center for the Public Health and Disasters at the University of California, Los Angeles (UCLA) [16], and hHAP [15] tools have considered 25 years (because this interval is necessary to witness some rare hazards). However, the FEMA and Coppola methods have not considered any time interval for collecting data [5, 12]. The Emergency Management Ontario Ministry of Community Safety and Correctional Services, 2012, has defined a definite time interval to overview the number of each hazard happenings [17]. Different methods are used to rank hazards in the hazard assessment tools and methods. In most of the methods, estimation of the "risk score" for each hazard has been used to rank and determine the importance. For example, in the Coppola method [5], Kaiser Permanente Hazard Vulnerability Analysis (HVA) tool [18], hHAP tool [15], and UCLA tool [18] used risk scores for each hazard to prioritize them. Each of these tools and patterns used different indicators to estimate risk scores and finally rank the hazards. In the Coppola model, indicators related to each hazard such as "frequency," "likelihood," "magnitude," "location of hazard occurrence," "estimated spatial extent of hazard impact," "duration of hazard event," "speed of hazard onset," "availability of hazard warnings," and "time-based patterns of the hazard" are used. In this pattern, background information of the community such as information on geographic environment, assets and infrastructure facilities, demographic features of the population, vulnerabilities, and responding capacities are also used to estimate the risk of each hazard [5]. Hazard ranking factors in FEMA are "likelihood of hazard occurrence" and "the importance of hazard impact" [12, 15], and both of them are the key criteria used in most of the hazard assessment tools and hazard assessment methods, and they have been used in our tool too [5, 12, 19].

In the present study, the criteria of "probability" with the constant coefficient [7] have been used first. But after some experience, it was concluded to reduce them to 2 instead. Since probability/likelihood of hazard occurrence is multifactorial and depends on changes in the present and future, there is a need to have accurate scientific studies to collect detailed information which is not possible now. The impacts of hazards are unique to every part of the country with many possible quantitative features [12]. Therefore, it is used based on the information obtained from the two criteria of hazard, i.e., "magnitude" and "vulnerability," to estimate the impact of the hazard. The "size of the affected geographic area," "number of displaced households," "number of fatalities," "number of injuries and illnesses," and "disruption to critical infrastructures" are the factors required to estimate the hazard impacts in the FEMA pattern [12]. In the hHAP tool, the impact of the hazard on "community," "public health system," "medical system," and "psychological health" are considered [15]. In the present study, 60 hazards were identified in the regions covered by the university of medical sciences (this includes the whole country to some extent); among which, the first 20 hazards were selected and reported based on their priorities. Among these 20 hazards, the first 5 were "traffic accidents," "earthquakes," "drought," "floods," and "epidemics," and the final three ones were "heavy snow," "storms," and "land subsiding."

Though many sources have reported 31 kinds of hazards in Iran [20–22], our study explored 60 different kinds of hazards including natural and manmade which needed to be considered. The results obtained by the Emergency Events Database (EM-DAT) [23] emphasized the priority and importance of earthquakes in Iran in comparison to other hazards. Based on the EM-DAT results, earthquakes had the most number of occurrences among other natural hazards during 1900–2016. Though the success of many hazard assessment tools and models depends on reliable information obtained from the community considering contextual/cultural factors, the approach of this study was to use a context-bond tool as a national tool with highly accurate information in the country covered by universities all over the country. It is very rare to find a tool among all the existing tools and methods with such comprehensive coverage. Hence, the tool was first used in a pilot study at the beginning of 2018 and then developed into hazard assessment software.

The experience of using this tool showed that the national tool used in this study was an achievement in comparison to other tools, and despite its new perspective, it was successful enough in extracting the health hazards of the country. However, it seems there are some problems in estimating the likelihood/probability of hazard. It is, therefore, suggested that other researchers look for a way to solve this problem and update the tool to get the first step in disaster risk management, which is understanding disaster risk. It is finally recommended to quantify the hazard assessment tools to provide more credible information.

5. Conclusion

In the present study, a health-oriented hazard assessment tool was developed with the support of the national government. Many functional aspects of disaster risk management depend on realistic and trustworthy information related to the hazard and its components in the target area. It is, therefore, necessary to assess the hazards by using national tools and valid scientific methods to make them available at all different levels for those involved in disaster risk management in the country. These tools need to be continually updated, and more valid information is needed for producing credible and strong scientific evidence to plan for country risk management. On the other hand, since it is difficult to predict the probability of hazards according to continuous changes of infrastructures and population characteristics and the multifactorial nature of this important component of risk, it is recommended to have more studies in the future to find the influencing factors on the likelihood of hazards. Urbanization, technological development, development, and climatic changes have subjected human beings to be exposed to more technological hazards and urban events, which introduce the need for advanced scientific studies in this field.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Article

Health Vulnerability Index for Disaster Risk Reduction: Application in Belt and Road Initiative (BRI) Region

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Abstract: Despite the importance of health vulnerability in disaster risk assessment, most of the existing disaster vulnerability indicators only emphasize economic and social vulnerability. Important underlying health risks such as non-communicable disease are not included in vulnerability measures. A three-phase methodology approach was used to construct a disaster risk model that includes a number of key health indicators which might be missing in global disaster risk analysis. This study describes the development of an integrated health vulnerability index and explains how the proposed vulnerability index may be incorporated into an all-hazard based disaster risk index in the Belt and Road Initiative (BRI), also known as the "Silk Road Economic Belt", region. Relevant indicators were identified and reviewed in the published literature in PubMed/Medline. A two-stage dimension reduction statistical method was used to determine the weightings of relevant dimensions to the construction of the overall vulnerability index. The proposed final health vulnerability index included nine indicators, including the proportion of the population below 15 and above 65 years, under-five mortality ratio, maternal mortality ratio, tuberculosis prevalence, age-standardized raised blood pressure, physician ratio, hospital bed ratio, and coverage of the measles-containing-vaccine first-dose (MCV1) and diphtheria tetanus toxoid and pertussis (DTP3) vaccines. This proposed index, which has a better reflection of the health vulnerability in communities, may serve as a policy and implementation tool to facilitate the capacity-building of Health-Emergency Disaster Risk management (Health-EDRM).

Keywords: Health vulnerability; Health-EDRM; disaster risk; Silk Road Economic Belt; map; Belt and Road Initiative

1. Introduction

Disasters have brought huge losses in human health and the economy globally. According to Economic Losses, Poverty & Disasters, 1998–2017 issued by the Centre for Research on the Epidemiology of Disasters and United Nations Office for Disaster Risk Reduction in 2018, climate-related and geophysical disasters alone have taken lives from 1.3 million people, and have affected 4.4 billion people in the world between 1998–2017. The report also highlighted a global direct economic loss of USD 2908 billion due to disasters within the same period [1]. Asia, similar to previous years, suffered from the highest disaster occurrence (more than 40% of the total) [2], while China, India, Indonesia, and the Philippines were four of the top five countries that were most frequently hit by natural disasters over the last decade [3]. Due to climate change, both the frequency and intensity of disasters have been predicated to increase in the 21st century [4]. Relevant risk assessment tools and disaster risk reduction plans are important for saving lives and reducing losses in the future.

Understanding disaster risk in all its dimensions is the first priority for Disaster Risk Reduction action in the Sendai Framework, which was the first major agreement endorsed by the United Nations (UN) General Assembly on Disaster Risk Reduction for policies and practices for disaster risk management [5]. Disaster risk can be conceptualized as a function of hazard, exposure, and vulnerability [6]. According to UNISDR [7], risk is defined as the harmful consequences resulting from interactions between hazards, exposure, and vulnerable conditions. Hazard refers to dangerous phenomena that may cause negative health impacts; exposure refers to the people who are present in hazard zones and subject to potential health losses; vulnerability refers to the characteristics and circumstances of a community that make it susceptible to the damaging effects of a hazard. Disaster risk assessment can be understood as quantifying these three components among the population.

There are major technical gaps in how to describe vulnerability, particularly to health risks, when constructing disaster risk indexes [8]. Existing vulnerability indicators/indexes mostly focus on economic and social vulnerability [9–11]. Most health vulnerability indexes were developed after 2010, and were related to human health vulnerability toward climate-related disasters such as heat wave [12–14], flooding [15], dengue fever [16], and climate change [17]. In addition, as the data used for index construction were largely based on the country's own capacity in data collection, multi-country comparisons are often difficult, as countries may have different data collection methods and capacities. The Index For Risk Management (INFORM), a collaborative work with the United Nations, and the World Risk Index, a joint work with the Integrated Research on Disaster Risk (IRDR), are sophisticated global disaster risk indexes that have accounted for health vulnerability [18,19]. However, the current indexes do not include important health-affecting factors such as chronic diseases. Chronic disease is an important aspect to be considered in disaster risk management, as discontinuous treatment and medicine, which is possible during a disaster event, can lead to adverse health consequences among chronic disease patients. For instance, the provision of insulin may sustain the well-being and survival of diabetes patients [20].

Under the influence of globalization, the spread of health risks is borderless, and the prevention and control of health emergencies (e.g., disasters) need to be managed collaboratively. China's Belt and Road Initiative (BRI), also known as the "Silk Road Economic Belt", was initiated in 2013 and aimed to connect the Asian, European, and African continents and their adjacent seas, and establish and strengthen partnerships among the countries along the Belt and Road [21]. Among these BRI countries, various types of disasters occur frequently, and the widespread damage and destruction caused by disasters seriously disrupts the functioning of a society, and poses a major socio-economic development challenge for the Belt and Road Initiative region. The BRI also provides a health cooperation platform to handle regional health emergencies, offers medical assistance, and disseminates experience in the field of health care [22]. Understanding disaster risk and vulnerability for the countries along the Belt and Road is crucial for resource allocation. Yet, current available health vulnerability indexes may not apply to the countries within Belt and Road Initiative.

Health-Emergency Disaster Risk Management (Health-EDRM) is an academic paradigm representing the intersection of health and disaster risk reduction that covers the systematic analysis and management of health risks surrounding emergencies and disasters [23]. This study falls into the primary Health-EDRM intervention category (prevention/preparedness) in the system (country) level.

The objective of this paper is to describe the development of a health vulnerability index that aims to be incorporated into the vulnerability index, and might be applied to the use of the all-hazard based disaster risk index in the BRI region. The developed index described in this study used open access data and proposed indicators that are available in most countries and make disaster risk comparison between countries possible. The proposed method can also be adopted by regions or populations that were not included in this study. The findings from this study provide evidence to support disaster risk reduction in the BRI regions, and serve as a basis for the development of a population-based disaster risk assessment tool.

2. Materials and Methods

A three-phase methodology approach was used to develop the final disaster risk model. Phase 1 of the approach focuses on the development of the health vulnerability index, which includes an extensive literature review to identify the relevant published indicators to construct health vulnerability. Phase 2 involves a two-stage dimension reduction statistical method to identify the weighting for the indicators that were included for the health vulnerability index development. Phase 3 aims to create the final disaster risk index by combining the three main component indexes (health vulnerability index, exposure, and hazard index), which can be described in the following equation: Risk = Exposure × Hazard × Vulnerability [6]. The health vulnerability index is combined with existing exposure and hazard indexes to form a disaster risk index at the national level. The exposure and hazard indexes were based and accessed through the Institute of Mountain Hazards and Environment at the Chinese Academy of Science (http://english.imde.cas.cn). As the mechanisms and the development of the two indexes were out of the scope of this study, they were not included in this paper's discussion.

2.1. Phase I

Data Scoping and Variable Selection

Variable selection criteria include: (1) any indicator that is conceptually relevant to health vulnerability or may capture the Health-EDRM risks of the community; (2) indicators that have been identified/suggested in relevant literatures or organizations (e.g., the World Health Organization (WHO), UN, INFORM model [18] and World Risk Index [19]), and (3) indicators that are available for open access from reliable sources (e.g., WHO and the World Bank) for all of the study regions. Since subsequent factor analysis cannot be performed with missing values, countries with missing values were excluded in the subsequent analysis. The countries/areas along the BRI region and countries/areas included in the analysis were listed in the supplementary material A1.

2.2. Phase II

Statistical Model for the Health Vulnerability Index

As this study made no assumption on the weighting for indicators, in order to determine the weightings and explore the importance of the underlying dimensions to the overall vulnerability, a two-stage dimension reduction statistical method was used. This method also increases robustness [10] and allows monitoring changes in the weighting of indicators over time. In stage one, factor analysis (FA) was used as the primary statistical procedure for dimension reduction. The observed and correlated indicators were assumed to be adequately explained by a lower number of unobserved and uncorrelated factors. Stage two modeling was based on the result of FA; the selected health indicators were used to produce a more compact representation of the indicators (factors).

Stage 1: Selected indicators are normalized and included in the FA analysis. The matrix of factor loadings was estimated via the maximum likelihood method, and the number of factors that is extracted should contribute cumulatively to the explanation of the overall variance by more than 60% [24]. The Chi-square test was used to examine whether the number of factors, k, are sufficient to account for the observed covariance [25]. A non-significant Chi-square test result ($p \geq 0.05$) indicates that k is sufficient to explain the observed covariance. The explanation power increases when k increases. To obtain the most efficient model, the smallest k that yielded a non-significant Chi-square test was chosen. The initial k tried was one, and then, k was increased by one at a time. Then, the process is repeated until the p-value of the Chi-square test ≥ 0.05 [25]. Factors identified from FA are sometimes expressed as a compound with a relative large number of non-zero weighting indicators, which may make factor interpretation hard. To make interpretations of factors easier, Varimax rotation [26] was conducted to obtain as few large loadings and as many near-zero loadings as possible.

Stage 2: The development of the Health Vulnerability Index (HVI) is based on the latent factors derived from the FA. Each latent factor has factor loading on every health indicator, measuring the correlation between the health factor and the health indicator. The construction of the weights of the selected health indicators is from the rotated matrix of factor loadings [24,27]: (1) the proportion on each latent factor of the total unit variance was extracted; (2) the intermediate weights of all of the health indicators were calculated from the factor loadings corresponding to the latent factor; (3) the proportion on each latent factor is multiplied by the intermediate weights of all the health indicators on each latent factor to generate the weights for all the selected health indicators. Finally, the weights were multiplied by the corresponding standardized health indicator, and were added together for every country's HVI. A higher value indicates a more vulnerable country. The HVI value of each country involved was categorized into five HVI clusters using the equal interval method for data presentation in the form of a vulnerability map. A five-level scale was selected, as it provides a good balance between risk-level differentiation and clarity, and has been widely adopted in risk-level presentations [28,29]. R version 3.4.1 and ArcMap version 10.4.1 were used.

2.3. Phase III

Disaster Risk Index Model

Exposure and Hazard

The exposure and hazard index were provided by the working dataset of The Institute of Mountain Hazards and Environment at The Chinese Academy of Science. The exposure index was estimated by using the population density data from the Socioeconomic Data and Applications Center [30] as a proxy. For hazard, the frequency of natural disaster was applied. Both indexes were in a pixel-based format, and can be illustrated using a map.

Disaster Risk Index

Raster values from the Exposure index, the Hazard index, and the Vulnerability index were multiplied to generate the final Risk index. Since both the exposure and the hazard indexes are pixel-based data, the vulnerability index was transformed from the country-based format to the pixel-based using ArcMap before combining with the other two indexes to form the final risk index.

$$\text{Calculation of Risk (Risk} = \text{Exposure} \times \text{Hazard} \times \text{Vulnerability)} \quad (1)$$

Logarithm transformations were applied for skewed data, including the exposure index and the hazard index. The log-transformed indexes and the vulnerability index were then transformed to a 0–1 scale using min–max normalization. The final disaster risk index was calculated by multiplying the three transformed components with equal weight (Formula (1)) [18,19]. The results were presented in the form of map in a scale with five risk levels.

3. Results

3.1. Key Indicators of Vulnerability

Based on the three evaluation criteria, nine health indicators were identified and included in the final index development. Table 1 describes the key health indicators included.

Table 1. Key indicators of health vulnerability and their relevance.

Dimension of Health Vulnerability	Indicator	Conceptual Relevance to Health Vulnerability
Vulnerable age [a]	1. Population ages 0–14 and population ages 65 and above (% of total)	Extreme age groups (children and elderly) are known to be more vulnerable to health risks and less likely to be resilient when a disaster strikes. This is an important component in the "dependency ratio". They are more likely to accumulate post-disaster health and service needs.
Premature mortality [b]	2. Under-five mortality rate (probability of dying by age five per 1000 live births)	Leading indicator of health in the United Nation (UN)'s Sustainable Development Goals (SDGs). It is closely linked to maternal health.
Preventable mortality [b]	3. Maternal mortality ratio (per 100,000 live births)	Leading indicator of health in the UN's Sustainable Development Goals (SDGs). In addition to preventable deaths, this indicator reflects the capacity of health systems to effectively prevent and address the complications occurring during pregnancy and childbirth.
Vaccination gap for measles [b]	4. Measles-containing-vaccine first-dose (MCV1) immunization coverage gap among one-year-olds (%)	Standard Expanded Program on Immunization (EPI) for common preventable Childhood Communicable Diseases for children <one year old. Coverage may be used to monitor immunization services as well as guide disease eradication and elimination efforts, and are a good indicator of health system performance. MCV1: Measles is one of the most contagious and mortality-causing diseases in displaced camps. DTP3: Tetanus is common preventable infection associated with injury/wound.
Vaccination gap for diphtheria, tetanus, and pertussis [b]	5. Diphtheria tetanus toxoid and pertussis (DTP3) immunization coverage gap among 1-year-olds (%)	
Chronic diseases status [b]	6. Raised blood pressure (SBP $\geq$140 OR DBP $\geq$90), age-standardized (%)	A proxy indicator for chronic non-communicable disease. Hypertension and heart disease are some of the leading causes of mortality and morbidity globally. Disease status and potential activity limitations among adults can impair one's ability to prepare, respond, or recover from a disaster.
Infectious disease [b]	7. Incidence of tuberculosis (per 100,000 population per year)	Tuberculosis (TB) is the second leading infectious cause of death, and one of the most burden-inflicting diseases in the world. SDGs include ending the TB epidemic by 2030. The incidence of tuberculosis gives an indication of the burden of TB in a population.
Coping capacity [b]	8. Hospital beds (per 10,000 population)	Health systems resources indicate the level of access to care and the provision of quality medical care, which are highly correlated with live-saving and health status.
	9. Physicians' density (per 1000 population)	

Source: [a] Data collected from the World Bank; [b] Data collected from the World Health Organization. DBP: diastolic blood pressure; SBP: systolic blood pressure.

The Health Vulnerability Index was constructed for the 147 countries along the Belt and Road region. Indicators one, six, and seven are related to population structure and health status; indicators four and five are used to monitor immunization services, which are good indictors of health system performance; indicators two and three are leading indicators of the level of child and maternal health, as well as the overall development in countries; and indictors eight and nine measure the availability of healthcare, and are important indicators of disaster coping capacity. The correlations between the nine health indicators were shown in Figure 1. All of the correlations presented are statistically significant (all *p*-values < 0.01).

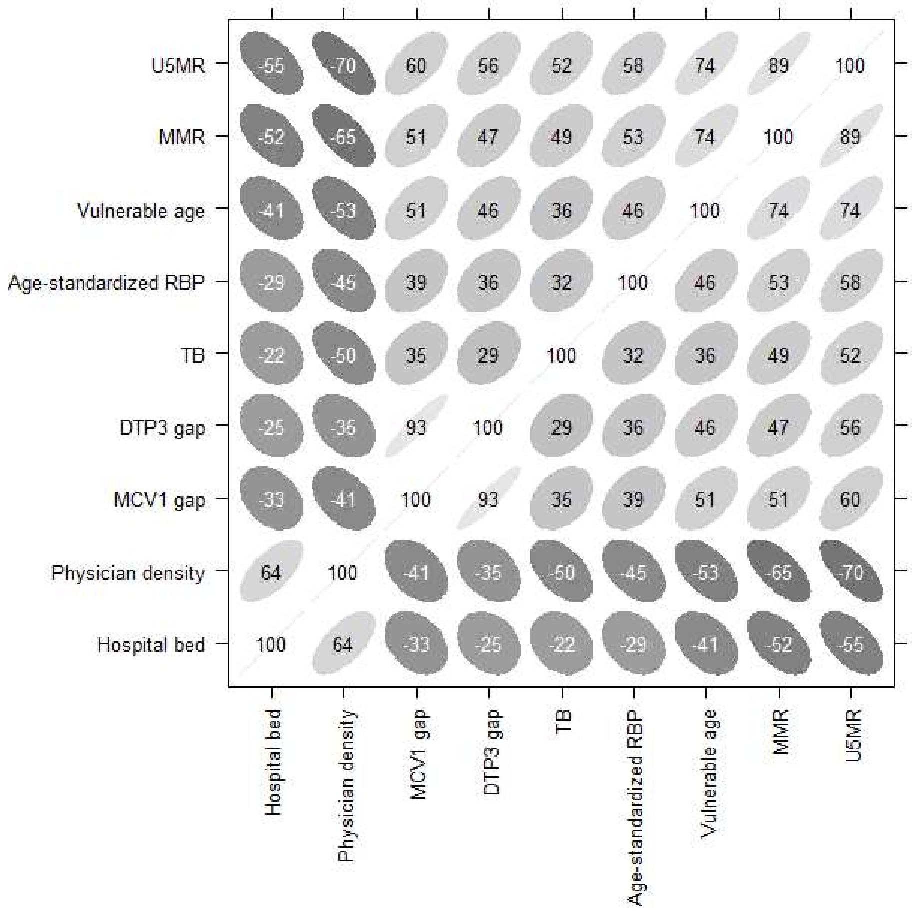
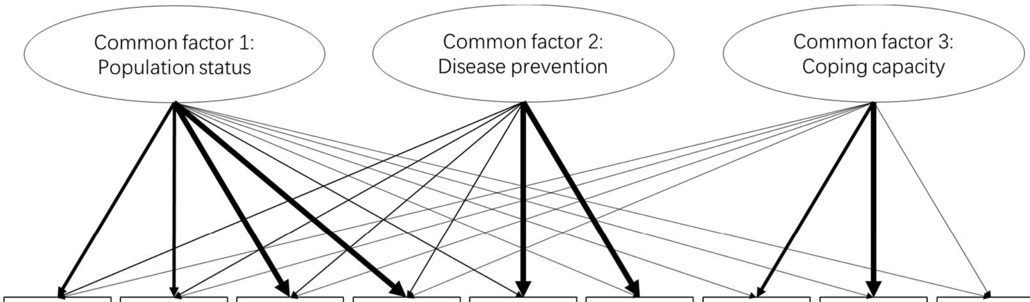


Figure 1. Correlation matrix of the proposed nine health indicators. Note: The figure depicts each correlation by an ellipse whose shape tends toward a line with a slope of one (or −1) for correlation coefficients near one (or −1), and toward a circle for a correlation coefficient near zero. In addition, 100 times the correlation coefficient is printed inside the ellipse (significance level at α = 0.05).

3.2. Underlying Dimensions of Health Vulnerability

The results of the Chi-square test for the sufficiency of the number of factors suggested that a three-factor solution was adequate to account for the observed covariances in the data among the 147 countries. Both of the eigenvalues of the three-factor solution were larger than one, and the three factors counted for about 71% of the total variance. Factor loadings after rotation are shown in Figure 2.



	Vulnerable age	RBP	MMR	U5MR	MCV1 gap	DTP3 gap	Hospital beds	Physician density	TB incidence
Factor 1	0.67	0.47	0.84	0.80	0.29	0.26	-0.34	-0.34	0.37
Factor 2	0.28	0.22	0.22	0.32	0.92	0.90	-0.13	-0.15	0.18
Factor 3	0.28	0.28	0.35	0.41	0.19	0.14	-0.55	-0.93	0.38

Figure 2. Factor loadings of the three latent factors. Note: Factor loadings are printed under the corresponding indicator. They are also indicated by the thickness of the arrow linking the factor and the indicator: the thicker the arrow, the higher the factor loading. Arrows are not shown if the absolute value of the factor loading is less than 0.2. Vulnerable age: people aged 0–14 or/and 65+ (%); RBP: Age-standardized raised blood pressure prevalence (%); MMR: Maternal mortality ratio (per 100,000 live births); U5MR: Under-five mortality rate (per 1000 live births); MCV1 gap: MCV1 Coverage Gap (%); DTP3 gap: DTP3 Coverage Gap (%); Hospital beds: Hospital beds density (per 10,000 population); Physician density: Physicians density (per 1000 population); TB incidence: Incidence of tuberculosis (per 100,000 population).

Since factor one is dominated by the maternal mortality ratio (per 100,000 live births) (MMR, 0.84) and the under-five mortality rate (per 1000 live births) (U5MR, 0.80), and moderately affected by vulnerable age (0.67) and age-standardized raised blood pressure prevalence (RBP) (0.47), this factor was labeled the "population status" factor. The second factor has its highest loadings on the measles-containing-vaccine first-dose (MCV1) gap (0.92) and diphtheria tetanus toxoid and pertussis (DTP3) gap (0.90), which was labeled the "disease prevention" factor. The third factor was highly correlated with physician density (0.92) and moderately with hospital beds (0.90), so it was labeled the "coping capacity" factor.

3.3. Factor Scores of Countries

The estimated scores of factors one to three for each country were calculated and categorized into five levels, as shown in Figure 3. Considering factor one, which reflects population status, Sierra Leone, Chad, and the Central African Republic are the most vulnerable countries, whilst Ukraine was shown to be the least vulnerable among all of the studied countries. For the second factor, Equatorial Guinea and Ukraine are prominent, because they had low MCV1 and DTP3 immunization coverage. For factor three, Thailand, the Solomon Islands, and Indonesia were at the highest end of the scale.

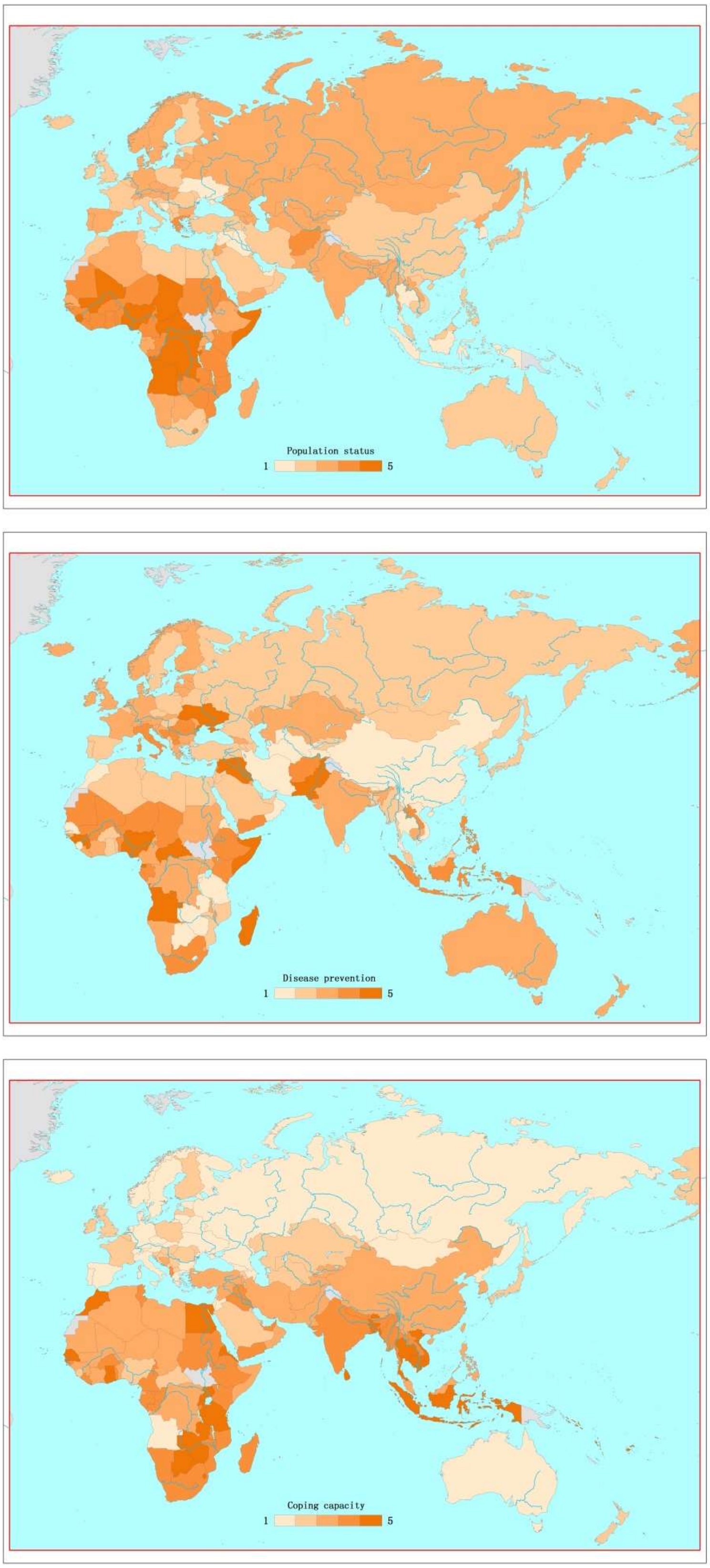


Figure 3. Factor scores of countries along the Belt and Road Initiative (BRI) region. Note: deeper color indicates a higher factor score and greater vulnerability.

3.4. Health Vulnerability Index of Countries

The development of the HVI was based on the FA model above, which captured the relative weights of the six health indicators. Weights for vulnerable age, RBP, MMR, U5MR, MCV1 gap, DTP3 gap, hospital beds, physician density, and incidence of tuberculosis (TB, per 100,000 population) were 0.10, 0.05, 0.14, 0.14, 0.15, 0.14, 0.07, 0.16, and 0.05, respectively. Greece, the Republic of Korea, and Belarus were the three least vulnerable countries, whereas countries labeled in the darkest color (the most vulnerable) were clustered in Africa, such as Somalia, the Central African Republic, and Chad (Figure 4).

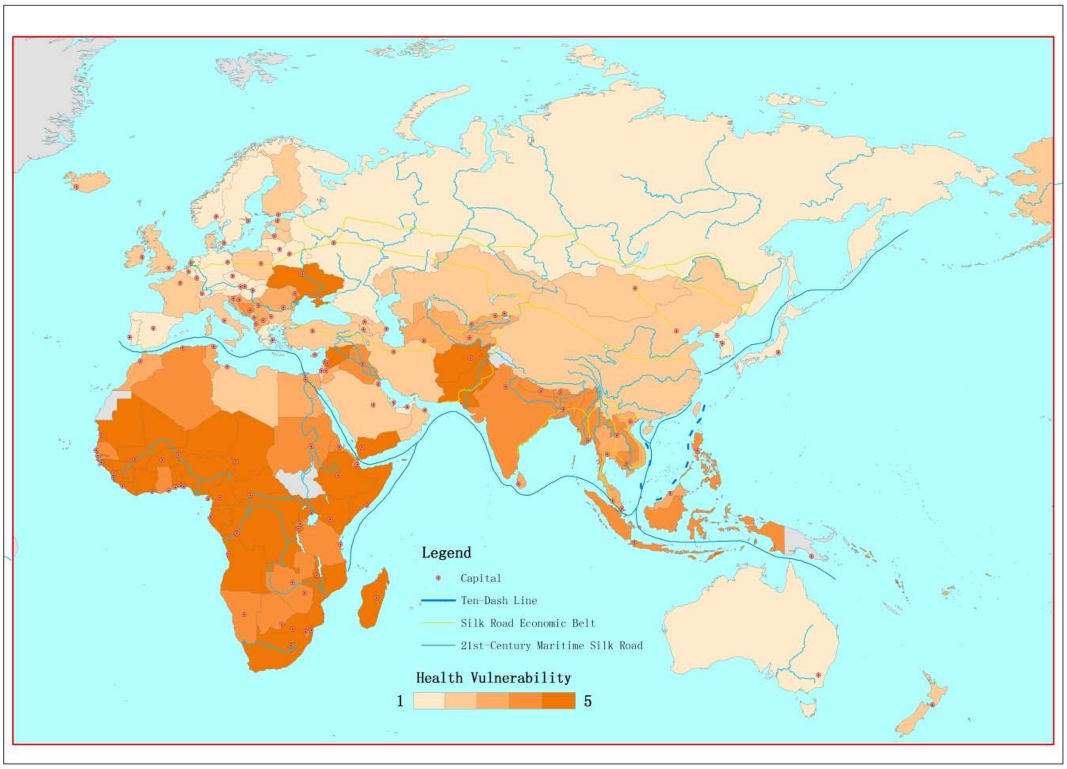


Figure 4. Health Vulnerability Index of countries along the Belt and Road Initiative (BRI) region. Note: deeper color indicates greater vulnerability.

3.5. Disaster Risk Mapping in Silk Road

The final disaster risk index along the Belt and Road region were calculated by combining the proposed vulnerability index, the hazard index, and the exposure index. The final index was in pixel-based format, and therefore was presented in a world map for illustration (Figure 5). The top five areas with the highest disaster risk that was identified in this study were in locations near the Philippines, Afghanistan, Bangladesh, Somalia, and Indonesia. Meanwhile, northwest China, North Africa, eastern Europe, and Australia were found to have relatively lower risks.

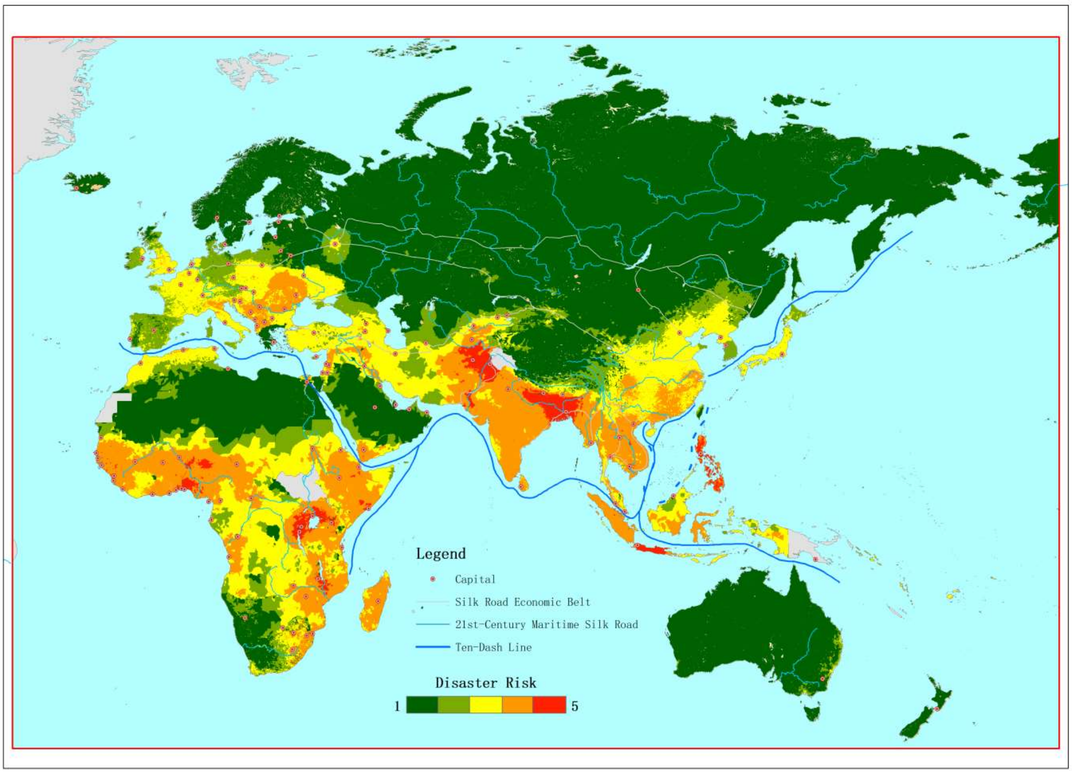


Figure 5. Health disaster risk of countries along the Belt and Road Initiative (BRI) region.

4. Discussion

This paper presents a three-phase methodology approach for disaster risk assessment that incorporated health vulnerability dimensions into an existing hazard-based disaster risk map development. The proposed health vulnerability assessment index covers seven health dimensions, including infectious disease, chronic disease, maternity, under five years old, healthcare services, immunization, and the dependency ratio. Under these seven dimensions, nine indicators were used for formulating the vulnerability index, namely: (1) proportion of population below 15 years and above 65 years, (2) under-five mortality ratio, (3) maternal mortality ratio, (4) prevalence of tuberculosis, (5) the age-standardized raised blood pressure, (6) physician ratio, (7) hospital bed ratio, and (8) coverage of the MCV1 and (9) DTP3 vaccines. Then, the vulnerability index that was formed was combined with an existing disaster risks index from the Institute of Mountain Hazards and Environment at The Chinese Academy of Science.

Based on the formula established in this study and the public data mentioned in the Methods session, Greece, the Republic of Korea, and Belarus were found to be the three least vulnerable countries, while Somalia, the Central African Republic, and Chad were the three most vulnerable countries. After combining the vulnerability index with the exposure and hazard indexes, areas close to the Philippines, Afghanistan, Bangladesh, Somalia, and Indonesia were shown to have the highest disaster risk among the 147 study countries along the BRI region.

The Index For Risk Management (INFORM) and the World Risk Index are global disaster risk indexes that have incorporated health related components for vulnerability. INFORM is a global risk assessment index that is a collaboration of the Inter-Agency Standing Committee Task Team for Preparedness and Resilience and the European Commission and is adopted in the Global Risk Map (https://globalriskmap.terria.io/About.html) (including 190 countries). These included tuberculosis prevalence, HIV prevalence, malaria death rate, and under-five mortality as vulnerability indicators, and have included physician density as a capacity-coping indicator. The World Risk Index (171 countries considered) presented by Birkmann and Welle, and the Integrated Research on Disaster Risk (IRDR) team [19], have combined susceptibility, lack of coping, and adaptive capacity within vulnerability. They considered a dependency ratio for susceptibility, physicians, and hospital beds ratio for coping capacity, and private and public medical expenditure for adaptive capacity. Table 2 below compares the health components considered in the two mentioned indexes and those included in this index. The INFORM model and the Word Risk Index were built with sophisticated calculations and variables from different aspects in risk assessments such as health-related components, economic status, political environment, and infrastructure. Yet, many important health vulnerability burdens such as non-communicable diseases were not included.

The study aims to advance the current disaster risk assessment to include health vulnerability, which will inevitably affect population vulnerability in times of crisis. Thus, the discussion here focused on health-related components. The index proposed in this study has included indicator(s) of seven important health components in disaster risk assessment. Specifically, although chronic diseases have been cited as the most important causes of mortality and morbidity [31], attention has yet to be placed on global disaster risk assessment. People living with chronic diseases usually highly rely on long-term medicine for disease management. Unstable medicine access during and after disasters may lead to preventable adverse health consequences for the affected individual and the community. Considering the increasing prevalence of chronic diseases globally, related factors are suggested to be included as a vulnerability indicators in estimating disaster risks.

Table 3 shows the top 10 countries with the highest vulnerability/lowest coping capacity obtained from the three indexes. Despite the lack of consideration of the socio-economic, political, and infrastructural aspects and the different health components considered in the proposed index, five out of the 10 countries also appeared in top 10 from the other two indexes. This suggested that the health dimension is a strong determinant for disaster risk vulnerability. It is of note that although South Sudan was shown to be the most vulnerable with least coping capacity in the INFORM model, due to the missing data for South Sudan in the dataset that was used in this study (WHO and the World Bank), South Sudan was not included in this analysis. Ukraine was the most vulnerable country in Europe according to this study. Its vulnerability was mainly due to the country's low vaccination rate, which was almost the lowest among all of the studied countries in the dataset. Since this study only accounted for health-related aspects calculating vulnerabilities, rather than other factors such as economic and political factors, Ukraine was found to be more vulnerable for disaster risk compared to the INFORM and the World Risk Indexes. The relatively higher coping capacity for European countries might reflect the better socio-economic status in these countries.

Vulnerability made substantial contributions to understandings and conceptualizations of disaster risk. When populations are exposed to natural disasters, vulnerable groups such as young children, older people, and people with mobility problems have more difficulties in evacuations, and might have a higher immediate risk of injuries. After extreme natural events, people might lose their homes and have to stay closely together in temporary shelters where hygiene and living conditions are usually compromised. In communities with low vaccination rates, outbreaks of infectious diseases might happen. Chronic diseases, as well as mental and psychological problems, also create health concerns and add extra stress to the healthcare system. Efficient medical services are important for handling immediate and indirect health needs in affected areas. Delayed or insufficient medical support to the affected people would increase fatality and morbidity. This could be due to the non-perfect healthcare system in local areas with poor coping capacity. Thus, this study proposed to include health vulnerability in estimating disaster risks. The results of this study have shown that populations with higher vulnerability were under higher overall risks than populations with lower vulnerability, given that they have comparable hazards and exposures. For example, both Japan and Bangladesh were prone to earthquakes (hazard), and were densely populated (exposure). However, after considering the vulnerability index proposed in this study, area near Bangladesh has a higher overall disaster risk than Japan.

Table 2. Health-related components considered in the Index For Risk Management (INFORM) model, the World Risk Index, and the index developed in this study.

Components	INFORM	World Risk Index	The Proposed Index
Infectious diseases	Tuberculosis prevalence		Tuberculosis prevalence
	Estimate % of adults (>15) living with HIV		
	Malaria death rate		
Chronic diseases			Age-standardized raised blood pressure
Maternal outcome	Maternal mortality		Maternal mortality
Children under five	Under-five mortality		Under five mortality
	Malnutrition in children under five		
Medical services and access	Physician ratio	Physicians ratio	Physicians ratio
		Hospital beds ratio	Hospital beds ratio
	Per capita expenditure on private and public health care	Public medical expenditure; private medical expenditure	
Immunization	Measles immunization coverage		Coverage of two the MCV1 and DTP3 vaccine
Dependency ratio		Proportion of population <15 years old and >65 years old	Proportion of population <15 years old and >65 years old

Table 3. The top 10 countries with the highest vulnerability/lowest coping capacity from the INFORM model, the World Risk Index, and the proposed index developed in this study.

Top 10 Countries/Regions with Highest Vulnerability/Capacity	INFORM		World Risk Index	The Proposed Index
	Coping Capacity	Vulnerability	Vulnerability Including Susceptibility, Coping Capacities, and Adaptive Capacities	Vulnerability
1	**South Sudan**	**South Sudan**	**Chad**	**Somalia**
2	**Somalia**	**Somalia**	Eritrea	**Central African Republic**
3	**Chad**	**Central African Republic**	Afghanistan	**Chad**
4	**Central African Republic**	**Democratic Republic of the Congo**	Haiti	Equatorial Guinea
5	**Democratic Republic of the Congo**	**Chad**	**Niger**	Nigeria
6	Yemen	Yemen	**Central African Republic**	**Guinea**
7	Guinea-Bissau	Syria	Liberia	**Sierra Leone**
8	Eritrea	Afghanistan	**Sierra Leone**	Mali
9	Liberia	Haiti	Mozambique	**Niger**
10	Togo	Sudan	**Guinea**	**Democratic Republic of the Congo**

The study has several limitations. Firstly, due to the study focus, vulnerability (including adaptive and coping capacity) related to other aspects such as sociodemographic and political aspects were not included for this specific model. Secondly, this study applied factor analysis in determining the underlying constructs of the selected predictors. It is important to highlight that factor analysis does not explain the cause of the convertibility [32]; the factors presented in this study were based on the understandings and experience in the field and the references considered. Despite the sample size that was used for this factor analysis being less than the common agreed size of 200 [32] due to the limited number of countries, it was larger than the suggested minimum size of 100 [32], which should provide considerable power for the analysis. Finally, the results presented were based on the 147 countries along the Belt and Road region; the reported vulnerability ranking is subject to change when different countries are considered.

Thirdly, this proposed index is highly driven by data availability and accuracy. Although the disability rate is another important health determinant in disasters that is advocated by WHO, due to the lack of data, disability was not included in this analysis. Similarly, this study can only include a few indicators as proxies for each health dimension due to the limitation of data. This study did not impute missing data due to simplicity and accuracy. Therefore, the number of missing data would be more than those used in the compared indexes. The accuracy of the results of this analysis was highly dependent on the accuracy of the open access data. Data from different organizations may not be consistent due to inconsistency in collection methods, study periods, calculations, imputation methods, or even data sources. Results should be read with caution.

In addition, although the use of all-hazard approach intended to include all disaster types for the hazard index, the health vulnerability index may face constrains in covering the whole disaster spectrum. For instance, physician density may be an important health indicator for coping capacity during disease outbreaks; however, it may be less relevant to injury risk and health vulnerability during and after tsunamis.

According to the WHO, disaster risk management involving health components can avoid or reduce relevant health impacts [33]. While disaster risk assessment is one of the important components of risk management, hazard, vulnerability and capacity are the three elements that were most commonly considered in disaster risk assessment [33]. Among various dimensions of human vulnerability, low sociodemographic status, female gender, large dependency ratio, chronic diseases and disability are risk factors for disaster-associated mortality and morbidity [33]. Some current risk assessment indexes indicated vulnerability or coping capacity by using sociodemographic factors such as age, poverty, ethnic minority and education level [34,35] while some of them also included health-related variables [18,19].

However, not many existing global based disaster risk assessment model considered underlying non-communicable diseases patterns. A country specific vulnerability index for wildfire from the Environmental Protection Agency, the United State, considered chronic diseases such as asthma, diabetes, hypertension and obesity [36]. This study suggests the inclusion of chronic disease in addition to the health-variables considered in current disaster risk assessment tools (World Risk Index, INFORM) and demonstrated how health-related vulnerability could be added into existing risk assessment tools using a relative simple statistical method and open access data. The results of this study could be served as a basis for future development of disaster risk assessment model or adding a health related component to the existing one.

Specifically, the BRI counties are undergoing rapid socio-economic development. Lifestyle changes and westernized diets may increase the prevalence of chronic diseases such as diabetes and cardiovascular diseases [22]. The index presented in this paper may provide a more comprehensive health-related disaster risk assessment tool which may of the Belt and Road Imitative countries. This would help in improving Health-EDRM capacity planning, resources distribution and arrangement for the regions.

5. Conclusions

This paper presents a health vulnerability index that aims to enhance disaster risk assessment for disaster risk reduction. The suggested health vulnerability index covers seven health vulnerability dimensions, including infectious disease, maternal mortality, under-five mortality, healthcare services, immunization, the dependency ratio, and chronic disease. This new index incorporated important health dimensions such as chronic diseases into the existing hazard-based disaster risk mapping approach.

Attention has to be paid specifically to the health vulnerability, which is associated with population living with chronic diseases. As more comprehensive health-related disaster risk assessments emerge, policy makers and program planners may engage in better resources and capacity planning, distribution, and arrangement to address the needs of Health-EDRM in the disaster-affected regions along the Belt and Road Initiative countries.

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The appended material is based on course revised/developed under the URGENT Project.

The course is being offered at the Jawaharlal Nehru University. The teaching is carried out using the published research material. As the course is multi-disciplinary, finding a text book is challenging. The appended notes are using the material available as Open Access, which is distributed under the terms and conditions of the Creative Commons Attribution license.

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