Disaster Risk Reduction: Why Do We Need Accurate Disaster Mortality Data To Strengthen Policy And Practice?

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Introduction

The Sendai Framework for Disaster Risk Reduction 2015-2030 aims to reinforce the shift in policy and practice of governments and stakeholders from managing disasters and other events to managing disaster risk. The Framework's success will be assessed through action at all levels—local, regional, national, and global. Its first global target is to "*substantially reduce global disaster mortality by 2030, aiming to lower the average per 100 000 global mortality rate in the decade 2020–2030 compared to the period 2005–2015*".

To measure success against meeting this target, mortality needs to be accurately quantified and interpreted, and is dependent upon valid, timely, ethically collected, standardised data. Key data sources include vital registration statistics, surveillance systems, and household surveys. Disaster mortality can then be estimated by counting relevant deaths or statistically inferred, for example by estimating the number of deaths during a defined period using excess mortality methodology.

Between 2005 and 2015, it was estimated that over 700 000 people had lost their lives, over 1.4 million had been injured, and approximately 23 million had been made homeless as a result of disasters (UNISDR, 2015a). These disasters had a disproportionate impact on highly vulnerable and low capacity groups, groups that are more susceptible to and have fewer resources to cope with the impacts of hazards. They are often more exposed to hazards than less vulnerable groups, and at the same time have less access to social safety nets and formal services, putting them at greater risk of mortality (Hallegatte, et al, 2017). While evidence suggests a steady rise in disaster-related losses, including economic costs and number of people affected, disaster mortality has not continued to rise (UNISDR, CRED, 2016).

However, measuring mortality is challenging. First, determining which deaths are relevant and comprehensively attributable to disasters is complex. Alongside the direct impact of a hazard on health, there are many indirect pathways to mortality, such as damage to critical infrastructure, the mediation of health effects through the disruption of healthcare services, or the spread of communicable diseases (Clark, Le Masson, 2017; Stanke, et al, 2013). Furthermore, the time period between exposure to a hazard and death can vary widely. The disruption of care for chronic conditions and onset of persistent stress can lead to a greater disease burden and deaths that may not occur for months or years after a disaster (Gnanapragasam, et al, 2016). To ensure mortality is not underestimated—particularly for certain types of hazards such as drought and cold weather—any agreed definition of a death caused by disaster needs to adequately address whether the death is a direct result of the hazard or an indirect consequence of the hazard's impact, and the length of time following a disaster that a death can be attributed to the disaster.

Secondly, data availability is not uniform across the world. The World Health Organization (WHO) regularly receives cause-of-death statistics from about 100 Member States, yet two-thirds (38 million) of 56 million annual deaths are still not registered (WHO, 2018a). Sources of available data vary in their completeness and quality, resulting in significant variation between mortality estimates. For example, in the early stages of a disaster, information is often incomplete and estimates are commonly derived from media reports without being updated once more reliable and accurate data becomes available.

The issues highlighted above need to be addressed, and guidance issued, to ensure global progress in achieving the outcomes and goals of the Sendai Framework. The primary aim of this paper will be to provide detail around some of the complexities involved with measuring disaster mortality, and will use practical case studies to demonstrate the clear need for accurate disaster mortality data. The paper will illustrate how this informs policy and ultimately strengthens disaster risk reduction in countries for all citizens.

What is a disaster death?

When considering the overall definition of a death resulting from a disaster, there are several variations in use by different relevant organisations, as outlined in Box 1:

Box 1: Definitions of a disaster death

"The number of people who died during the disaster, or directly after, as a direct result of the hazardous event"
Sendai Framework (UNISDR, 2015a)

"Killed – people who lost their lives as a consequence of a hazardous event"
United Nations Office for Disaster Risk Reduction Open-ended Intergovernmental Expert Working Group preliminary report – not included in final report as not agreed (UNISDR, 2015b)

"Number of people who lost their life because the event happened"
Emergency Events Database (Guha-Sapir, 2009)

The EMDAT definition can further be quantified as *"the number of deaths registered in a disaster loss database when the reporting by the original data source is stable and no longer changing".*
Integrated Research on Disaster Risk (IRDR, 2015)

"ICD-10 codes in vital registration data corresponding to exposure to forces of nature, disaster"
International Classification of Diseases-Version 10 (WHO, 1992); Global Burden of Disease (Haagsma, et al, 2016)

The definitions range from being very broad in their scope, as per the Emergency Events Database (EMDAT) definition, to very specific, as per the Global Burden of Disease definition. The varying adoption of these different definitions by those involved in enumerating disaster mortality has contributed to the challenges in determining comparable estimates of mortality across geographical locations and time.

When considered in detail, the definition of a death that results from a disaster needs to reflect both the type of death, and the timescale over which the death is expected and can be attributed to different types of disasters.

Type of death

Disasters are wide ranging in their type, impact and likelihood of causing mortality. Analysis of the EMDAT data found flooding to be the most common type of disaster, and associated with a large financial and health impact but a small number of fatalities. However, rarer events can also have a large impact and account for the highest proportion of mortality, as demonstrated by the 2004 Asian tsunami (UNISDR, CRED, 2016).

Deaths resulting from disasters are generally disaggregated into direct deaths and indirect deaths, as illustrated in Table 1 below.

Table 1. Direct and indirect disaster death definitions (adapted from Integrated Research on Disaster Risk, 2015).

Death	Description	Example
Direct	Result directly from the disaster through physical force or other direct consequences	Drowning in flood water Heatstroke from heatwaves Gunshot and blast wounds during conflict
Indirect	Result from the disaster but from other causes, when unsafe or unhealthy conditions are present during any phase of a disaster and contribute to a death (Combs, et al, 1999)	Electrocution and carbon monoxide poisoning following storms Acute malnutrition due to food insecurity following droughts

Reflection suggests that indirect deaths should include deaths where a disaster may have exacerbated or contributed to an individual's ill health, for example through exhaustion, stress, and pre-existing chronic conditions. These deaths are often the outcome of the indirect impacts of the disaster on a society, such as an interruption in health service delivery or home evacuations, and are visible in the long-term after disasters. This pattern has emerged in the weeks and months after hurricanes, for instance, with observed increases in the crude mortality rate for myocardial infarction and cardiovascular events (Swerdel, et al, 2014) and in the number of deaths due to diabetes (Hendrickson, Vogt, 1996).

Timescale over which a disaster can cause deaths

Direct and indirect deaths can be further categorised into those that are short- or long-term depending on when they occur relative to a disaster's onset. For rapid onset hazards, most resulting deaths will be direct and occur in the short-term, while indirect deaths accumulate over a longer time for slow onset hazards and long duration disasters.

Definitions that vary according to directness and temporality will therefore capture different types and numbers of deaths. To take the example of the Sendai Framework definition, while its use in monitoring progress will improve standardisation and account for different national capacities for measuring mortality, its technical guidance recommends focusing on short-term deaths that are the direct result of the hazardous event, as they are more feasible to attribute, collect and report. This is likely to result in an underestimation of indirect disaster deaths and mortality from prolonged disasters, such as drought.

The importance of understanding the causes of death by type of disaster and time to death can be illustrated by the example of mortality after floods and storms, two types of hydrometeorological hazards. A systematic review of the causes of death between 1980 and 2017 found a prominence of indirect deaths, mostly within noncommunicable and chronic disease-related deaths (Table 2). When mortality is distinguished between the two disasters, storms produce a greater impact on short-term mortality. The majority of the studies (19 out of 27) used data collected within one month after the flood or storm, yet it is likely that the indirect mortality of both disasters continues into the longer-term. The fact that only one-third of the published, peer-reviewed articles studied mortality beyond one month illustrates gaps in individual study level data and understanding on how disasters can affect long-term and indirect mortality.

Table 2. Reported deaths from storms and floods, by cause and percentage of total deaths*

[a] Cause not reported, [b] Number of cases

Group	Storms		Floods	
	Deaths (%)	Cause	Deaths (%)	Cause
Injuries and poisonings				
Drownings	3.1 – 94.7	Contact with flood waters	5.8 – 82.6	Contact with flood waters

Poisonings	2.7 – 17.5	Carbon monoxide, ingestion of drug or substance	4.3	Carbon monoxide
Burns and electrocutions	0.6 – 11.4	Lightning strike, fires, chemical burns, smoke inhalation, power source	2.4 [a]	
Trauma	0.6 – 100	Falling trees, flying debris, motor vehicle accidents, falls, boating accidents, power tools		
Crush injuries and asphyxia	1.3 – 14.3	Structural collapse, falling trees	14.4	Structural collapse
Violence	0.6 – 61.0	Gunshot wound, homicide, suicide		
Other	1.9 – 3.0	Hypothermia, cerebrovascular accident, landslide	26.0	Landslide
Infectious and parasitic diseases				
Gastrointestinal infections			27.3 – 47.6	Diarrhea
Leptospirosis	1 – 15 [b]	Leptospirosis	11 [b]	Leptospirosis
Bacterial	2.6 – 6.1	Sepsis		
NCDs and chronic illnesses				
Cardiovascular event	3.0 – 57.5	Myocardial infarction, hypertension		
Respiratory event	2.7 – 12.1	Chronic obstructive pulmonary disorder, pulmonary conditions, respiratory failure	6.0	Chronic respiratory conditions
Brain syndromes	2.6 – 6.2	Seizures, central nervous system events		
Gastrointestinal or genitourinary disease	1.3 – 3.0	Pancreatitis, renal failure		
Other	3.0	Cirrhosis, cancer, myopathy		
Other				
Obstetric	3.1	Obstetric hemorrhage	2.6	Obstetric problems
Natural causes	2.7 – 34.4 [a]		11.0	Old age
Neurologic	3.0 – 25.0	Intracranial hemorrhage		
Other	3.0	Shock		

*References included in the table: Atchison, Wintermeyer, Kelly, 1993; Brewer, Morris, Cole, 1994; CDC, 1986; CDC, 1989; CDC, 1992; CDC, 2000; Cookson, et al, 2008; Combs, et al, 1996; Dechet, et al, 2012; George McDowell, et al, 1996; Jani, et al, 2006; Jones, et al, 2004; Kalina, Malyutin, Cooper, 2016; McNabb, et al, 1995; Myung, Jang, 2011; Natuzzi, et al, 2016; Nelson, et al, 2006; Ragan,

et al 2008; Sanders, et al, 1999; Seil, Spira-Cohen, Marcum, 2016; Siddique, et al, 1991; Staes, et al, 1994; Trevejo, et al, 1998; Vilain, et al, 2015; Wkly Epidemiol Rec, 2000; Yi, et al, 2015; Zane, et al, 2011.

Sources of disaster mortality data

Mortality is estimated by calculating crude death rates, and requires two types of data: population data and death data.

Population data

Population data is required to place the number of deaths in a country in context, and to improve comparability of estimates. The Sendai Framework guidance recommends using the whole population of a country. This information is usually more readily obtainable through census data, though there are two limitations to be aware of with this approach. Firstly, censuses are typically conducted every ten years. As a result, the data is often out of date, particularly in countries with rapid population change. Inter-census estimates are available from organisations such as the World Bank, but these are often markedly revised when subsequent census estimates are available.

Secondly, if a disaster is localised, assessing the number of deaths out of the whole country's population will underestimate the impact of the disaster on affected populations. While this is of limited concern when looking at absolute number of deaths, it may have implications for interpretation of trends when comparing across time within a given country. When determining rates, the population at risk is typically taken as the denominator and presented as person-time. This can be defined as the sum of the individual units of time when individuals were exposed to a hazard, which can be very challenging to calculate.

Death data

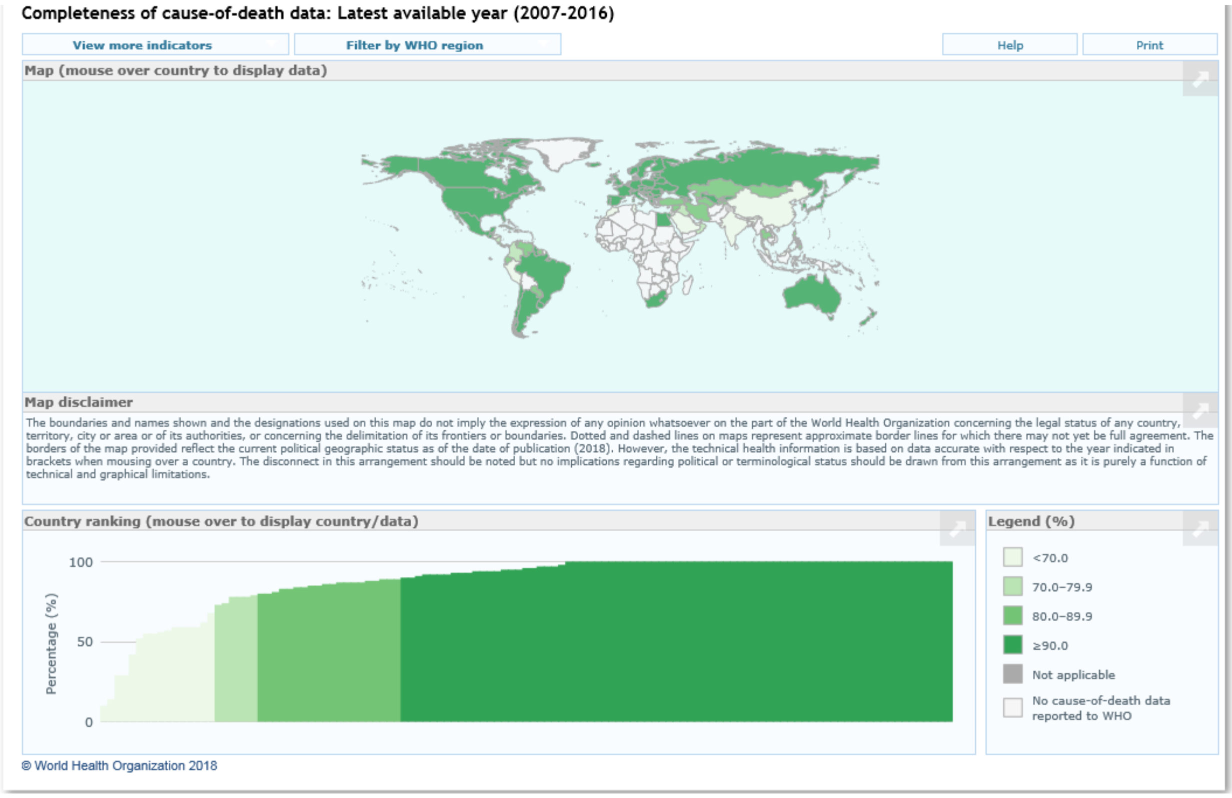
WHO reports that worldwide, nearly half of deaths are registered with information on cause-of-death. However, incomplete death registration and incorrect or missing cause-of-death information limits the use of these data in many countries (WHO, 2018a). WHO reports that a total of 84 countries collect medium- or high-quality information on deaths and their causes, meaning that the data are of sufficient quality for monitoring trends in mortality by cause. Just over half of upper-middle-income countries and over 80% of high-income countries collect medium- or high-quality cause-of-death data. At the other end, 81 countries collect data of very low quality or do not register deaths at all; this includes all low-income countries and two-thirds of lower-middle-income countries.

Irrespective of the cause of death, obtaining robust data on mortality is challenging. Countries with well-functioning Civil Registration and Vital Statistics Systems (CRVS) typically monitor mortality through the continual registration of deaths, which are considered to produce the most thorough and accurate mortality statistics (Rampatige, et al, 2014). About half of WHO's 194 Member States register at least 80% of deaths of people aged 15 years and older, including information on cause of death (WHO, 2018a).

There is a recognised need to improve CRVS systems globally (Lo, Horton, 2015), as approximately 60% of deaths go unaccounted for in registration systems globally (Clarke, et al, 2018; Mikkelsen, et al, 2015). More than 100 nations, primarily in low and middle-income countries, lack functioning CRVS systems; only 57% of countries, territories and areas assessed by the UN Statistical Division had at least 90% death registration coverage in 2014 (Byass, 2007; WHO, 2018a). A CRVS scaling-up investment plan has set a goal of universal civil registration of deaths, including cause of death, for all individuals by 2030 (Independent Expert Advisory Group on a Data Revolution for Sustainable Development., 2014).

Though all countries are vulnerable to disasters and loss of life, there is generally a higher exposure to disasters and risk of death in low- and middle-income countries, which are the same countries that tend to lack vital registration data, further magnifying the data gap (Osuteye, Johnson, Brown, 2017) (Figure 1).

Figure 1. Completeness of cause-of-death data, 2007-2016



Disaggregated data

As well as accurate information on the scale of deaths, the groups of the population that have been affected needs to be determined. Whilst all communities are vulnerable to the risks associated with disasters, the risk of death is greatest among groups least likely to be identified in census data, which has implications for the robustness and ability to disaggregate that data (Ishiguro, et al, 2015). Though age and gender are typically reported in vital registration and survey data, it is not always the case, and characteristics such as disabilities or ethnic minority are reported less frequently. Additionally, there are vulnerable population groups, such as undocumented migrants, who will not be registered in such data sources, and will not be accounted for when assessing the impact of disasters.

Other approaches

Alternative approaches for estimating mortality and its causes include household or hospital sample surveys and demographic surveillance sites (Hill, et al, 2007). However, as these are ad hoc and typically done through sampling, they are liable to introduce high levels of statistical inaccuracy into estimates if not reliable, valid or replicable (SDSN TReNDS, 2017). Using hospital or healthcare facility records to estimate mortality assumes that affected populations have equal and continued access to health services and facilities before, during, and after disasters.

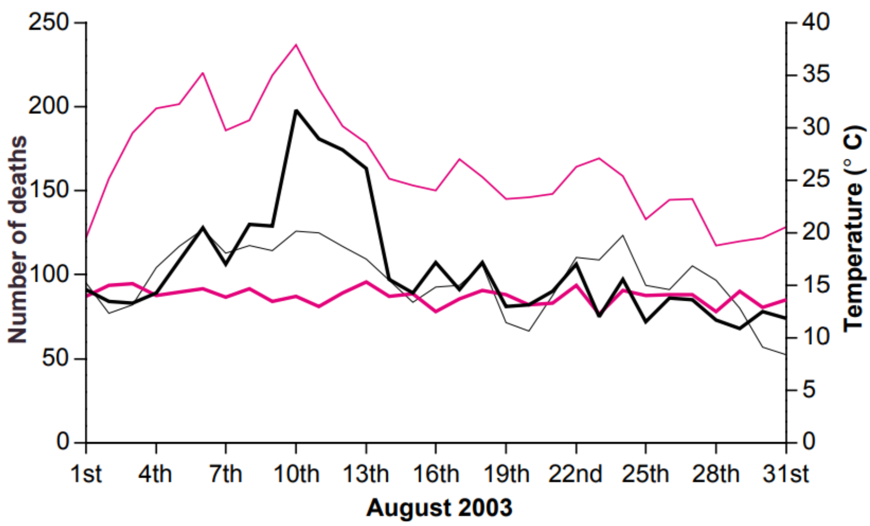
The review of disaster mortality data and sources raises the following points: how disaster mortality is defined; where the data comes from; how mortality estimates are generated; and how disaster mortality data is interpreted. This paper uses case studies to illustrate the different opportunities and challenges in measuring disaster mortality. The case studies reflect various approaches to how mortality data is sourced, collected, analysed and interpreted in different contexts. The first case study shows how estimating excess mortality from a death register during a heatwave had a rapid and sustained impact on practice and policy. Case study 2 demonstrates how existing mortality data and standardised methods can be used to identify problematic hazards and support the case for action. The third case study is an example of how response to previous disaster mortality estimates continues to pay off in subsequent disasters, yet continued assessments can help build a more robust dataset. Case study 4 highlights the need to understand the content and source of mortality data to drive strategic plans, through a concentrated approach to reveal causes of death. Case study 5 underscores how various data sources, methodologies, and time points can produce very different mortality estimates from a single disaster.

Case study 1: Hot weather and England

Hot weather is linked with increased mortality across the world. Such excess deaths are not just deaths of those who would have died anyway in the next few weeks or months due to illness or old age. There is strong evidence that these summer deaths are indeed 'extra' and are the result of heat-related conditions. They occur in part due to our inability to adapt and cool ourselves sufficiently, with relatively more deaths occurring in the first days of a heatwave, as well as during the first hot weather spell of any season.

A notable example of the mortality impact of heatwaves was seen during the 2003 European-wide heatwave in August. In Northern France, unprecedentedly high day and night-time temperatures for a period of three weeks resulted in 15 000 excess deaths with the vast majority among older people (Fouillet, et al, 2006). Excess summer deaths show regional variations, which relate largely to differences in temperature levels across the country. In England, 2 000 excess deaths were seen in the south during the 2003 heatwave (Figure 2) (Kovats, Johnson, Griffith, 2006).

Figure 2. Daily mortality in London amongst over 75 year olds during August 2003 (thick black line) and maximum daily temperature (thin pink line). Also shown are baseline mortality (thick pink line) and minimum temperature (thin black line) (Johnson, et al, 2005).



As a consequence of this excess mortality in 2003, the first Heatwave Plan for England was in place by the following year. The plan is a framework for local adaptation, with a focus on collaboration and year round activity to prevent the health consequences of extreme temperatures. The main components of the plan are:

- A heat-health alerting system, from June 1st to September 15th, based on daily meteorological assessment by the UK Met Office. Alerts range from level zero (year round planning) to level four (national emergency).

- Standardised warnings; cascaded through the health and social care system to support action by front line staff
- Co-ordinated, multi-agency response at local and national level through emergency services, local authorities, government departments, the National Health Service and others
- An underlying evidence review, entitled "Making the Case", which brings together evidence systematic literature reviews of the health impacts of hot weather and effective interventions for key population groups, accompanied by a series of guides for front line staff including health and social care workers, those in the education sector and the general public.

Part of the Heatwave Plan for England includes rapid estimation of the impact of such heatwaves on mortality (Public Health England, 2018a). The mortality impact of heat is more rapid in onset than cold weather and thus needs to be assessed on a daily timescale as overall weekly patterns may well mask the impact. (Green et al, 2012). An online death registration system has been operational in England since 2009, and permits such rapid estimation of the mortality impact, potentially allowing for identification of vulnerable individuals and facilitates prioritising public health measures, particularly if the event is persisting. Reporting delays between the date of death and date of registration are corrected for and statistical models are constructed to determine the expected number of daily deaths for the time of year. If the number of deaths that are observed are significantly higher than the expected number, then excess mortality is said to have occurred.

As the impact of heat on mortality varies each year, the utility of this has been demonstrated. For example, during the 2013 heatwave in the UK, despite a sustained heatwave, the impact on mortality was considerably less than expected with a small cumulative excess of 195 deaths in people aged 65 years or more, which was nearly a fifth of the 650 excess deaths predicted based on observed temperatures through initial modelling work. This was also markedly less than similar prolonged heatwaves seen in 2006 (2 323 deaths) and 2003 (2 234 deaths) (Green, et al, 2016). In summer 2016, three heatwaves affected England, with 908 excess deaths in total during the summer period. Whist peak temperatures were similar in each of the three heatwaves, mortality declined in each successive event (612 excess deaths in 65+year olds in the first heatwave, 296 excess deaths in 65+ year olds in the second, and no significant excess deaths during the third and longest heatwave of the summer (Public Health England, 2018b)).

On this crude assessment of the decline in heatwave mortality over time, the Heatwave Plan for England can be considered to be a successful policy intervention in response to disaster mortality; however more formal evaluation is needed. An independent evaluation of the effectiveness of the Heatwave Plan has been commissioned by Public Health England and the Department of Health and Social Care. This vital report will be published in early 2019.

Recently, the risks to health, wellbeing and productivity from high temperatures were identified as one of the highest priority areas of inter-related climate change risks for action in the United Kingdom, in the second UK Climate Change Risk Assessment (CCRA) (Committee on Climate Change, 2017). The UK Government is required to compile such a risk assessment every five years as part of the Climate Change Act (2008). In response to the CCRA, the government has published a National Adaptation Programme in 2018, which includes an objective to develop a single adverse weather and health plan (including cold and hot weather, drought, flooding and thunderstorm asthma) by 2022. This will outline action on the recommendations of the independent evaluation of the heatwave plan. Potential approaches include bringing together and improving existing guidance in order to inform action across the health system and local communities, reduce health risks associated with adverse weather, address the CCRA health risks, and bring consistency and coherence of approach to the impacts of adverse weather on health. This approach has been welcomed in the report of a 2018 inquiry into the health effects of heatwaves and adaptation to climate change by the UK Parliament Environmental Audit Committee.

Case study 2: Cold weather in Europe

Across most temperate countries, there are a higher number of deaths in winter months compared to the summer. The main causes of excess winter mortality are cardiovascular or respiratory diseases, including seasonal respiratory infections. The main population groups affected are the elderly and those with chronic health problems.

The underlying determinants of such seasonal increases in mortality during the winter months are a complex combination of interacting factors, including physiological adaptation to the changes in temperature, cold housing and the predominant circulating strain of influenza. By assessing mortality in a standardised way, it is easier to interpret patterns and assess progress made to tackle the problem of excess winter mortality by different countries.

One such assessment sought to achieve this across 31 European countries (Fowler, et al, 2015). For each country, the Excess Winter Death Index (EWDI) was calculated, defined as the ratio of deaths in the winter period (taken as December to March) compared with deaths in the non-winter period for each year from 2002 to 2011. A trend of increasing mortality from northern to southern Europe was found, with increasing mean winter temperatures. Significant differences were seen by country, with no association between the range in temperatures seen within a given winter and EWDI. Substantial variation was seen between countries of similar climate, supporting the case for policy interventions to tackle the problems of cold-related harm to health, fuel poverty and cold homes (Figure 3).

Aside from seasonal increases in deaths during winter months, there can be acute increases in mortality, requiring more rapid surveillance and action than the approach taken in the multi-year study outlined above. Specific short-term causes include extreme cold snaps and circulation of respiratory viruses such as influenza. Such acute increases can be detected through weekly mortality data after adjusting for the overall seasonality. The EuroMOMO (EuroMOMO, 2018) initiative looks to provide a standardised approach to assessing this across Europe on a week by week basis, where adjusting for seasonality can provide an estimated number of deaths each week. Thresholds to mark variation from expected values are set using upper *z*-scores. If the number of deaths in a given week exceeds this threshold then significant excess mortality is reported to have occurred. This standardised model is designed to be used in real-time on a weekly basis; its utility was demonstrated during the 2009 influenza pandemic as part of efforts to rapidly determine the impact on mortality. As there are inevitable reporting delays between date of death and date of registration, complete data can take months to come through. There is therefore a correction in the data for reporting delay.

To determine the causes of these acute increases can be challenging as factors such as cold weather and acute respiratory infections can temporally coincide, making it difficult to disentangle their impact. Statistical modelling approaches are required, typically multivariable regression, incorporating mortality data, climate data and disease data and identifying temporal patterns. One such approach building on from the EuroMOMO approach is FluMOMO (Pebody, et al, 2018), providing a standardised approach to estimate the association of influenza with excess mortality while adjusting for extreme temperature. It is posed that this tool can assist in rapidly assessing the impact of influenza, which can vary considerably by age group and season.

Together, such epidemiological rigour helps support the case for action on the health impacts of cold weather as the winter period not only sees a significant rise in deaths but also a substantial increase in illnesses. The first Cold Weather Plan for England (Department of Health, 2011) was published in 2011 and aims to help raise awareness of the harm to health from cold, as well as providing guidance on how to prepare for and respond to cold weather. It is now clear that in an average winter in England, most of the health burden attributable to cold occurs at relatively moderate mean outdoor temperatures (from 4-8°C depending on region). This is why the plan includes year-round and winter-through actions, as well as emergency responses to extreme winter weather.

Figure 3: Excess winter deaths index (EWDI) between 2002 and 2011 in Europe, by quintile (Fowler et al., 2015)

Case study 3: Mortality during a large flood in Malaysia

In December 2014, a large scale flood affected the eastern areas of peninsular Malaysia, triggered by torrential rains. It was considered the worst flood disaster in the past few decades, and lasted for more than 15 days (Bibi Zarina, 2015). Nearly half a million population were displaced in six states, with 390 907 evacuees placed at formal evacuation centres (Department of Social Welfare Malaysia, 2015). Twenty-one drowning deaths were reported to local health authorities, of which 11 were in Kelantan, the worst affected state (Ahmad Razin, 2015).

Despite the severity of the flood, the number of reported deaths was relatively small. Past experience of flooding and a concerted effort from various government agencies and other relevant stakeholders may have helped keep the number of drowning deaths low. Malaysia has a comprehensive disaster management program, including daily surveillance of communicable and noncommunicable diseases during and post-flood, and early evacuation plans for high risk groups, like persons with chronic diseases, to ensure they are able to continuously access medical care (Ministry of Health Malaysia, 2008).

Research conducted by the local health departments identified additional health impacts of the flood (Table 3). In addition to the 21 drowning deaths that were reported, health department surveillance data identified five deaths from leptospirosis up to three months post flood. This additional cause of mortality during floods, detected through local research efforts, was not included in the formal reporting. In this case, the indirect impact of floods in the months that follow, as well as integration of local data sources, are important to consider for future mortality estimation and identification.

Table 3: A summary of research on health in Kelantan after the 2014 flood

Author	**Summary**	**Results**	**Mortality**
Mohd Radi, et al, 2018	Leptospirosis outbreak – health department surveillance data	Increase in leptospirosis cases from 357 cases pre-flood to 725 cases post-flood	1 death during flood, 4 deaths in 3 months post-flood
Hashim, et al, 2016	Vulnerability analysis to flood-related communicable diseases – health department surveillance data	No recorded cases of dysentery, cholera or tetanus. Minimal change in number of malaria, typhoid, paratyphoid, or hepatitis A and E cases. High incidence of dengue fever pre-flood (2 053 cases), followed by reduction post-flood (438 cases)	Not reported
Sulaiman, et al, 2016.	Infant feeding concerns during flooding – hospital admissions data	93 cases admitted for diarrhea, compared to 22 cases in the same period the previous year	0 deaths reported
Lee, et al, 2016	Small intestine bacterial overgrowth – community survey	80 (37.9%) participants had chronic abdominal pain. Significant association between persistent abdominal pain post-flood and poor WASH practices and gut dybiosis	Not reported
Baharudin, et al, 2016	Psychological distress and resilience – community survey	Adolescent flood victims were found to suffer from depression (27.3%), anxiety (58.4%), and stress (23%).	Not reported

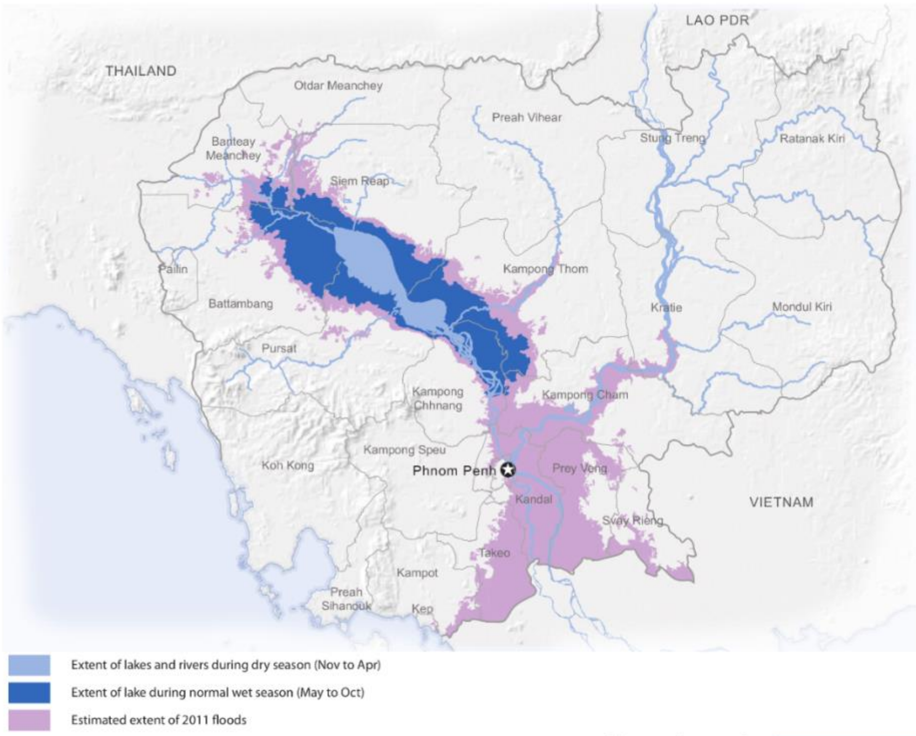
Case study 4: Drowning deaths during the 2011 floods in Cambodia

Floods are a regular occurrence in Cambodia. During the rainy season between June and November, the Mekong River and Lake Tonle Sap overflow into extensive floodplains, where approximately ninety percent of Cambodia's mostly agricultural population lives (FAO, 2012). Regions in these flood plains are highly adapted to annual flooding, using strategies like elevated houses and raised walkways to manage flooding (Figure 4). However, floods often exceed their expected extent, and flood disasters remain a problem and a threat in many regions (UNISDR, ESCAP, 2012).

Figure 4. House in Cambodia

Extensive flooding occurred in 2011, as a result of heavier than expected monsoon rains and a series of tropical storms in the region (Figure 5). Flood waters peaked at the end of September and began to recede in early October (Mekong River Commission, 2014). Over 1.2 million people in 18 provinces were affected (UNISDR, ESCAP, 2012), with a final total of 250 deaths reported by the National Committee for Disaster Management (An, 2014), for a crude mortality rate of 21.8 deaths per 100 000 affected people. Thailand, while also severely affected by flooding, reported 884 deaths out of 13.6 million affected – a rate of 6.5 deaths per 100 000 affected (UNISDR, ESCAP, 2012). The high number of drownings during the flood prompted the Ministry of Health to conduct an assessment in order to explore the underlying causes of the drowning deaths.

Figure 5. The extent of the floods in Cambodia, during October 2011



Adapted from: (ReliefWeb, 2018)

The assessment was conducted by the National Institute of Public Health (NIPH) in Cambodia in January 2012. To establish the number of drowning deaths, NIPH sent a structured questionnaire to provincial health departments in all severely affected provinces. No case definition for drowning deaths was used, but all deaths occurred in flooded communities between May and December 2011. The assessment team also conducted interviews with a percentage of the families of the deceased. Two hundred and sixty two drownings were reported to NIPH by the provincial health departments.

The majority of deaths in the assessment were the indirect result of navigating the risks involved with daily life in the presence of a flood and unique to the risk factors in the Cambodian context. This is reflected in the causes of drowning, where the majority fell into water (47%) while doing their daily work, like fishing, finding grass for their animals, or taking care of their rice fields. Drownings were most frequent when flood waters reached villages and rice fields, and the two main locations for drowning were in flooded rice fields, or in flood water under houses. Less than half of the deaths happened in open or permanent water, like rivers or lakes. A shortage of transport options during the flood meant people travelled in overcrowded boats – 18% of deaths were caused by boats capsizing. Children under the age of 15 years made up 39% of all drownings, as they were at risk for falling into water from raised houses, especially during the day when caretakers were often outside of the home and children were unsupervised. Eighty percent of the deaths coincided with the peak of the flood, while another 15% happened during the initial rise of water before the flood and during the recession of the flood water. This reflects the point that if disaster mortality is to be captured completely, the time period when deaths should be counted as disaster-related needs to be specified.

Eighty percent of the deaths coincided with the peak of the flood, while another 15% happened during the initial rise of water before the flood and during the recession of the flood water. The assessment raises an additional question – where will the data to measure mortality come from? Deaths and cause of death are not routinely registered in Cambodia. In 2014, only about 10% of deaths were officially registered (Ministry of Interior Cambodia, 2014), and the number of deaths had to be requested from the provincial health departments in this assessment. Regularly capturing disaster mortality would require data from many sources and levels to be consolidated. This poses a challenge for the denominator of mortality estimates as well. Cambodia conducts a census every ten years, but accurate inter-census population estimates are difficult to obtain. Cambodia's successful assessment of the causes of drowning was extensive, but like in many other contexts, the capacity to conduct similar assessments regularly is not a sustainable long-term solution for sourcing data. In response to disasters like the floods in 2011, Cambodia has in recent years placed an emphasis on managing disaster risk (Ministry of Health Cambodia, 2015; National Climate Change Committee, 2013), in part by improving information systems and reporting for disaster management, in order to strengthen their capacity to count the impact of disasters on the population.

Case study 5: Mortality estimates from Hurricane Maria in Puerto Rico

Puerto Rico is an unincorporated territory of the United States located in the northeast Caribbean Sea, with a population of approximately 3.3 million. While it is classified as a high-income country on the basis of the Gross National Income per capita, the median household income is less than in the mainland United States, and there are high levels of income inequality, with a large proportion of the population living below the poverty line. It was hit by Hurricane Maria, a category 4 hurricane, in September 2017, only a few weeks after it was hit by Hurricane Irma (Figure 6). Widespread damage and impact was seen, with heavy associated economic losses. There were notable damages to the hospital system and a power cut which took weeks to restore. These factors are thought to have likely resulted in a high number of deaths. However, estimates of the number of deaths from Hurricane Maria have varied widely over time and by the method used, illustrating the wide range of approaches, differences, and difficulties in providing timely, robust hazard mortality estimates .

An initial estimate of the number of deaths in Puerto Rico was given as 16 when the President of the United States visited two weeks after Hurricane Maria hit. Subsequent official government estimates revised the number to 64 at the end of 2017 (Telemundo, 2017). This official death count only considered deaths with a “hurricane-related” cause of death on the death certificates. However, reports from the ground were that the number of deaths was considerably higher than this and that the indirect consequences of the hurricane likely had a significant impact. Coupled with concerns around the availability of mortality data, legal cases have been raised to the Department of Health to provide data and improve its transparency (Associated Press, 2018). It also prompted a number of media organisations to begin compiling their own estimates.

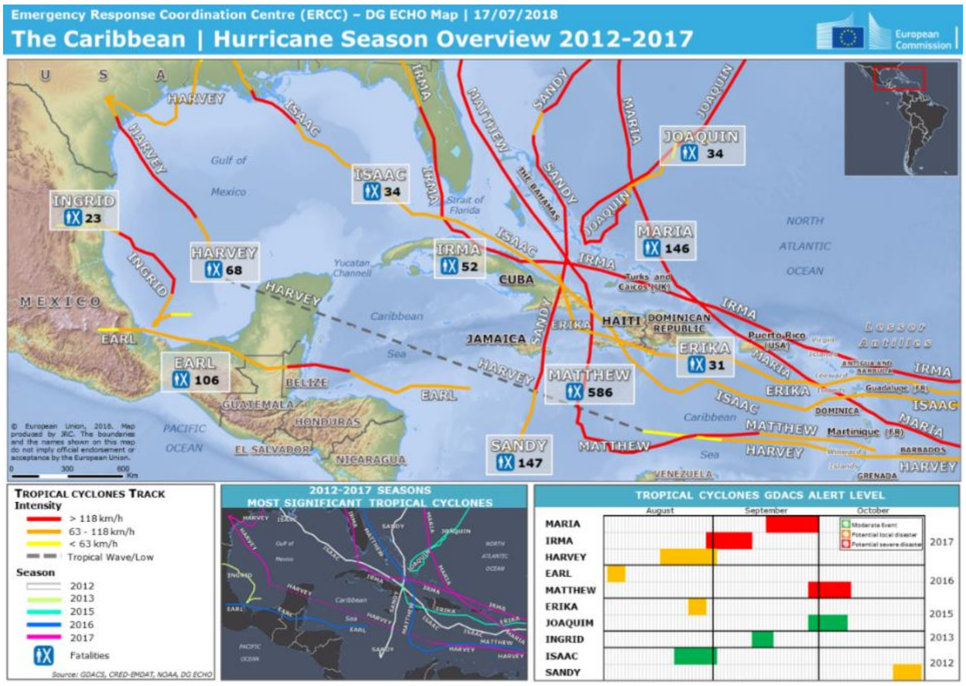
The debate around the number of deaths intensified following the publication of a study in May 2018 (Kishore, et al, 2018) that estimated the number of excess deaths at 5 740 (with a 95% confidence interval of 1 506 to 9 889), nearly seventy times higher than the original estimates, with the majority of deaths resulting from interruption of services such as healthcare, electricity, and water access. The data from the study was gathered through a household survey, and the household mortality rate extrapolated to the complete population and compared to the mortality rate for the same period in 2016.

There has been a critical review of the paper, with the wide 95% confidence intervals indicating a high level of uncertainty, and questions around the validity of comparing survey-based data to historic official registration data. Excess mortality estimates compared across the same data source result in lower figures but still significantly higher than the official count. In a subsequent published study (Santos-Lozada, Howard, 2018), data from before Hurricane Maria was used to estimate the average number of expected deaths, and the actual number of deaths each month were compared to what was expected. Using a conservative estimate, a total of 1 139 excess deaths were seen (95% confidence interval from 1 006 to 1 272), with levels returning to the historic range by December of 2017, three months after the hurricane.

An independent review has been commissioned by the government of Puerto Rico to estimate the total number of deaths, using official records from vital statistics. In June 2018, they reported that compared to the initial official death count of 64, there were 1 427 more deaths in the four months after the hurricane than expected, but stated it would update official estimates after the review is completed (Government of Puerto Rico, 2018).

The importance of determining the order of magnitude of resultant deaths cannot be understated. While the initial estimate of 16 deaths was perceived to reflect good management and preparation, the updated estimate highlights the impact of this hurricane. Having a clearer idea of the related mortality should help to inform future planning and that the public health preparation and response to such a disaster, if it were to happen again, would be optimal.

Figure 6. Overview of hurricanes in the Caribbean, 2012 – 2017 (ERCC, 2018)



Discussion

The case studies have shown a variety of approaches in use to define, collect, interpret and analyse disaster mortality data in different settings, and highlight some of the opportunities for adapting methods and theory for use in other contexts. Common methods of recording and reporting mortality include, as discussed earlier, CRVS, passive and active surveillance systems, household surveys, healthcare facility record reviews, and health and demographic surveillance sites. Yet, monitoring disaster mortality through vital registration systems alone has been shown to potentially result in an underestimation of impacts (Choudhary, et al, 2012). The case studies illustrate this, and how multiple data sources could be combined for assessing mortality estimates. For example, Cambodia's proactive and practical collection of mortality data within a short time period identified an additional twelve deaths that were not initially reported, and the use of multiple types of data in FluMOMO to specifically differentiate between cause of death from cold weather and influenza. These approaches, though not replicable in all settings, may help stimulate practice and policy.

When data is acquired from multiple sources, consideration also needs to be given to data interoperability. Such datasets are often held by different departments or organisations and have different standards and definitions, making it difficult to combine and make compatible. Having data standards in place will greatly simplify data processing and its utility, allowing for functional use more rapidly.

The availability of data can be a major obstacle for developing systems in measuring mortality and driving progress towards the Sendai Framework targets. The easiest opportunities arise when well-functioning registration systems collect accurate and complete mortality data. England's comprehensive heatwave plan was developed in rapid response to disaggregated mortality data from their registration system. However, the availability of population-level data is an issue in many settings, where collecting accurate data on long-term and indirect causes of mortality can be challenging. Individual or local data collected after specific events can also start the process of change, as seen in Cambodia and Malaysia. In addition, the granularity of the data can be of use to understand the vulnerability and risks of particular groups and improve disaster management strategies, such as warning systems, information systems, and preparedness measures for infrastructure and basic needs.

Country-specific data is one avenue for measuring mortality but could be supplemented by taking advantage of broader mortality assessments and systems, particularly in countries where no such data is readily available. The Global Burden of Disease (GBD) is a worldwide, comprehensive study of three decades of mortality, collecting data on a variety of causes of death at global, national, and regional levels (Haagsma, et al, 2016). The GBD could be used as a platform to assess disaster-related mortality using advanced modelling approaches. The extraction of baseline health measurements for some of the SDGs from the GBD is already being explored (WHO, 2018b). Initiatives and programs like the World Health Organization's Global Reference List of 100 Core Health Indicators and The Lancet Countdown: Tracking Progress on Health and Climate Change provide additional insights and resources on what causes morbidity and mortality outcomes to how countries can move towards common systems and definitions for collecting and reporting health data (Watts, et al, 2017; WHO, 2018b).

The complexity around how to define a disaster-related death remains. Previous experience and evidence suggests that definitions should be standardized, and incorporate (at a minimum) direct and indirect causes of death. These will differ depending on the type of disaster, as seen in the marked difference in the causes of death that have been reported after flood and storm disasters. A straightforward approach would be to use systematic reviews as a starting point for definitions, to identify causes of death after specific disasters and for countries to understand their own risks to different types of disasters. Although systematic reviews have their shortcomings – notably that results are difficult to generalize to a specific context, and their benefit relies on the quality of the research included – reviews can summarize the mortality evidence so that measures remain specific and relevant.

Using standardized definitions for direct and indirect causes-of-death could help ensure that deaths are being accurately captured (Noe, 2011), and reduce the current discrepancies in cause-of-death classification (Saulnier, Ribacke Brolin, von Schreeb, 2017; Sibai, 2004).

Similarly, the time between the disaster and the death must be assessed to accurately capture disaster mortality. As seen in the case studies, mortality during heat waves must be monitored daily, otherwise trends will be masked, yet the majority of deaths after Hurricane Maria appeared in the weeks after the hurricane. The deaths were indirect, the result of the hurricane's effect on infrastructure and access to healthcare, which reflects similar long-term effects from other studies on hurricanes (Gautam, et al, 2009; Hendrickson, Vogt, 1996). The existing evidence should be used to evaluate the direct and indirect causes of disasters, and to set an appropriate temporal cut-off for disaster-related deaths.

Accurate measures of disaster mortality are a prerequisite for meeting the Sendai Framework target of reducing global disaster mortality. Beyond governmental and international policies and practice, science and technology should support the methods and processes used to define, measure, and report disaster mortality, and an evidence-based approach to the implementation of the Framework has already been called for (Aitsi-Selmi, Murray, 2015). Gaps in generating, sharing, and using data to reach the Framework targets have been identified (Calkins, 2015), and suggest an area where an engaged science-policy interface for best practices in measuring disaster mortality could be of value.

Conclusions

It is vital that disaster mortality is measured as accurately as possible. Knowing the expected causes of mortality across the spectrum of disaster types, the limitations and opportunities of data sources, and having accurate figures for the number of deaths and which population groups are predominantly affected all drive action. Countries should find a method of measuring mortality that works for them and their resources, and for the hazards they face. This will take leadership and action at all levels, from local and regional to nationally and globally. This paper hopes to contribute by outlining what we need to know to measure mortality, what potential limitations to be aware of, and how that knowledge can impact policy and practice.

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