The Epidemiology of Natural Hazards

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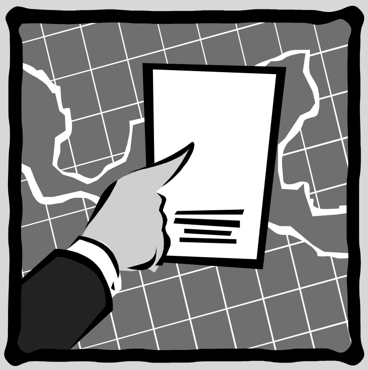
Disasters may arise from several types of events. Natural hazards, including tornadoes, are one example. Most natural hazards are weather or geologically based.



floods
hurricanes/cyclones
tornadoes
earthquakes
volcanic eruptions
tsunamis
avalanches
droughts/famine
blizzards
heat & cold waves

The most widely recognized types of natural hazards are those listed here. Disasters related to extreme weather events (floods, cyclones, tornadoes, blizzards, droughts) occur regularly. Events related to extremes of the the earth's geology (earthquakes, volcanic eruptions) occur less frequently, but result in major consequences when they happen. Tsunamis often result from earthquakes. Avalanches result from massive accumulations of snow.

Selected Natural Disasters

Year	Event	Location	Death toll
1900	Hurricane	Galveston	6000
1902	Volcanic Erup.	Martinique	29,000
1902	Volcanic Erup.	Guatemala	6000
1906	Typhoon	Hong Kong	10,000
1906	Earthquake	Taiwan	6000
1906	Earthquake	San Francisco	1500
1908	Earthquake	Italy	75,000
1916	Landslide	Italy/Austria	10,000
1928	Hurricane/flood	USA	2000

Natural hazard disasters have been documented for ages. The following slides illustrate some of the major natural disasters that have occurred around the world over the last 100 years. Major natural disasters, in terms of significant loss of life, have been documented in all decades, in all parts of the world, and with respect to all types of natural hazards.

Selected Natural Disasters

Year	Event	Location	Death toll
1923	Earthquake	Japan	143,000
1933	Tsunami	Japan	3000
1938	Hurricane	USA	600
1939	Earth/tsunami	Chile	30,000
1946	Tsunami	Japan	1400
1948	Earthquake	USSR	100,000
1949	Floods	China	57,000
1951	Volcanic Erup.	PNG	2900
1954	Floods	China	40,000

Earthquakes, cyclones/hurricanes, and tsunamis account for significant levels of mortality in these league tables. Volcanic eruptions, while rare, also carry a large death toll.

Selected Natural Disasters cont.

Year	Event	Location	Death toll
1959	Typhoon	Japan	4600
1963	Cyclone	Bangladesh	22,000
1965	Cyclone	Bangladesh	30,000
1968	Earthquake	Iran	12,000
1970	Cyclone	Bangladesh	300,000
1972	Earthquake	Nicaragua	6000
1976	Earthquake	China	250,000
1977	Cyclone	India	20,000
1978	Earthquake	Iran	25,000

Selected Natural Disasters cont.

Year	Event	Location	Death toll
1988	Earthquake	Armenia	25,000
1989	Hurricane	USA	56
1990	Earthquake	Iran	40,000
1991	Cyclone	Bangladesh	140,000
1992	Hurricane	USA	52
1998	Hurricane	Honduras	10,000
1999	Earthquake	Turkey	18,000
1999	Earthquake	Taiwan	1000
2004	Earthquake	Iran	25,000

In recent years, differences in mortality from natural disasters have been pronounced between developed and developing countries. Take note of the mortality related to hurricanes in 1992 and 1998 in the USA and Honduras respectively. Also, note the two earthquakes in 1999. These were of similar magnitudes (on the Richter scale), but demonstrate marked differences in mortality.

What does Public Health Do in a *Natural* Disaster?

- Assess health impacts in the community
- Environmental health assesses water safety and sanitation
- Public health nurses coordinate with Shelter Operations
- Acute communicable disease tracks infectious diseases
- Injury program tracks injuries and fatalities
- Health Officer coordinates information for the public and health care providers

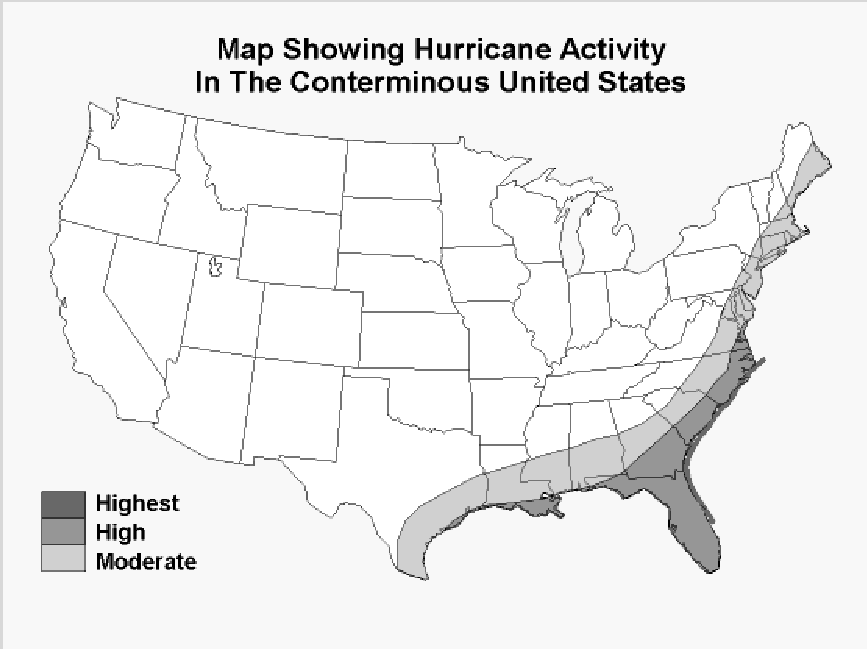
Shoaf

An epidemiologists' role in a natural disaster is as a member of a public health team responding to the disaster. They will be involved in activities ranging from a rapid needs assessment of the health needs of the community in the aftermath of the disaster, to building a surveillance system to monitor communicable disease, injuries or deaths, to conducting small investigations to identify factors related to these health conditions.

Hurricanes/Cyclones

NOAA

The next series of slides will examine the risks and effects associated with specific natural hazards. For each of the following categories of natural hazard disasters, I will discuss the primary health effects associated with them, known information on risk factors for the hazard, or risk factors related to the impact of the hazard, and mitigation strategies to reduce their impact. I begin with a discussion of hurricanes and cyclones.



USGS

Over the last century, scientists have learned a great deal about hurricanes. In the United States, several agencies actively monitor their development and progress. This information often leads to predictions regarding the most likely path that the hurricane will follow, and where it may strike land.

The picture above highlights the areas having the greatest amount of hurricane activity in the United States. Florida, Louisiana, and the Atlantic seaboard are at the highest risk. Areas further inland may receive increased amounts of rain associated with the hurricane (and sometimes tornadoes) which can pose a flooding threat.

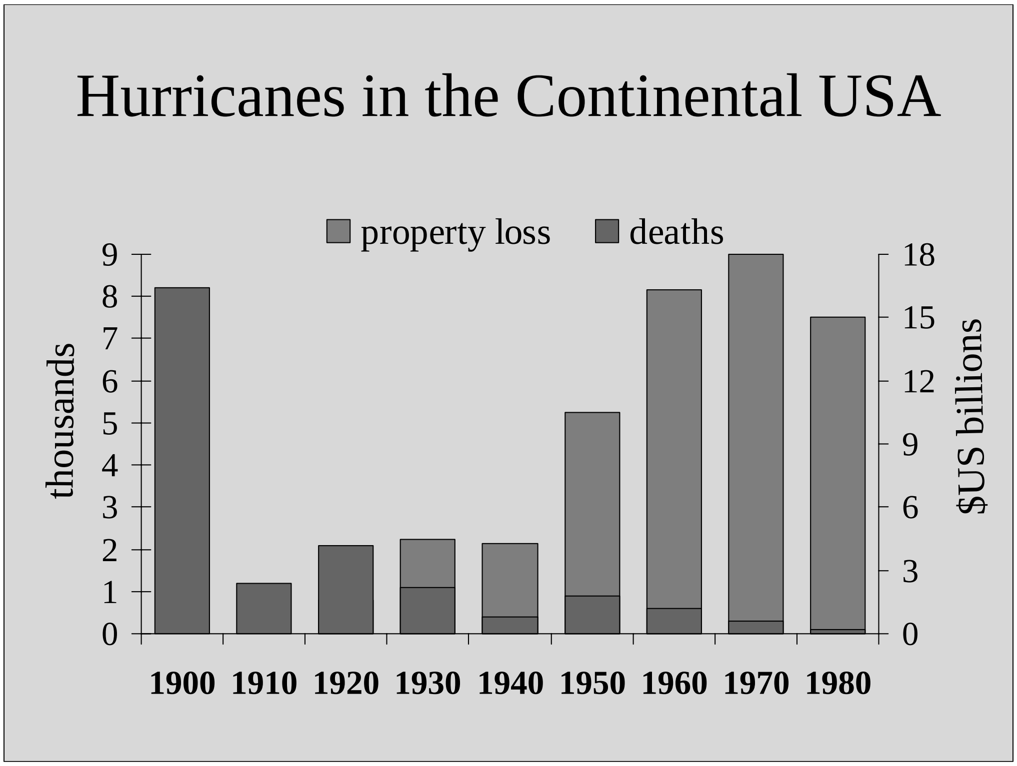
Hurricanes/Cyclones

Direct Hazards

- Drowning from …
  - –storm surge
- Injuries from ...
  - –flying debri

The primary health issue arising from direct contact with hurricanes or cyclones lies in the risk for drowning from the storm surge associated with the landfall of the storm. Most deaths associated with hurricanes are drowning deaths. This risk is followed by the hazard for injuries from flying debri due to the high winds. These health issues are important in the impact phase of a hurricane.

After a hurricane passes through an area, other hazards become important. Among them are injuries incurred from the clean-up effort, mental health issues, infectious disease concerns related to diarrhea an GI tract bugs, and health issues arising from the lack of appropriate health care services.



The active surveillance of hurricanes in the United States and the active learning process related to the surveillance of hurricanes is one type of mitigation strategy. A mitigation strategy is an organized plan to attempt to reduce the impact of a disaster. In epidemiologic terms, it represents prevention.

The primary prevention strategy in the event of a hurricane is to provide early warning and evacuation. Evacuation is key as the storm surge represents the greatest threat. As evidenced above, this approach has been quite successful in reducing the number of deaths associated with hurricanes in the United States. This is particularly enlightening, because the number of events has not decreased. In fact, the amount of property loss (costs) continues to increase. Hurricane Katrina in 2005 represents a deviation from this common pattern.

Katrina Death Toll

- As of May 19, 2006, the confirmed death toll (total of direct and indirect deaths) stood at 1,836, mainly from Louisiana (1,577) and Mississippi (238). However, 705 people remain categorized as missing in Louisiana, so this number is not final even nine months after the storm. Many of the deaths are indirect, but it is almost impossible to determine the exact cause of some of the fatalities.

Wikipedia

The death toll from Hurricane Katrina is approaching 2000 persons. This represents more deaths related to one hurricane than has been seen in the United States for several decades combined. Many argument that it is an illustration of the impact of poor disaster planning and implementation efforts.

From an epidemiology point of view, there are other lessons to be gained from Hurricane Katrina as well. From this slide, one can note several issues of importance to epidemiologists. Namely, the importance of having a case definition of what constitutes a death related to the hurricane and what does not. How should missing persons be handled? Are they presumed dead? A forthright case definition can address this point.

Another epidemiology issue involves defining which deaths are direct and which are indirect. The normal definition of a death that is directly related to an event is a death which arises from direct contact with the natural hazard or its elements. In Hurricane Katrina, this would include death related to the storm surge and high winds. Most individuals would also include the flooding deaths. Indirect deaths can encompass a range of other issues, which arise mainly after the storm passes through. Deaths related to the clean-up after Katrina, for example, would be indirect.

The time frame of analysis is also important here for an epidemiologist. Over what time frame (or how long after the event) should events be considered as an indirect factor related to the storm. Here we are in June 2006, nearly 10 months after the storm, and there is still some discussion over potential indirect deaths related to the storm. Again, assigning a case definition that incorporates a time frame can be important for accurately characterizing the impact of the event.

*Cause of Death Attributed to Hurricane Hugo --- South Carolina, 1989**

<u>Impact Phase</u>

Drowned while bringing boats inland (5)
Drowned by storm surge in mobile home (1)
Crushed by mobile home/trailer (4)
Crushed by collapsing house (1)
Multiple blunt trauma from tree falling into house (1)
Suffered head injury when car hit by falling tree (1)

*Number of death in parentheses.
Data from CDC: Medical examiner/coroner reports of deaths associated with Hurricane Hugo ----- South Carolina. MMWR 38:754-7792, 1989.

The next set of slides illustrate the health and injury issues which commonly arise in a hurricane.

During the impact phase (when the hurricane makes landfall), the primary issue is drowning related to the storm surge, as illustrated here in the deaths related to Hurricane Hugo. Persons riding out the storm on boats or in low lying areas are particularly vulnerable. Deaths from falling debris (in this case; trees) are also a concern.

*Cause of Death Attributed to Hurricane Hugo --- South Carolina, 1989**

Post-impact Phase

Electrocuted while working on power lines (1)
Smoke inhalation in house fire caused by candle (8)
"Heart attack" due to stress (6)
Asphyxiated while trapped under uprooted tree (1)
Burned in house fire caused by candle (1)
Neck laceration caused by chain saw (1)
Electrocuted while clearing debris (2)
Head injuries when hit by tree during clean-up (1)
Electrocuted while repairing roof (1)

*Number of death in parentheses.

Deaths after a hurricane impact are varied, including injuries (electrocution, struck by trees, and fires).

TABLE 1. Deaths related to Hurricane Floyd, by cause of death — North Carolina, 1999

Cause of death	Number*	(%)
Drowning	36	(69)
In motor vehicle	*24*	
In boat	*7*	
As pedestrian	*4*	
In house	*1*	
Motor-vehicle crash (excluding drowning)	7	(13)
Myocardial infarction	4	(8)
Fire (burns and trauma from escape attempts)	2	(4)
Hypothermia	1	(2)
Electrocution	1	(2)
Fall	1	(2)

*n=52.

Hurricane Floyd posed a different hazard with a large amount of flooding that accompanied the huge rainfalls with the hurricane. This led to a very high number of drowning deaths, mainly among individuals in motor vehicles.

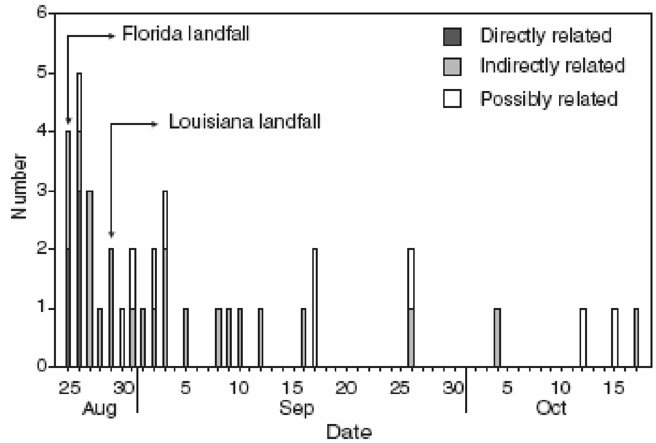


FIGURE. Number of deaths related to Hurricane Katrina (directly, indirectly, and possibly), by date — selected counties,* Florida and Alabama, August–October 2005

* Surveillance covered all 67 counties in Florida and Baldwin and Mobile counties in Alabama.

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5509a5.htm

The data are now emerging from Hurricane Katrina. A review of hurricane-related deaths in Florida and Alabama noted 5 direct deaths and 24 indirect deaths, and a handful which could not be determined (as to their relationship with the storm). The direct deaths occurred in the first 2 days at landfall. The indirect deaths are dispersed throughout the month (and longer- note October 17) after the storm.

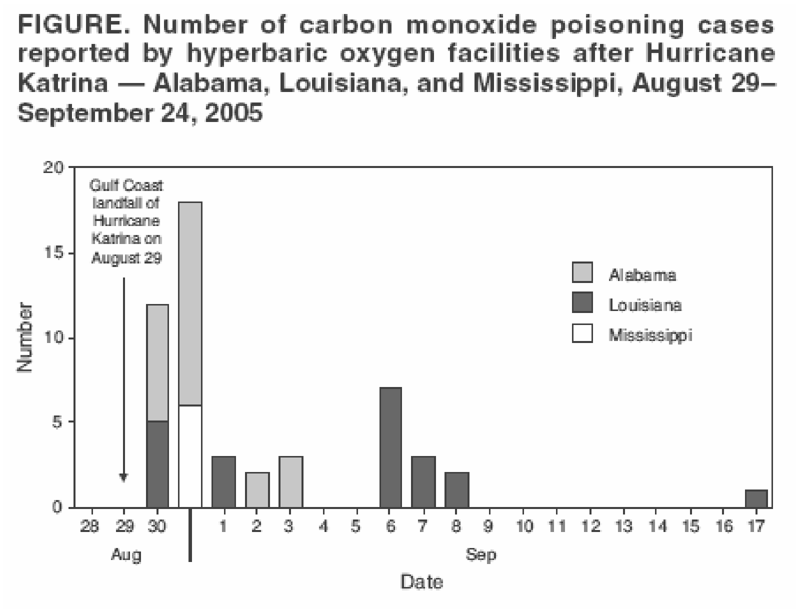
TABLE. Number of deaths directly, indirectly, or possibly related to Hurricane Katrina, by cause of death — selected counties,* Florida and Alabama, August–October 2005

	Florida					Alabama			
Cause of death	**Direct**	**Indirect**	**Possible**	**Total**	**(%)**	**Indirect**	**Possible**	**Total**	**(%)**
Drowning	3			3	(21)	1		1	(4)
Car collision		3†		3	(21)	1		1	(4)
Hit by falling tree limb	2	2		4	(29)				
Carbon monoxide poisoning		2		2	(14)				
Fall from ladder		1		1	(7)				
ASCVD§						6	3	9	(38)
Chronic alcoholism						1		1	(4)
Sepsis						1		1	(4)
Seizure						1		1	(4)
Other CNS¶ disease						1		1	(4)
Traumatic brain injury						1	1	2	(8)
Homicide (gunshot wound)							3	3	(13)
Suicide						1	1	2	(8)
Asphyxia						1		1	(4)
Undetermined			1	1	(7)		1	1	(4)
Total	**5**	**8**	**1**	**14**		**15**	**9**	**24**	

* Surveillance covered all 67 counties in Florida and Baldwin and Mobile counties in Alabama.
† Two deaths in Walton County were associated with weather conditions during the second landfall of Hurricane Katrina.
§ Atherosclerotic cardiovascular disease.
¶ Central nervous system.

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5509a5.htm

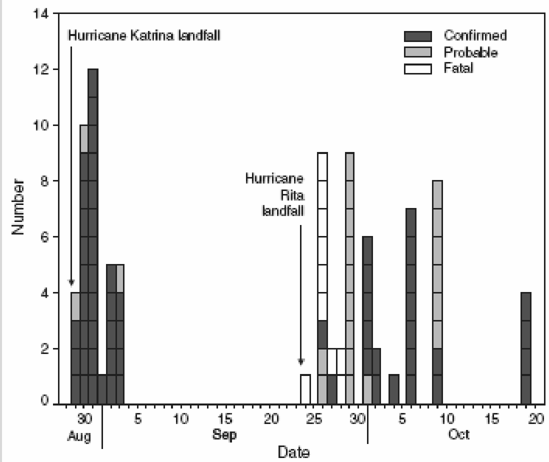
The actual causes of these deaths in Alabama and Florida are shown here. The direct deaths included 3 from drowning and 2 from being struck by a falling tree limb.



http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5439a7.htm

A significant issue in Hurricane Katrina and other hurricanes are indirect deaths and injuries from carbon monoxide poisoning. Major storms often knock out electrical power for days. Thus, several individuals have turned to using generators for electricity in these times. The side effect of this practice is a spike in carbon monoxide poisonings related to generator use, as many individuals operate generators in an unsafe fashion. This slide illustrates that many individuals were seen after Hurricane Katrina for carbon monoxide poisoning.

FIGURE. Number of cases of carbon monoxide poisoning after Hurricanes Katrina and Rita,* by date of medical contact — Alabama and Texas, August–October 2005



* All cases during August 29–September 3 occurred in Alabama, and all cases during September 24–October 19 occurred in Texas.

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5509a4.htm

Data from Hurricane Rita in Texas in 2005 again note a very high rate of carbon monoxide poisoning. 10 deaths were observed in Texas in the first 5 days following the hurricane's landfall.

TABLE 2. Carbon monoxide poisoning case severity and outcome, by generator placement — Alabama and Texas, August–October 2005

Generator placement	No. of cases	Deaths No.	Deaths (%)	Median COHb* level (%)	Received HBO† treatment No.§	Received HBO† treatment (%)
Inside home	26	9	(34.6)	17.2	9/21	(42.9)
Outside, fully enclosed space¶	6	1	(16.6)	15.5	0/5	(0)
Outside, partially enclosed space**	19	0	(0)	13.7	6/19	(31.6)
Outside, open area	31	0	(0)	10.7	9/30	(30.0)

* Blood carboxyhemoglobin.
† Hyperbaric oxygen.
§ Denominators varied depending on the number of cases with outcome information available.
¶ Included garages, sheds, and enclosed porches.
** Included carports and open porches.

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5509a4.htm

Most of these fatal carbon monoxide poisonings were related to individuals placing gas-powered generators inside their homes. The poor ventilation of the exhaust of the generator led to the poisoning. In fact, the column outlining median COHb levels demonstrates that the further away that a generator is placed from the home, the lower the exposure to carbon monoxide.

The safety message originating from this work is that generators should never be placed inside the home when in use, they should be placed as far away from the home as possible. Also, it is strongly recommended that carbon monoxide detectors be used when generators are powered up.

CDC Morbidity & Mortality Weekly Reports (MMWR) - H. Katrina

Previous natural disasters epidemiology validated – skin, diarrhea, respiratory disorders most common

"Infectious disease outbreaks are rare following natural disasters, especially in developed *countries…specific etiologies are usually predictable*, reflecting infectious disease endemic to the affected region before the disaster"

First few days post disaster – *injury & soft tissue infections (including carbon monoxide poisoning)*

Up to one month after a disaster – *Airborne, waterborne, and foodborne diseases*

Potential exposure to dead bodies, human & animal – no evidence exists that exposure to bodies after a disaster leads to infectious disease epidemics. However persons handling corpuses and carcasses might be expose to infectious pathogens & should use appropriate protective equipment

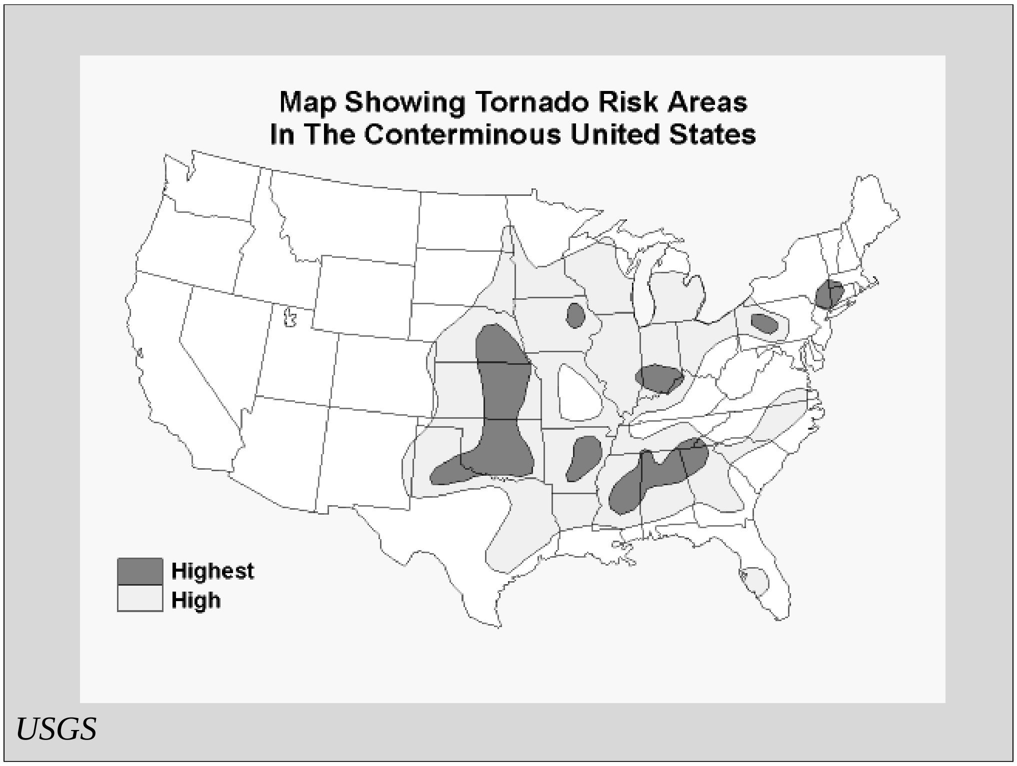
Elestwani 2006

The overall lessons emerging from Hurricane Katrina is that injuries and infections were the primary issue to deal with in the first few days following the disaster. Waterborne and foodborne diseases were of concern at later points in time. Another issue of importance, thoughout, but particularly in the first few days were deaths and illnesses occurring from the inadequate access available to medical institutions (e.g. persons unable to obtain dialysis, etc.).

Tornadoes

NOAA

A weather hazard of unique importance to the United States is the tornado. Tornadoes can produce significant destruction and loss of life.



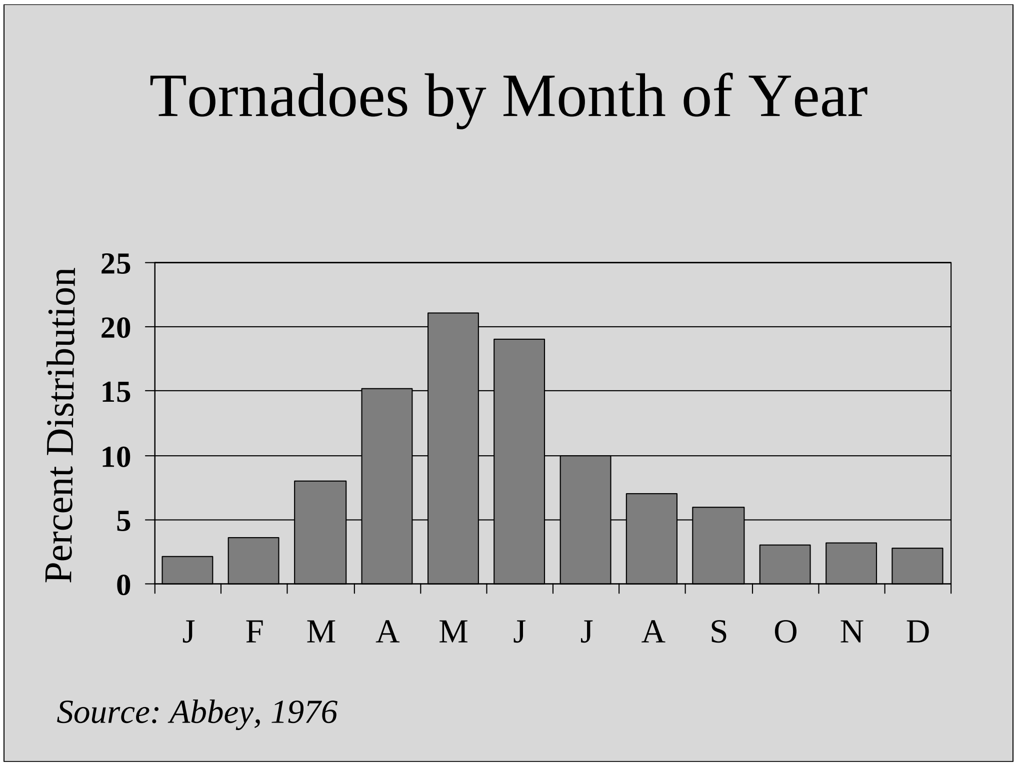
An analysis of past tornado events provides several clues on the likely risk factors associated with their occurrence. For example, the map above illustrates the geographic locations most affected by tornadoes. The plain states of the midwest are at greatest risk, as well as Mississippi, Alabama, and Georgia.

Tornadoes

Direct Hazards

- Injuries from …
  - –flying debri
  - –structural collapse
    - head/chest trauma

The primary hazard from a health perspective in a tornado is the risk for injuries from flying debris. The high winds and circular nature of a tornado leads to the elevation and transport of anything that is not fastened down. Most victims of tornadoes are affected by head and chest trauma due to being struck by debris or from a structural collapse. Some individuals are injured while on the ground. Others are lifted into the air by the tornado and dropped at another location.



Distinct patterns also exist with respect to the time of day in which tornadoes occur, and the month of the year. Illustrated here is the percent distribution of tornadoes by month. April, May and June represent the months when most tornado events are observed. By time of day, most events happen between the hours of 5pm and 12 midnight.

Table 1
Original Fujita Scale Circa 1971 [4]

Fujita-scale	Wind speed (MPH)	Qualitative damage description
F0	40 to 72	Light damage – some damage to chimneys and TV antennae; breaks twigs off trees; pushes over shallow rooted trees.
F1	73 to 112	Moderate damage – peels surface off roofs; windows broken; light trailer houses pushed or overturned; some trees uprooted or snapped; moving automobiles pushed off the road.
F2	113 to 157	Considerable damage – roofs torn off frame houses leaving strong upright walls; weak buildings in rural areas demolished; trailer houses destroyed; large trees snapped or uprooted; railroad boxcars pushed over; light object missiles generated; cars blown off highway
F3	158 to 206	Severe damage – roofs and some walls torn off frame houses; some rural buildings completely demolished; trains overturned; steel-framed hangar-warehouse type structures torn; cars lifted off the ground; most trees in a forest uprooted, snapped or leveled.
F4	207 to 260	Devastating damage – whole frame houses leveled, leaving piles of debris; steel structures badly damaged; trees debarked by small flying debris; cars and trains thrown some distances or rolled considerable distances; large missiles generated.
F5	261 to 318	Incredible damage – whole frame houses tossed off foundations; steel-reinforced concrete structures badly damaged; automobile-sized missiles generated; incredible phenomena can occur.
F6	319 and above	Inconceivable damage – should a tornado with the maximum wind speed in excess of F5 occur, the extent and types of damage may not be conceived. A number of missiles such as ice boxes, water heaters, storage tanks, automobiles, etc. will create serious secondary damage on structures.

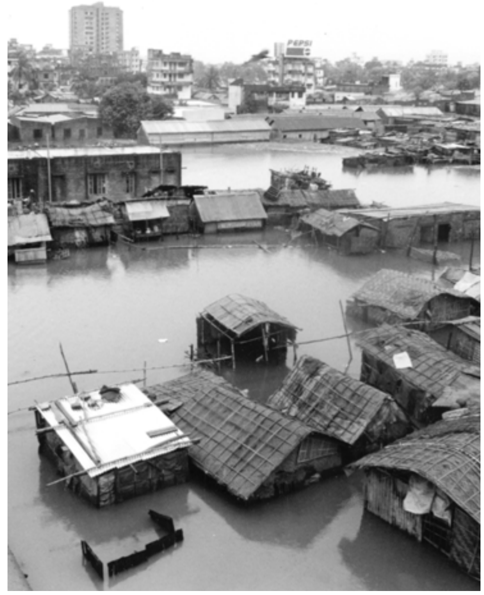
A link between deaths and injuries and the severity of the tornado has been established based upon past tornadoes. The Fujita Scale is used to classify the severity of the tornado event. The larger the number, the more significant the level of damage and death and injuries.

Mitigate Tornado Injuries by ..

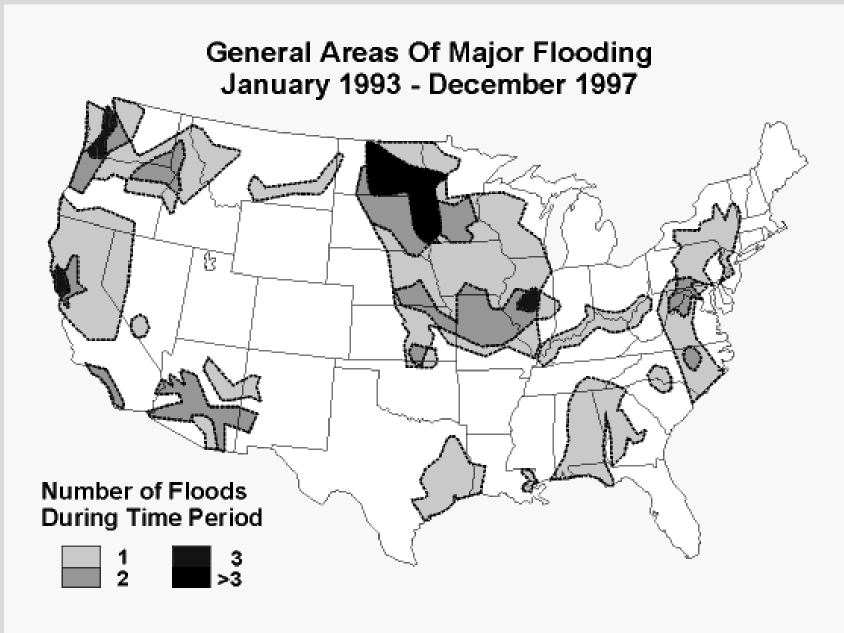
- Pre-Event measures
  - –early warning systems
  - –pursuing prediction methods
- Post-Event measures
  - –avoid downed power lines

Mitigation strategies for tornadoes are primarily focused on providing as early a warning as possible of an approaching tornado. The warning system most widely used today is the issuance of tornado watches and tornado warnings by the National Weather Service. A tornado watch is an advisory that the weather conditions are conducive to the development of a tornado. A tornado warning is an advisory that an actual tornado has been sighted. Early warning is important as it allows the public to seek shelter in protected areas. Most often this will be the basement of a home, or a culvert if driving along a road.

Floods

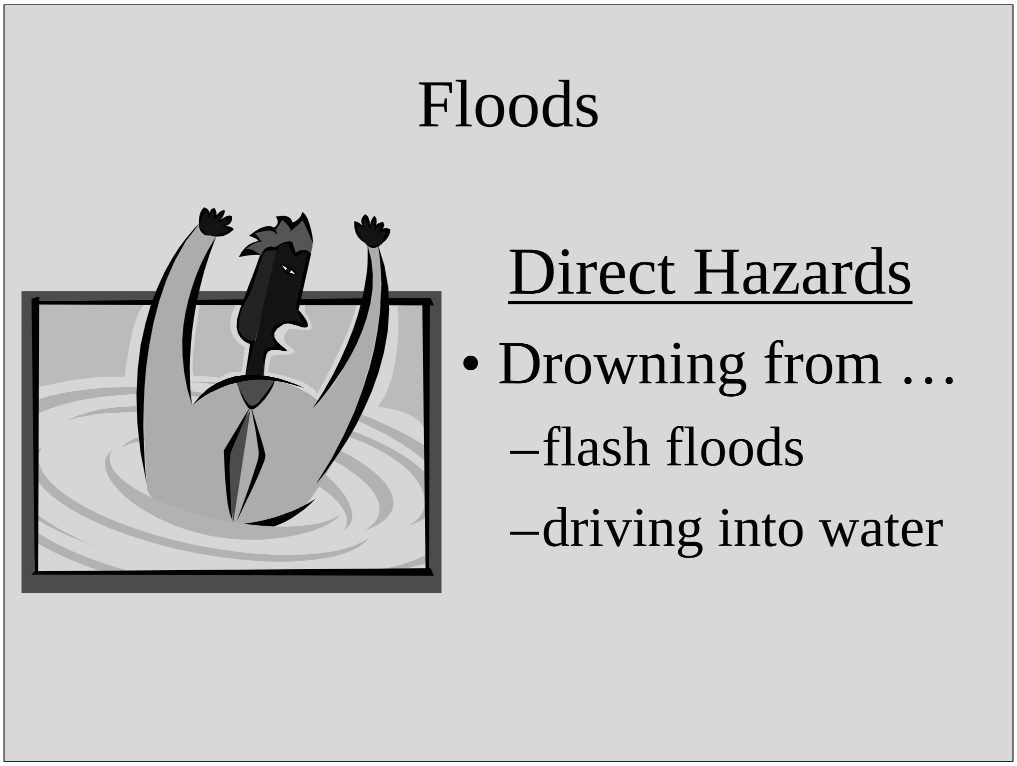


Flooding events represent another type of disaster. Floods may originate very quickly following a quick rain storm, or they may develop over a period of days (sometimes weeks) following an extended period of rain or quick snow melt. Flash floods are of particular concern because of their sudden onset.



USGS

Floods occur very frequently, often on a seasonal basis. This figure illustrates the areas of the United States with the greatest number of floods over the last five years. The upper midwest and Pacific northwest have been particularly vulnerable to floods.



The primary hazard from flooding regards drowning. This is particularly evident for flash floods. One identified risk factor for victims of flash floods is driving in an automobile. Whether a flood overtakes a car, or an operator drives the car into flowing water, this is not the place where you want to be. Many victims of flash floods drown within their vehicle.

A longer term health concern from flooding is the development of disease from inundated sanitation stations. Large floods pose a hazard to existing sanitation and drinking water systems.

Central Texas Storms, Oct 1998

- October 17-20, 1998 - 22 inches of rain
- 31 deaths associated with the storm system
- direct death - physical contact with storm
- indirect death - no physical contact, but the death would not have occurred if no storm
- 29 direct deaths
- 24 drowning deaths, 3 MI, 3 trauma, 1 hypothermia

An example of the human mortality related to flash floods is the experience of Central Texas following heavy rains in October 1998. The vast majority of direct deaths related to this event were drownings.

Risk factors for mortality during the flash flood event, Puerto Rico, 5-6 Jan 1992

	Odds Ratio	95% confidence interval
Gender		
Female	referent	
Male	0.9	(0.3-2.5)
Age (years)		
0-14	referent	
15-44	2.9	(0.7-16)
≥ 45	1.6	(0.3-11)
In a motor vehicle		
No	referent	
Yes	15.9	(3.5-144)

The risk factors for flash flood deaths are emerging in the literature in the last 10 years. This study from Puerto Rico noted a higher involvement of young adults and persons in a motor vehicle. In fact, the predominant message emerging from this study is the large role played with drowning deaths among individuals in motor vehicles.

Table II Occupants of motor vehicles involved in weather-related, single-vehicle crashes in 7 counties (Craven, Johnston, Nash, Pitt, Pender, Warren, Wayne) of eastern North Carolina, 15–17 September 1999 (the days before, during, and after landfall of Hurricane Floyd), by depth of vehicle submersion[a]

	Occupants who drowned ($N = 14$)	Occupants who survived ($N = 83$)
Depth of vehicle submersion		
Partly submerged	0	8
Fully submerged	14	5
Not submerged	0	65
Unknown	0	5

Sources: North Carolina medical examiner records and motor vehicle crash

Table III Proportions of motor vehicle occupants who drowned in weather-related, single-vehicle crashes in 7 counties (Craven, Johnston, Nash, Pitt, Pender, Warren, Wayne) of eastern North Carolina, 15–17 September 1999 (the days before, during, and after landfall of Hurricane Floyd), by vehicle submersion[a] and effect of current

	Deaths/occupants (%)		
	Submerged	Not submerged	Unknown
Vehicle swept away	10/11 (90.9%)	0/0 (0.0%)	0/0 (0.0%)
Vehicle not swept away	4/16 (25.0%)	0/65 (0.0%)	0/3 (0.0%)
Unknown	0/0 (0.0%)	0/0 (0.0%)	0/2 (0.0%)

Sources: North Carolina medical examiner records and motor vehicle crash reports.

Table IV Roadway characteristics of motor vehicle–related drowning deaths associated with inland flooding after Hurricane Floyd, North Carolina, 15–17 September 1999

	Deaths
Familiarity with roadways	
Length of residence in county	
<2 years	2
2–5 years	1
>10 years	13
Destination at time of death	
Work site	6
Homes of family or friends	5
Grocery store	2
Own home	1
Unknown	2
Route of travel to destination	
Usual route	11
Different route	4
Unknown	1
Roadway exposure during the study period	
Number of destinations since 15 September, excluding final destination	
1–5 destinations	8
None	6
Unknown	2
Number of miles traveled since 15 September, excluding final trip	
>20 miles	3
11–20 miles	2
1–10 miles	3
None	6
Unknown	2

Source: Proxy informants who knew the deceased persons well.

Traffic Inj Prev. 2003 Dec;4(4):279-84

Further details of the factors related to motor vehicle-related drowning in flash floods are available from a study of the flash flood deaths with accompanied Hurricane Floyd. Most deaths occurred to individuals who were in vehicles which were fully submerged in the water. Most deaths were among vehicles which were swept away by the flood waters, and most deaths were among individuals who were driving on roads close to home that they were very familiar with.

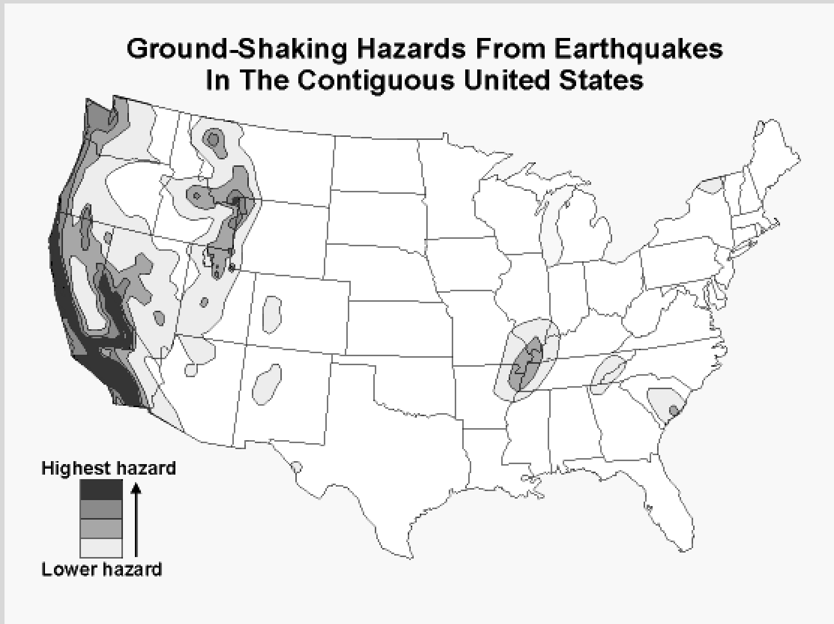
Yale JD, Cole TB, Garrison HG, Runyan CW, Ruback JK. Motor vehicle-related drowning deaths associated with inland flooding after hurricane Floyd: a field investigation. Traffic Inj Prev. 2003 Dec;4(4):279-84.

Mitigate Impact of Floods by ..

- Pre-Event measures
  - –early warning systems for flash floods
  - –education on flood hazards
- Post-Event measures
  - –maintain sanitation systems
  - –maintain vector control systems

Prevention strategies in flooding focus upon pre-event and post-event measures. Before a flood, one is concerned with providing an early warning to flash flood events, as well as public education on flood hazards (automobile driving). During and after the flood, the issue is one of maintaining proper sanitation systems and proper control of vector populations.

Earthquakes



USGS

Earthquakes can occur in several areas of the world. That is because geological fault lines exist worldwide. The Pacific Rim countries are particularly vulnerable to these events. This figure illustrates the areas of the United States (Alaska and Hawaii excluded) at greatest risk for earthquake tremors. This largely encompasses the state of California.

Earthquakes

Direct Hazards

- Injuries from …
  - –structural collapse
  - –rock slides on hills
  - –tsunamis

Earthquakes are a significant global concern. Earthquakes of varying magnitude occur everyday. Most are small, but the potential for a large quake exists. What scientists don't yet know, though, is when a large quake might be expected to occur. In 1997, 13 significant earthquakes were noted in the CRED database (source: World Disaster Report).

The primary health concern associated with earthquakes are injuries arising from structural collapse. Most injuries occur amongst individuals trapped within their homes or businesses at the time of the earthquake. Another issue in large quakes is the development of tsunamis. Quite recently, Papua New Guinea was struck by a tsunami following an earthquake in the Pacific Ocean. Several thousand individuals were swept out to sea by the tsunami.

Seismic, structural, and individual factors associated with earthquake related injury

- Study design
- Definition of injury
- Data Sources
- Severity of Injury
- Population
- Bias
- Findings

- Case-control study
- fatal or hospital-admitted
- coroners office/hospital records
- moderate to severe
- Los Angeles County
- controls identified by phone
- higher risk in elderly, women, and apartments

http://ip.bmjjournals.com/cgi/reprint/9/1/62.pdf

An illustration of the factors contributing to earthquake injuries is available from a study following the Northridge earthquake. This study found a higher risk for earthquake injuries among older individuals, persons living in apartments, and women.

Peek-Asa C, Ramirez M, Seligson H, Shoaf K. Seismic, structural, and individual factors associated with earthquake related injury.
Inj Prev. 2003 Mar;9(1):62-6.

Earthquake Injuries

Table 3 Distribution of individual characteristics and risk of injury using location matched controls

Characteristic	Cases	Age matched controls	Location matched controls*		
			Controls	OR	95% CI
Mean age (range)†‡	55.0 (18–95)	54.8 (18–97)	46.8 (21–98)	1.3	1.1 to 1.6
Number (%) above age 65‡	40 (38.8)	39 (37.9)	18 (17.5)	2.9	1.2 to 7.4
Number (%) by gender‡					
Male	36 (35.0)	36 (35.0)	59 (57.3)	1	
Female	67 (65.0)	67 (65.0)	44 (42.7)	2.4	1.2 to 5.1

*Models are controlled for building factors. Model fit was assessed using likelihood ratio tests. All models had $\chi^2 > 36.1$ and p values < 0.0001.
†Odds ratio (OR) for age per 10 years.
‡Adjusted for age and gender.
CI, confidence interval.

Table 4 Distribution of building characteristics and risk of injury using location and age and gender matched controls

Characteristic	Cases	Location matched controls*			Age/gender matched controls†		
		Controls	OR	95% CI	Controls	OR	95% CI
Building type							
Residential single unit	45 (43.7)	70 (68.0)	1		75 (72.8)	1	–
Residential multiple unit	47 (45.6)	29 (28.2)	3.8	1.7 to 9.7	24 (23.3)	2.9	1.2 to 8.3
Commercial/other	11 (10.7)	4 (3.9)	6.4	1.4 to 47.6	4 (3.9)	6.9	1.3 to 49.5

The level of risk related to these factors are shown in these tables from the study. Persons injured in the earthquake were older than those not injured. Females were over-represented among the injured by a ratio of 2:1. Persons living in multiple residential units (apartment buildings) were 4 times more likely to be injured compared to those living in homes.

Peek-Asa C, Ramirez M, Seligson H, Shoaf K. Seismic, structural, and individual factors associated with earthquake related injury.
Inj Prev. 2003 Mar;9(1):62-6.

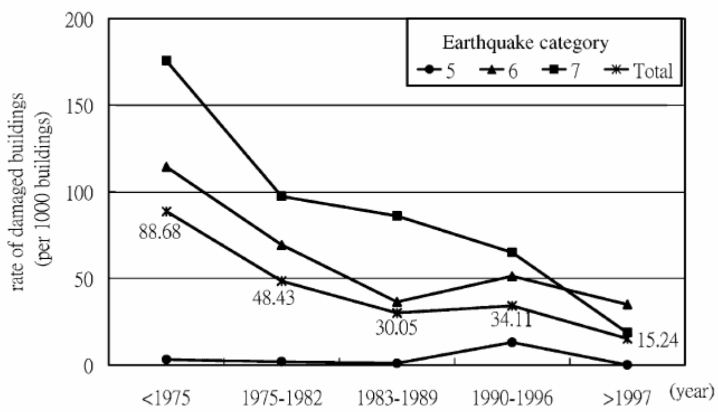


Fig. 2. Damage of buildings according to the construction time and area of earthquake category in 1999 Chi-Chi earthquake, Taiwan.

Evidence from the 1999 earthquakes in Turkey and Taiwan also illustrate the value of building codes as a means of prevention of earthquake injury. These data are from Taiwan and demonstrate that newer buildings (which tend to follow more stringent building codes to prevent the collapse of the building in an earthquake) were damaged at lower rates than older buildings.

Table 3. Injury and death statistics by site

Location	Date	Richter	# Injuries (source)	# Deaths (source)	Injuries/ death	Deaths/100 injuries
Armenia (country)	7-Dec-88	6.9	15,000	25,000	0.6/1	167
Gumri Armenia	"	"	682	561	1.21/1	82.6
Spitak Armenia	"	"	239	494	0.48/1	208.3
Loma Prieta, California	17-Oct-89	7.1	3,757	67	56.1/1	1.8
Northridge, California	17-Jan-94	6.7	9,000	57	150.9/1	0.6
Kobe, Japan (city only)	17-Jan-95	6.9	14,678	4,571	3.2/1	31.3
Kobe, Japan (metro area)	"	"	94,900	5,480	17.3/1	5.8

Another illustration of the role of population density and vulnerability in determining the size of an earthquake disaster is shown here. These 4 earthquakes occurred in roughly the same time period (1988-94) and had the same level of severity (magnitude on the Richter scale). However, the outcomes of the earthquakes were very different. Armenia, for example, is a developing area with low levels of economic development. It incurred high numbers of injuries and deaths. Kobe, Japan, on the other hand is very well advanced economically, but an area that is vulnerable from a population density point of view. It also experience high numbers of deaths and injuries.

Table 2. Level of development

Site/infrastructure	Armenia	San Francisco Bay Region (Loma Prieta)	North Los Angeles County (Northridge)	Kobe, Japan
EMS organization	Low	High	High	Medium
Public health organization	Medium	Medium	Medium	High
Tertiary care availability	Medium	High	High	High
Emergency management organization	Low	High	High	Medium
Health sector emergency management	Low	High	High	Low

EMS = emergency medical services.

Economic development affects not only the potential scale of the disaster (larger scales in poorer areas), but also the ability to respond to disasters after they occur. This point is illustrated in this slide, where the economically underdeveloped area of Armenia also had a diminished ability to respond to the earthquake because of poor organization of emergency health services, and only adequate public health and acute care health services.

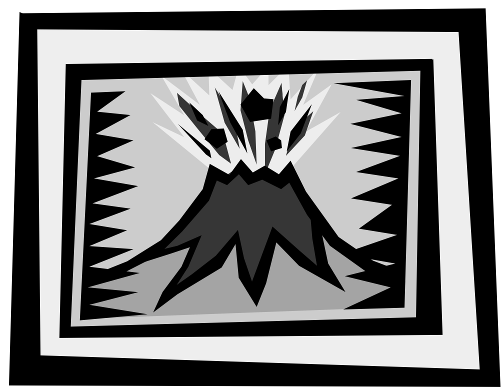
Mitigate Earthquake Injuries by ..

- Pre-Event measures
  - –establishing building codes
  - –pursuing prediction methods
- Post-Event measures
  - –improve methods for rescue
  - –advise on aftershocks

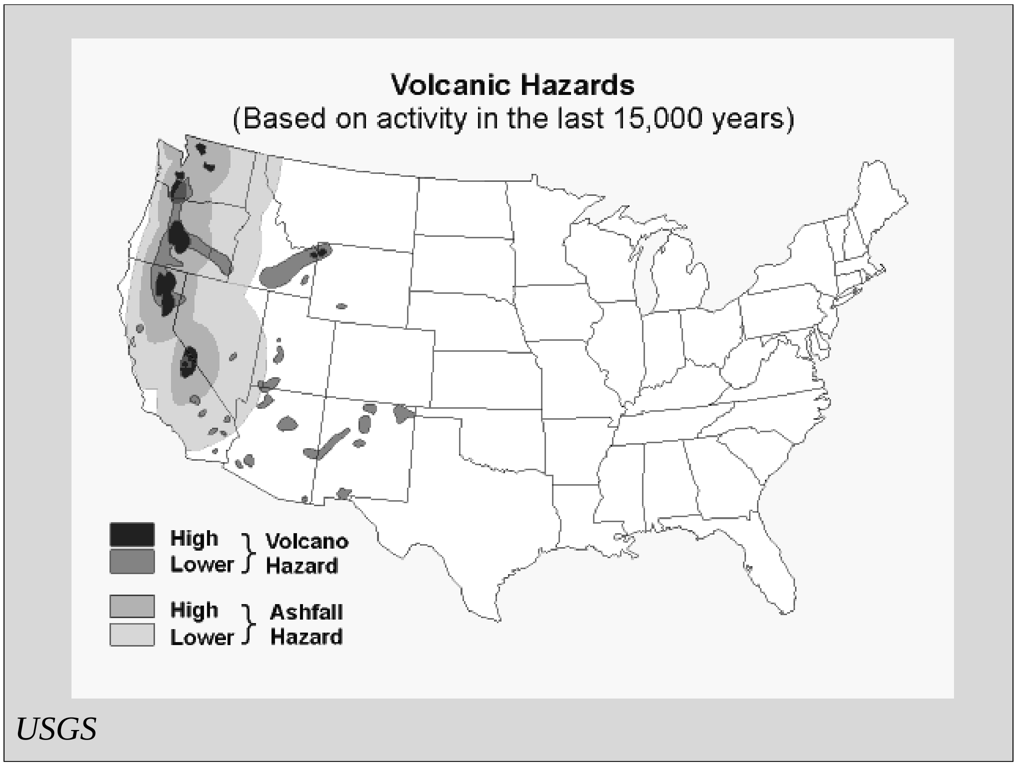
The most well known prevention strategy in earthquakes is the prevention of a building from collapsing. Several jurisdictions in earthquake prone areas require that all new buildings follow certain construction codes. These codes ensure that the building is structurally sound in the event of a significant tremor.

Several areas of research, though, are continuing in the area of earthquakes. Foremost, scientists are seeking better ways of predicting when large tremors will occur. Secondarily, there is a recognized need to develop better rescue strategies for retrieving individuals from collapsed buildings.

Volcanic Eruptions



Volcanic eruptions are rare, but can be catastrophic when they occur. Data from CRED indicate that there were 3 eruptions designated as disasters in the year 1997. Over the 25 year period (1972-1996), there was an average of 6 eruptions per year, causing an average of 1017 deaths and 285 injuries.



The risk from volcanoes, geographically, is well known. Several areas in the world contain active and dormant volcanoes. The Pacific rim contains several active volcanoes. We see here the risk pattern for the 48 states of the continental US. Almost all events have been confined to the Pacific states. The most recent explosion of significance was the eruption of Mt. St. Helens in Washington state.

Mitigation strategies in volcanoes include early warning systems and evacuation. Today, there generally are several investigations regarding the dormancy status of volcanoes. These are undertaken to identify any changes that may warrant preventive action. While geologists in Monteserrat were not able to predict when the volcano on that island would erupt, they were able to identify a markedly increased risk for eruption. On the basis of this information, island authorities and the British government recommended the evacuation of much of the island. Efforts such as this will likely mean that the odds for another disaster on the scale of that in Pompeii will be significantly diminished.

Volcanoes

Direct Hazards

- Respiratory illness from …
  - ash, gases
- Drowning from …
  - tsunamis
- Injuries from …
  - mud flows
  - lava flows

Several health outcomes are associated with volcanic eruptions. Most notably, respiratory illnesses are of particular concern following an eruption. This may arise from the inhalation of toxic gases for persons close to the volcano at the time of the eruption. Or, it may arise from the inhalation of ash from the volcano. For individuals in close proximity to the volcano, some danger exists from lava flows, or more likely mud flows.

Patterns of mortality and injury after natural disasters

Death risk	Deaths exceed injuries	Injuries exceed deaths
HIGH	Storm surges, Tsunamis, Flash floods	Earthquakes
LOW	Floods	Tornadoes, Hurricanes (no surge)

Source: Seaman 1984

An overview of the morbidity and mortality patterns of several disaster events provides a clue to the lethality associated with particular weather hazards. In general, disaster events that involve water are the most significant in terms of mortality. Floods, storm surges, and tsunamis all have a higher proportion of deaths relative to injuries. On the other hand, earthquakes and events associated with high winds tend to exhibit more injuries than deaths.

Short-term Effects of Major Natural Disasters

EFFECT	EARTHQUAKES	HIGH WINDS (WITHOUT FLOODS)	TIDAL WAVES/ FLASH FLOOD	FLOODS
Deaths	Many	Few	Many	Few
Severe injuries requiring extensive care	Overwhelming	Moderate	Few	Few
Increased risk of communicable diseases	Potential risk following all major disaster (Probability rising with overcrowding and deteriorating sanitation)			
Food Scarcity	Rare	Rare	Common	Common
	(May occur due to factors other than food shortage)			
Major population movements	Rare	Rare	Common	Common
	(May occur in heavily damaged urban areas)			

Adapted from Emergency Health Management After Natural Disaster. Office of Emergency Preparedness and Disaster Relief Coordination: Scientific Publication No 407. Washington, DC, Pan American Health Organization, 1981.

The overall picture (all aspects of health, not just injury) of the short-term impact of disasters is shown here. Additional concerns, particularly in developing areas, include the availability of food and population displacement due to floods.