Chapter 14
Disasters and Population Health

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Abstract Events of mass trauma are relatively common global phenomena with widespread impact on human health. We conducted this systematic literature review using the National Library of Medicine's PubMed database. We investigated the effect of disasters on six main topic areas of interest: injury and mortality, health systems and infrastructure, mental health, infectious disease, chronic disease, and health behavior. This review covers 182 articles on both natural and man-made disasters, excluding war. We present the results by topic area, across disaster type. This work highlights the scope and heterogeneity of disaster research today, providing a contextual background in which to formulate interventions and disaster planning efforts.

Introduction

The experience of mass traumatic events, or disasters, is a relatively common human experience. The Red Cross estimates nearly 500 disasters occur worldwide every year (excluding droughts and war) in which nearly 50,000 people die, 74,000 are injured, 5 million are displaced, and 80 million people are affected (cited in Norris, Baker, Murphy, & Kaniasty, 2005). Recent high-profile disasters have focused attention on disasters in the peer-reviewed scientific literature as well as in the popular press. However, attention to disasters and their influence on population health tends to be sporadic and focused on the short-term and direct consequences of these events. In many respects, understanding the full scope of the population health consequences of disasters requires an understanding of the short-term and long-term consequences of these events as well as both their direct and their indirect consequences.

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K.E. Cherry (ed.), *Lifespan Perspectives on Natural Disasters*,
DOI 10.1007/978-1-4419-0393-8_14,

This chapter reviews the public health effects of disasters in six main areas: injury and mortality, health systems and infrastructure, mental health, infectious disease, chronic disease, and health behavior. Using a population health framework, we will use the available evidence as a springboard for a discussion about the potential full-range population effects of mass traumatic events. We will also identify opportunities for research and future directions in the area.

Method

We conducted an initial title/abstract PubMed search for terms related to our six main topic areas of interest. We limited our search to manuscripts published in the past 10 years (as of July 2008) in English using human subjects, and we excluded studies on disaster preparedness or preparedness guidelines. We limited this search to studies mentioning any study design in their title or abstract. For those main areas where our initial search results were limited (<30 articles), additional searches were conducted with less stringent limitations (e.g., no requisite mention of study design) and/or with additional search terms. Lastly, we investigated articles referenced by reviewed articles for topics not illuminated adequately by our initial search.

Results

Our initial search yielded 118 results, 93 of which were relevant to our review. Some topic areas were over-represented by this search (e.g., mental health, $n = 67$), while others were very limited (e.g., infectious disease, $n = 11$). Additional searches for more limited topics (injury and mortality, health systems and infrastructure, infectious disease, and health behavior) and for articles referenced in reviewed articles yielded 89 additional articles.

In all, our review represents 182 articles: 26 about earthquakes, 37 about storms and floods, 11 about mass fires, 48 about terrorism, 46 about technological disasters, and 14 were research across disaster types. The best-represented disasters were the September 11, 2001 terrorist attacks (35 articles), followed by the Enschede Fireworks Disaster (16 articles), the Indian Ocean Tsunami (12 articles), and the Chernobyl Disaster (12 articles). We present the results of our review below by topic type.

Injury and Mortality

We reviewed over 45 articles on the impact of disasters on injury and mortality, including cross-sectional, cohort, and case studies as well as review articles. Our article base included samples from the general population and from rescue and cleanup personnel. Original research articles on injury and mortality in the general population commonly used medical records from area hospitals and administrative death files. Much of the research on occupationally exposed groups used records from routine occupational medical assessments. Studies using questionnaires, surveys, or focus groups were rare and these instruments were distributed in camps for displaced persons or through hospitals. Review articles were rarely systematic and topics ranged from broad (e.g., all sudden impact disasters, Stratton & Tyler, 2006) to specific (e.g., lightning strike, O'Keefe Gatewood, & Zane, 2004).

We begin this section with a review of current theory regarding distribution of trauma death over time and examine its applicability to disaster settings. Next, we discuss vulnerability factors, followed by a review of disaster-specific injury and mortality patterns, and the burden of emergency response and cleanup activities. Lastly, we briefly discuss the long-term impact of disasters on injury and mortality patterns in affected populations.

Temporal distribution of trauma-related death. The temporal distribution of trauma-related death describes the timing of deaths from trauma after the occurrence of a traumatic event. Though challenging to measure in the disaster setting, the temporal distribution of trauma-related disaster deaths has important practical applications for disaster planning. In a seminal article, Baker, Oppenheimer, Stephens, Lewis, and Trunkey (1980) reviewed all trauma-related deaths in San Francisco in 1977, describing a trimodal temporal distribution (see Fig. 14.1). According to this model, the first and largest peak in deaths occurs almost immediately after trauma due to apnea from severe disruption of the nervous or cardiovascular system; the

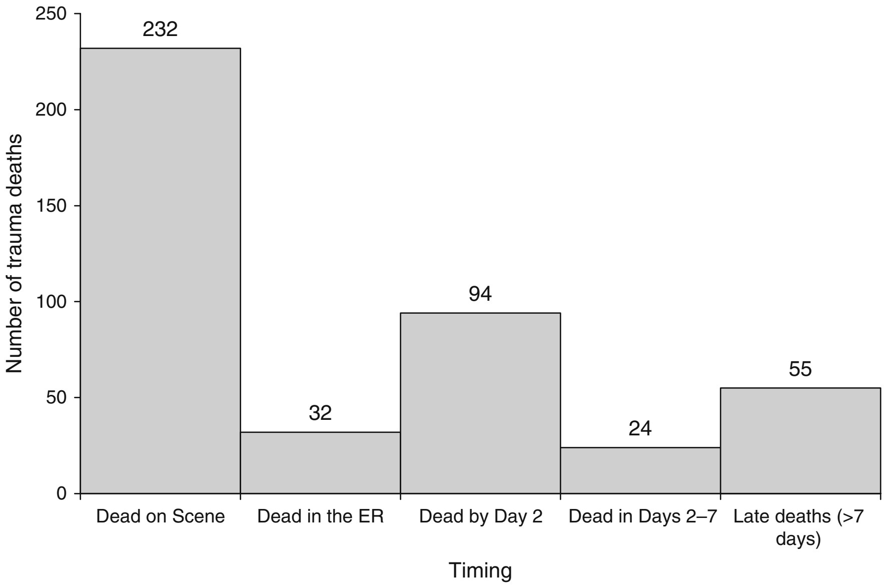

Fig. 14.1 Outcome and length of survival for 437 patients who died from trauma. Reprinted from Baker et al. (1980) with permission from Elsevier

second peak occurs minutes to hours after the trauma as a result of intracranial hematomas, ruptured abdominal organs, penetrating chest trauma, or a combination of injuries; the final peak occurs in the following weeks primarily due to sepsis or organ failure (Johnson & Travis, 2006). Since the time of Baker et al.'s report, researchers have found the temporal distribution of trauma-related deaths to be heterogeneous across different populations and varying over time (Demetriades et al., 2005; Meislin et al., 1997; Sauaia et al., 1995). Nonetheless, one can see how this model, applied on a mass scale, could be useful in disaster settings.

Following the 2004 Indian Ocean Tsunami, Johnson and Travis (2006), working at Krabi Hospital in Thailand, hypothesized a temporal distribution of tsunami-related death that is heavily biased toward the first peak, primarily due to drowning and massive physical injury, with a reduced third peak of deaths. This hypothesis is supported by Nishikiori et al. (2006a, 2006b), who found that 82% of tsunami-related deaths in Ampara district, Sri Lanka, took place within 1 day of the disaster, with an additional 18% within the following 7 days; they found no deaths reported more than 2 months thereafter. The primary causes of tsunami death were drowning, injury, and crush (Nishikiori et al., 2006a). A peak in trauma-related deaths was observed within 3 days of the 1995 Hanshin-Awaji earthquake in Japan, with a later peak in illness-related deaths (Tanaka et al., 1999).

The first peak of trauma deaths may be even greater with intentional man-made disasters, such as bombings and other terrorist attacks, which are both localized and designed specifically to take human life. Of the 168 fatalities in the Oklahoma City bombing, 163 (97%) were dead on-scene (Teague, 2004). There were very few live rescues from the rubble following the September 11, 2001 terrorist attacks (Bradt, 2003). Studies in the United States show that the majority of injuries presenting to hospitals after disaster tend to be minor (Mallonee et al., 1996; Stratton & Tyler, 2006; Teague, 2004). This may be due, in part, to the low number of live rescues after more severe disasters. Paradoxically, less severe disasters may produce far more burden of injury than more severe ones. For example, the 2003 US blackout nearly doubled the emergency medical system load in New York City during the 29 hours the city was without power, with increases in a range of call types, including difficulty breathing, injury, cardiac arrest, seizure, active labor, gunshot, and falls (Freese et al., 2006).

Certainly, there is substantial evidence that earlier rescue after disasters predicts greater probability of survival (Gautschi, Cadosch, Rajan, & Zellweger, 2008). In their review of earthquakes, Peleg, Reuveni, and Stein (2002) found that the vast majority of survivors were rescued within the first day, while those who are rescued on day 2 or beyond had a much lower probability of survival. In the 1995 Oklahoma City bombing, most of the 38 individuals requiring extrication were rescued within 45 minutes of detonation and only 3 survivors were rescued over 3 hours after the bombing (Teague, 2004). In the 2004 Indian Ocean Tsunami, Johnson and Travis (2006) noted that many victims likely perished as a result of heat and sun exposure while awaiting medical care. With increased emergency response and transportation time, those at risk of death within the first few hours of disaster will likely perish before reaching major treatment centers. This may also help explain why many studies based on medical records show that the majority of disaster-related injuries are minor (Mallonee et al., 1996; Stratton & Tyler, 2006; Teague, 2004).

Vulnerability factors. Several studies have identified demographic and circumstantial risk factors for injury and death following disasters. Demographic groups with low pre-disaster resources, mobility, and power are the most vulnerable to disaster-related injury and death (see Allen & Wayne, Chapter 8, for a related discussion). Circumstantial risk factors tend to be more disaster dependent. Nishikiori et al. (2006b) found that women, children, and the elderly were at higher risk of death due to the 2004 Tsunami in Sri Lanka. Chou et al. (2004) found that people with mental disorders, moderate physical disabilities, and recent hospitalization were more likely to die in the 1999 Taiwan earthquake. After Katrina, Brunkard, Namulanda, and Ratard (2008) found that mortality was higher among blacks and people 75 years and older. There is mixed evidence income-associated vulnerability. Chou et al. (2004) found that lower-income individuals were at higher risk of death after the tsunami, while Shoaf, Sareen, Nguyen, and Bourque (1998) found no association between income level and injury in three California earthquakes.

Lastly, for those who have poorer pre-disaster health, disasters may precipitate death, specifically with respect to cardiovascular events. Studies in Athens, Greece, and Northridge, California, both found excess cardiac mortality associated with earthquakes in these locations (Leor, Poole, & Kloner, 1996; Trichopoulos, Katsouyanni, Zavitsanos, Tzonou, & Dalla-Vorgia, 1983). In addition, the Northridge study found a decline in cardiac deaths to below baseline in the 6 days following the day of the earthquake (Leor et al., 1996). This pattern indicates that the earthquake and its associated stress may have hastened cardiac death in those who were already at risk of dying in the near future (Stalnikowicz & Tsafrir, 2002).

In an interesting comparison, Brown (1999) found no increased acute myocardial infarction (AMI) hospital admissions after the Loma Preita earthquake, which unlike the Athens or Northridge earthquakes, occurred during the daytime. Brown concludes that it was the stress of *both* earthquake and wakening that triggered the increase in cardiac death after the Northridge earthquake and that, in less vulnerable time periods (i.e., the daytime), there is no significant increase in incidence of heart attack during disasters. The literature supports the hypothesis that activities both before and after disasters may predict risk of injury or death. Glass and Zack (1979) found that cardiac deaths remained elevated for 8 days after blizzards in Massachusetts, 90% of which were due to ischemic heart disease, with an increased risk for men. The continued elevation in death suggested to the authors that activities after the storms (for example, shoveling snow and, oddly, sexual activity evidenced by excess births 9 months after a 1978 blizzard) may have resulted in the observed sustained rise in cardiac mortality.

Location at the time of disaster is another important circumstantial risk factors for death. Being indoors at the time of a tsunami or an earthquake is associated with increased risk of death (Nishikiori et al., 2006b; Peleg et al., 2002). Accordingly, factors influencing probability of being indoors at the time of earthquake, such as time of day and year, may have implications for mortality (Peleg et al., 2002). Occupation may be tied to location during disaster and thus tied to vulnerability; for example, being a fisherman was associated with tsunami death (Nishikiori et al., 2006b). The character and location of a building is especially important in the context of earthquake, including the type of ground built upon, building height and materials, quality of construction, distance to epicenter (Peleg et al., 2002), type of dwelling (Shoaf et al., 1998), and peak ground acceleration (Schultz, Koenig, & Lewis, 2007; Shoaf et al., 1998). Shoaf et al. (1998) also found that those who moved or attempted to move after an earthquake were more likely to report being injured. In a study of the Union Carbide Disaster, about one-half of those exposed to the gas cloud reported fleeing their homes – most often by walking or running and sometimes for hours – resulting in increased ventilatory rate (Dhara, Dhara, Acquilla, & Cullinan, 2002). Dhara et al. (2002) show that a total exposure index that integrates physical activity following disaster with exposure duration and location is associated with health outcomes, independent of distance to the plant.

Disaster-specific injury and mortality patterns. Because disasters are so diverse – from fires to floods to earthquakes – injury and mortality patterns cannot be adequately summarized across disaster types. This section is not meant as a comprehensive list of all possible health consequences of each disaster type, but rather as a review of the chief injuries and causes of death as supported by the literature.

In conventional weapon terrorism, the main medical concern is blast trauma injury, which may have systemic effects including effects on the lungs, abdomen, ear, eye, extremities, and other injuries (Born et al., 2007), although injuries in multiple anatomical regions are common (Kalebi & Olumbe, 2006). Gas-filled structures – namely lungs, GI tract, and the auditory system – suffer high levels of damage due to the high external pressure of an explosive wave (Crabtree, 2006). Among survivors, common injuries include soft-tissue injuries, fractures, sprains, strains, head injuries, and maxillofacial injuries, including soft-tissue injuries and eye injuries (Mallonee et al., 1996; Odhiambo, Guthua, Macigo, & Akama, 2002). Head injury may be a common cause of death (Kalebi & Olumbe, 2006). Bombings are also associated with shrapnel injuries, traumatic amputation, burns, inhalation injuries, crush syndrome, and pregnancy complications (Crabtree, 2006).

The largest concerns during fire disasters are toxic gas and smoke inhalation, as well as burns (Gewalli & Fogdestam, 2003; Meyer, 2003; van Harten et al., 2006). After electrocution, cardiopulmonary arrest is the most common cause of death; common injuries include neurologic injury, headache, burns, blunt and explosive injuries, eye and ear injuries, fetal death, hematologic abnormalities, and endocrine and sexual dysfunction (O'Keefe Gatewood & Zane, 2004).

The largest concerns for injury and mortality in floods and storms include drowning, extremity fractures, soft-tissue wounds, sprains, lacerations, near-drowning-associated aspiration pneumonias, and hypothermia (Llewellyn, 2006; Maegele et al., 2005). Primary mortality concerns after earthquake include spinal cord injury and crush syndrome (Rathore et al., 2007; Sever et al., 2002).

Chemical and radiological disasters are different from those discussed thus far in that much of the burden of injury is not immediate and may only become apparent after longer-term follow-up. Of 134 plant employees and first responders diagnosed with acute radiation sickness following the Chernobyl Disaster, there were

28 short-term (2 months) and 14 long-term (15 years) deaths, with underlying bone marrow failure and beta burns as the main contributors to early deaths (Mettler, Gus'kova, & Gusev, 2007). The action of chemical exposures depends on the chemical in question and may be system wide. For example, nosocomial exposure to Thorium X in the 1940s was associated with damage to the bone and cartilage as well as cancer of the bone, connective tissue, breast, thyroid, liver, kidney, pancreas, uterus, and bladder (Spiess, 2002), while exposure to dioxin-contaminated cooking oil in Italy in 1976 was associated with mortality from lymphoemopoietic, digestive, and respiratory cancers (Pesatori et al., 2003). Acute irritation and damage to the respiratory, ocular, and gastrointestinal systems were the main immediate effects of the Union Carbide gas leak in Bhopal, India (Beckett, 1998), although there is evidence for persistent ocular, respiratory, immunity, genetic, neurological, neurobehavioral, and reproductive effects as well as cancer (Dhara & Dhara, 2002). Many chemical exposures may be brought about as a result of other disasters, for example, rescue or cleanup workers after bombings may be exposed to damaging chemicals from collapsed buildings, or toxic gases may be released as a result of materials burning in a fire.

Lastly, many disaster-related injuries result from the breakdown of safety controls, infrastructure, and from individuals' attempts to adapt to the disaster. For example, the use of portable generators led to 47 carbon monoxide poisoning incidents during the 2004 Florida Hurricane season, leading to nearly 150 nonfatal and 6 fatal cases of carbon monoxide poisoning (Sniffen et al., 2005). Dog bite and electrocution injuries are also associated with floods and tsunamis (Llewellyn, 2006), while insect stings and bites associated with hurricanes and floods (Diaz, 2007).

Burden of emergency response and cleanup activities. Those who come to search for and rescue disaster victims are often at a high risk for injury and morbidity themselves (see Speier, Osofsky, & Osofsky, Chapter 12, for a related discussion). Cleanup activities, which may take years, also place workers at risk for toxic exposures. These groups represent secondary victims of disaster. Nowhere is this topic better documented than in the case of the September 11, 2001 terrorist attack attacks on New York City. Of the 2,801 individuals killed, 403 were fire personnel or law enforcement, together composing 14% of the dead (Bradt, 2003). After the collapse of the first tower, emergency medicine personnel on-scene were forced to stop triage and flee for their own safety (Asaeda, 2002). Rescue efforts had to contend with extreme heat and underground fires, falling hazards, dust and smoke, wind gusts, toxic substances, and waste disposal (Bradt, 2003).

Relief workers after September 11, 2001, terrorist attack suffered ocular injuries, headaches, sprains, and strains as well as symptoms of the skin, eye, nose, and throat (Bradt, 2003; Feldman et al., 2004). There is overwhelming evidence of compromised respiratory health of rescue and cleanup workers after September 11, 2001, terrorist attack and other disasters (Banauch et al., 2003; Feldman et al., 2004; Mauer, Cummings, & Carlson, 2007; Skloot et al., 2004). One report estimated that within 1 year after September 11, 2001 terrorist attack, cleanup workers suffered an average decline of lung volume equivalent to 12 years of normal age-related decline (Banauch et al., 2006). Respiratory protection measures are known to be effective in the post-disaster setting. Workers often reported using no protection, and the most common form used was a hardware store paint/dust mask (Banauch et al., 2006; Feldman et al., 2004; Mauer et al., 2007), which provides no benefit (Banauch et al., 2006). Respirators with canisters appear to provide some protection against large airway dysfunction (Skloot et al., 2004).

The evidence from the Enschede Fireworks Disaster in 2000 shows similarities to the research on September 11, 2001 terrorist attack rescue and cleanup activities. Workers involved in cleanup and rescue activities after the Enschede Fireworks Disaster showed increase in musculoskeletal, GI, respiratory, and non-specific or medically unexplained ill health (Dirkzwager, Yzermans, & Kessels, 2004; Morren, Dirkzwager, Kessels, & Yzermans, 2007).

Long-lasting impact. Injuries and deaths sustained in disasters have a long-standing impact on affected communities. Many individuals suffer permanent disability as a result of injuries sustained during disaster. For example, many survivors of the 2005 earthquake in Pakistan who suffered spinal cord injuries became paraplegic and required ongoing aggressive rehabilitation in settings where rehabilitation resources are scarce (Rathore et al., 2007; Tauqir, Mirza, Gul, Ghaffar, & Zafar, 2007). Complications of paraplegia in this setting included pressure ulcers, urinary tract infections, deep venous thromboses, bowel problems, and surgical wound infections (Rathore et al., 2007; Tauqir et al., 2007). Moreover, when these individuals return to their communities, motor problems may make original employment impossible. Gul et al. (2008) demonstrated that their training program in telemedicine effectively prepared paraplegic survivors make the transition to cognitive employment, but it is unknown whether these individuals were able to obtain and keep employment as a result of these new skills.

Kirigia, Sambo, Aldis, and Mwabu (2002) conducted a cost analysis to quantify the economic burden of disaster-associated deaths in the WHO Africa Region. They found that each death due to natural and technological disasters reduced the gross domestic product significantly by US $0.018, a substantial loss in an area where about 50% of the population lives on under US $1 per day. Keeping in mind that the Kirigia study was insensitive to the costs of injury, health care, reconstruction, and property damage among others, it may not be possible to accurately calculate the full cost of disasters.

As mentioned previously, disability from chemical exposures may be long term or permanent. A teratogenic agent is a chemical or an environmental factor that is known to cause damage to the developing fetus. For disasters involving chemical exposure, research often focuses on teratogenic outcomes, which affect communities for generations to come. The nosocomial thalidomide disaster of the 1950s and 1960s led to birth defects characterized by reduction deformities of the limbs and sensory nervous system for children whose mothers were exposed to the drug (McCredie & Willert, 1999). There is even some evidence, though inconclusive, for congenital effects of the Chernobyl Disaster throughout Europe (Hoffmann, 2001). Children with birth abnormalities and their families require additional community support and health services throughout their lives. We will cover additional evidence of chronic outcomes of disaster in the section Chronic Disease.

Health Systems and Infrastructure

We reviewed over 40 articles on the impact of disasters on health systems and infrastructure, including cross-sectional, cohort, and case studies as well as review articles. We examine both the burden of disasters on the health system and the challenges to provision of health services in the disaster setting. Studies looking at health services utilization or patient needs often used medical records, records of sick leave from work, or surveys. Studies evaluating damage to the health system or the health system response were commonly case studies or review articles utilizing administrative data; surveys and key informant interviews were used less frequently.

We begin this section with a discussion of the challenges to rescue and emergency medical operations during and immediately following disaster, followed by a review of the longer-term impact of disasters on health-care delivery. Next, we discuss emergency medical assistance teams and challenges to the provision of medical services unrelated to the disaster. We close this section by reviewing primary care and mental health-care utilization patterns in the aftermath of disaster.

Challenges to rescue and emergency medical operations. During disasters, safety of emergency and rescue workers may pose a significant challenge. While rescuing patients and providing medical attention in a timely manner is important, rescue and emergency medical workers run the risk of becoming casualties themselves if safety precautions are not followed or if the disaster takes an unexpected turn (Bradt, 2003; Teague, 2004). Rescue workers after September 11, 2001 terrorist attack had to contend with extreme heat and underground fires, falling hazards, wind gusts, and toxic substances (Bradt, 2003). Health systems must make sure that their workers have adequate prophylaxis against toxic exposures, for example, respirators to prevent pulmonary damage (Skloot et al., 2004). Rescue personnel working after the Marmara Earthquake reported their most important personal problems were health, accommodation, food, and safety (Altntas & Delooz, 2004).

Those same rescue workers after Marmara reported that their most important organization/system problems were coordination and disaster management (Altntas & Delooz, 2004). Because of their very nature, disasters pose a threat to even the best laid preparedness plans. After September 11, 2001 terrorist attack, the emergency operations centers (EOC) was first established in World Trade Center Building 7, but relocated first on September 11 because of impending building collapse, and second on September 14 due to inadequate space (Bradt, 2003). The placement of EOCs must keep safety and stability in mind.

Damage to the infrastructure, especially for non-localized disasters like earthquakes, is challenging to the provision of medical services to victims and existing patients. Existing health facilities may need to be evacuated and even condemned in the post-disaster setting (Peleg et al., 2002; Schultz et al., 2007; Sepehri & Meimandi, 2006). Where hospitals cannot be evacuated in time, they face some severe obstacles to providing care. In the days following Katrina, multiple large hospitals in New Orleans operated without power or sanitation in extreme heat (Brunkard et al., 2008). At least 70 hospital inpatients died in New Orleans hospitals and 57 victims' bodies were recovered from hospitals in the days immediately following the storm, indicating that their deaths occurred in the hospital as a result of the storm (Brunkard et al., 2008). Systems of particular concern to hospitals are oxygen supply, electricity, water, and elevators (Peleg et al., 2002). Determining hospitals' risk for damage may be difficult after sudden-onset disasters. For example, Schultz et al. (2007) showed that distance from the earthquake epicenter, the measure typically used by emergency managers, may be a less valid predictor of hospital closure than peak ground acceleration. However, peak ground acceleration data require ongoing data collection and communication in the post-disaster setting.

Another challenge to disaster-related emergency care that is nearly universal across all types of disasters is increased response time. During the New York City blackout, emergency medical response was enhanced by enlisting cross-trained firefighter and first responder companies to supplement demand; nonetheless, call-processing times within the city's September 11, 2001 terrorist attack telephone system were the rate-limiting step in emergency care – they increased fourfold during the hours of blackout (Freese et al., 2006). A challenge to both emergency transportation and patient transfer during disasters is a transportation corridor (Gautschi et al., 2008). Establishing safe and efficient transportation routes to and from the disaster site is important where roads, themselves, are damaged, but also after disasters involving mass exodus of people from buildings into the streets.

When hospitals have not been damaged, they may expect to be overwhelmed first by patients and later by families. Emergency care systems in the United States function near-capacity at times, with little elasticity for absorbing disaster-associated surge in demand (Stratton & Tyler, 2006). In the aftermath of the Gothenburg Disco Fire, misinformation and lack of communication led to the hospital's emergency disaster plan not being launched and on-scene triage not being established (Gewalli & Fogdestam, 2003). As a result, the "scoop and run" technique of patient transportation was practiced, placing major burden on receiving hospitals. Indeed, loss of communication during disasters has been reported by hospitals after many types of disasters, from earthquakes (Peleg et al., 2002; Rathore et al., 2007) to terrorist attacks (Bradt, 2003; Frank, Dewart, Schmeidler, & Demirjian, 2006), to tsunamis (Maegele et al., 2005).

Timing of patient load and arrival of outside assistance are often unfortunately mismatched. In a review of sudden impact disasters in the United States, the earliest outside assistance arrived was 24 hours (range of 24–96 hours), with peak demand occurring within 24 hours of disaster (Stratton & Tyler, 2006). After September 11, 2001 terrorist attack, the first disaster medical assistance team arrived 36 hours after the disaster (Bradt, 2003). After the Oklahoma City bombing, hospitals saw patients arriving as soon as 15 minutes post-disaster with peak arrival time of 60–120 minutes post-disaster (Teague, 2004). It is this mismatch that led Llewellyn (2006) to recommend that emergency units plan to be self-sustaining for 72 hours post-disaster, with a special emphasis on the importance of communications, supplies (especially, tetanus antitoxins, antibiotics, and insulin), and record keeping. Bradt (2003) also stressed the importance of system assets in the September 11, 2001 terrorist attack response, including action planning from incident command, GIS products, wireless technology, and workers' respite care.

Some populations may present ethical dilemmas to those providing emergency care. For example, Opium addicts suffering from a severed drug supply following the Bam Earthquake often tried to leverage rescue operations to obtain drugs and prevent withdrawal, with relative success (Movaghar et al., 2005). After September 11, 2001 terrorist attack, administrators of methadone maintenance programs in New York City faced an ethical dilemma as well: many patients reported trouble making the trek to their programs due to interrupted public transportation or chose to go to other closer clinics instead (Frank et al., 2006). Administrators were forced to make decisions about dosage for guest patients, sometimes without verification, and about take-home dosages for their own patients, given the instability of public transportation.

Challenges to health care in the post-disaster setting. Even after those directly injured have been treated, population health continues to face significant challenges after disasters. Those with chronic conditions may have been separated from their providers, their records, or their medications as a result of the disaster (Stratton & Tyler, 2006). In addition, personal care for even serious conditions may be placed on the backburner to the more pressing concerns of finding loved ones, arranging for burials, and surveying damage (Guha-Sapir, van Panhuis, & Lagoutte, 2007). Connecting these individuals to care in a timely manner is essential (see Allen & Wayne, Chapter 8, for discussion).

Disasters may result in permanent disability, with accompanying need for follow-up. Rathore et al. (2007) suggested the creation of a registry for those suffering paraplegia following earthquake to facilitate their continued contact with the medical system and rehabilitation planning. In fact, registries/lists of injured individuals or survivors have been implemented after some disasters, for example, the Oklahoma City bombing (Tucker et al., 2007), the Luby Cafeteria Shooting (North, McCutcheon, Spitznagel, & Smith, 2002), and the Enschede Fireworks Disaster (Dirkzwager, Kerssens, & Yzermans, 2006). However, these lists require high-quality data collection and collaboration during the disaster and may not be possible for more large-scale disasters where the health system itself is under fire.

Tourists and expatriate victims, residing in a country other than their upbringing, may return to their home countries to be treated, carrying with them both common and uncommon polymicrobial infections of multiple-resistant pathogens (Maegele et al., 2006; Uckay, Sax, Harbarth, Bernard, & Pittet, 2008). Although these pathogens are unlikely to spread to other patients (Uckay et al., 2008), health systems of home countries may be challenged to deal with them in the weeks to months following their return home.

Outside of rescue and medical operations, immediate public health concerns include food, clean water, sanitation, and shelter for survivors (Llewellyn, 2006). Those who have been displaced from their homes are vulnerable to insects, heat and cold, and other environmental hazards (Llewellyn, 2006). A study in a Sri Lankan relief camp 1 month after the 2004 Tsunami found that 16.1, 20.2, and 34.7% of children were wasted, stunted, and underweight, respectively, while 37% of pregnant women were undernourished (Jayatissa, Bekele, Piyasena, & Mahamithawa, 2006). Researchers in this study stressed the importance of food diversity, vitamin A megadose supplementation for children, and nutritional surveillance.

At times, the patient demand may greatly exceed the capacity of existing health systems. Cyclone-related flooding in Mozambique in 2000 led to the displacement of nearly 450,000 people; the small village of Hoke, for example, with an original population of 22,000, received approximately 33,000 displaced people, with only one local health facility (Hashizume et al., 2006). Flooding associated with the hurricanes, combined with lack of shelter, put many displaced persons at risk for malaria (Loveridge, Henner, & Lee, 2003). Where the existing health system is unequipped to diagnose patients in an efficient manner, new methods of diagnoses may be called for; the use of outside assistance is essential in areas with scarce health resources (Hashizume et al., 2006; Loveridge et al., 2003).

While the time period immediately after disaster may see an influx of support from within and outside the affected communities, that support may waver in the months to follow. Although there were excess blood donations shortly following September 11, 2001 terrorist attack (Glynn et al., 2003) and the Marmara earthquake (Sonmezoglu et al., 2005), blood donations were paradoxically short several months after Maramara.

Lastly, both administrative and individual cleanup operations place a certain burden on natural hazards and social well-being of disaster-effected areas. Cleanup operations from Ground Zero in New York City, namely, demolition activities, raised concerns about the integrity of a landfill wall on the Huron River (Bradt, 2003). Cleanup efforts may also put individuals at risk of contact with unusual hazardous substances, for example, Freon or asbestos (Bradt, 2003). After an Indian earthquake, wood used to cremate dead bodies exhausted survivors' supplies for cooking and heating (Ligon, 2006).

Emergency medical assistance teams. Because emergency medical assistance teams usually arrive on-scene within days to weeks of the disaster (Stratton & Tyler, 2006), existing emergency medical systems bear the brunt medical demands of severely injured and dying patients within the first few days of disaster (Llewellyn, 2006; also see Speier et al., Chapter 12). Nonetheless, emergency medical teams provide assistance to the much more numerous patients with minor medical conditions and those who have been displaced or evacuated as a result of disaster. Over 95% of patients seen by emergency medical teams responding to 1992 Hurricanes Andrew (Florida) and Iniki (Hawaii) were triaged to yellow (delayed care) or green (walking wounded) and around 90% of patients in each storm were sent home after their visit. The most common chief complaints of patients were wounds, musculoskeletal pain, medication refills, upper respiratory infections, rashes, and abdominal complaints (Nufer & Wilson-Ramirez, 2004). The most common pharmaceutical needs of medical assistance teams following natural disasters include tetanus vaccinations and wound care, respiratory, antibacterial, analgesic, gastrointestinal, and psychiatric medications as well as medication refills (Nufer & Wilson-Ramirez, 2004; Sepehri & Meimandi, 2006).

Medication refills are an important consideration for victims with pre-existing conditions. After a series of four hurricanes in 2004, 5.4% of Florida residents reported worsening of existing medical conditions and 13.6% reported difficulty obtaining medications (Stratton & Tyler, 2006). The first week after the establishment of a Red Cross field hospital in post-tsunami Aceh, workers saw an excess of patients with chronic conditions, which they attributed to the complete absence of health services in the previous 2 weeks, causing interruption of treatment for patients with existing conditions (Guha-Sapir et al., 2007).

Challenges to other medical services. The simultaneous relocation of facilities and patients after disaster, along with the possible destruction of medical records, may pose a challenge to re-aligning patients and their care providers. For example, Hyre, Cohen, Kutner, Alper, and Muntner (2007) studied hemodialysis patients in New Orleans, finding that nearly 45% had missed one or more treatments as a result of Hurricane Katrina, with over 15% missing three or more treatments. Again, this is not a surprising statistic given all nine hemodialysis treatment facilities in New Orleans where participants who were recruited were closed in the immediate aftermath of Katrina and two remained closed throughout the conduct of the study. Moreover, participants in the Hyre study were living in 18 states at the time of interview.

Damages to infrastructure are often inequitable. Using geographic information systems, Guidry and Margolis (2005) found that low-income schools where the majority of students were Black had twice the risk of flooding after Hurricane Floyd of 1999 as non-low-income schools with a majority of non-Black students. Damages to other infrastructure, for example, public transit, may disproportionately affect lower-income residents who may not have any other available mode of transit. As mentioned previously, problems with public transportation were sited as a major challenge to receipt of care for existing medical problems (Frank et al., 2006).

Primary health-care utilization. Victims of disaster and residents of affected communities often have increased demand for many health-care services. Care for injuries sustained may be lifelong; on the other hand, physical symptoms immediately following disaster may return to baseline levels after months or years. Primary health-care utilization for physical complaints after disaster is closely tied to psychological health both before and after disaster, as well as disaster-exposure level. The following risk factors have been identified for primary health-care contacts: (a) *direct exposure level to disaster* – witnessing the disaster, residing in a disaster-affected area (Dorn, Yzermans, Kerssens, Spreeuwenberg, & van der Zee, 2006; Remennick, 2002); (b) *indirect consequences of disaster*– loss of a child as a result of disaster (Dorn et al., 2006); (c) *participation in the disaster response*– rescuing people, supporting injured victims, identifying victims, or remains (Slottje et al., 2008); (d) *exposure to negative life events* (Boscarino, Adams, & Figley, 2006); (e) *post-disaster mental health services utilization* (den Ouden, Dirkzwager, & Yzermans, 2005) *and depression* (Boscarino, Adams, & Figley, 2006); and (f) *pre-disaster lifetime traumatic event experience* (Boscarino, Adams, & Figley, 2006).

There is strong evidence that post-disaster increases in health services utilization are mediated by psychopathology. For example, self-reported post-traumatic stress disorder 18 months after the Enshcede Fireworks disaster-predicted family practice reported vascular problems over the following 2 years (Dirkzwager et al., 2007).

The authors of this study suggest that the effects of psychopathology may operate through neurobiology, health behaviors, or heightened symptoms perception. The den Ouden study (2005) showed that individuals who visited a specialized mental health institution (MHI) after disaster presented with greater health problems to their general practitioners (GP) before the disaster, compared to survivors who did not visit the MHI; in addition, the MHI group had increased rates of GP attendance both 1 and 2 years after disaster, compared to their own baseline as well as controls (den Ouden et al., 2005). This suggests that those who are already vulnerable before disaster, with greater physical and mental health complaints, are more sensitive to the effects of disaster on their physical health.

Several studies show that primary health-care utilization in post-disaster settings is not closely tied to the severity of physical symptoms, themselves. For example, in an industrial hygiene evaluation of a workplace very close to the World Trade Center Disaster found that medical service utilization among workers in the New York City building was no different than that of workers in Dallas, TX, despite increased reports of constitutional symptoms, like headache, eye, nose, and throat irritation (Trout, Nimgade, Mueller, Hall, & Earnest, 2002). Van den Berg et al. (2007) studied a group of individuals residing in the area affected by the Enschede Fireworks Disaster; they found that the majority of self-reported physical symptoms were not presented to a general practitioner; moreover, decision to consult a GP for an individual symptom was dependent on persistence, rather than on impairment and distress.

Lastly, disaster experiences may affect the satisfaction with health-care services. Remennick (2002) found that immigrants to Israel from Chernobyl Disaster-affected areas used more health services and were less satisfied with quality of health care and their providers' attitudes than immigrants from non-affected areas in 1997. The fact that cancer-related anxiety was highly prevalent *more than a decade* after the accident reflects a unrelenting psychological toll of exposure to nuclear accidents.

Mental health services utilization. Mental health services utilization (MHSU) has been studied extensively in the post-disaster setting. Data on MHSU are closely tied to primary health-care utilization, as both physical and psychological symptoms are often presented to primary-care physicians. In one study, correlation between general practitioner-reported and self-reported psychopathology was highest for intrusive and avoidant symptoms, but much lower for depression, anxiety, and sleep symptoms (Drogendijk et al., 2007). The authors of this study suggest that some symptoms (e.g., depression) may be more likely than others to be superseded by physical symptoms when presented simultaneously to physicians.

Risk factors for MHSU after disaster include (a) *level of exposure to disaster* – being trapped even if uninjured, residence in an affected area (Boscarino, Adams, Stuber, & Galea, 2005; Dorn et al., 2006; Smith, Christiansen, Vincent, & Hann, 1999; van der Velden et al., 2006); (b) *indirect consequences of disaster* – loss of a child or relocation (Dorn et al., 2006; Soeteman et al., 2007; van der Velden, Yzermans, Kleber, & Gersons, 2007b); (c) *residence in a geographically proximate area* (Ford, Adams, & Dailey, 2006); (d) *having a perievent panic attack* (Boscarino, Adams, Stuber, et al., 2005); (e) *access* – having private insurance, a regular doctor (Boscarino, Adams, Stuber, et al., 2005; van der Velden et al., 2007b); (f) *demographics* – female gender, single, migrant status, white race (Boscarino, Adams, Stuber, et al., 2005; van der Velden et al., 2007b); (g) *history of psychological problems* (Soeteman et al., 2007; van der Velden et al., 2007b); (h) *poor post-disaster mental health* or mental health symptomatology (Ford et al., 2006; Jordan et al., 2004; van der Velden et al., 2006, 2007b); and (i) *receiving post-disaster mental health treatment* (den Ouden et al., 2005; van der Velden et al., 2007b).

Many of the risk factors listed above for MHSU are similar to the risk factors for primary health-care utilization. There is ample evidence that both pre-disaster conditions (e.g., psychological morbidity, demographics) and disaster-related experiences (relocation, panic attack) have implications for MHSU in the post-disaster setting.

Mental Health

We reviewed 75 articles on the mental health impact of disasters, including cross-sectional, cohort, and case studies as well as review articles. Our article base included samples from the general population and from rescue and cleanup personnel. Much of the research on this topic uses cross-sectional or cohort study designs, relying on surveys, interviews and, when available, medical records.

Studies that included a comparison group did so in primarily two ways: (1) by comparing pre-disaster mental health to post-disaster mental health (e.g., time series, pre-post surveys) and (2) by assessing mental health outcomes in groups with different levels of disaster exposure/consequences (e.g., injured vs. uninjured victims, residents of affected cities vs. comparison cities). Some did not incorporate a comparison group in their study design, but explicitly asked about disaster-related mental health outcomes or increase/decrease since a disaster. Though these studies may suffer problems with information bias, they at least allow the respondent to specify whether changes in their mental health have occurred as a result of disaster (rather than as a result of other things unique to the individual such as divorce or death in the family).

Lastly, some studies did not incorporate a comparison group and did not specify disaster-specific outcomes – these studies were primarily looking at risk factors for psychopathology in the post-disaster context/setting, rather than as a result of the disaster itself. These studies are difficult to interpret in disaster research because the reader has no idea whether the distribution or prevalence of psychopathology is (a) different from normal or (b) occurred as a result of a disaster (rather than as a result of other things). We have included all types of studies in our review below; studies in this last group are marked with an asterisk (∗).

The different mental health measures summarized in this review include non-specific measures of mental health, sleep problems, somatic complaints and medically unexplained symptoms, post-traumatic stress disorder, depression, anxiety, behavioral problems (in children), adult mental health and in utero exposures, suicidality, and problems with occupational and daily functioning.

Non-specific measures of mental health. The incidence of mental health problems after disaster has been measured in a number of ways, from psychological problems presented to physician to sickness absences due to psychological problems to self-reported symptomatology in interviews or surveys. We include in this category studies that measured poor mental health status, stress, worry, grief, mental health complaints, negative affect, psychological impairment, non-specific distress, momentary moods, vitality, and health-related quality of life (HRQoL). Some studies focused on rescue and cleanup workers, while others focused on affected survivors, the general population, or special populations, like children (Dirkzwager et al., 2006), or people with chronic illness (van den Berg, van der Velden, Yzermans, Stellato, & Grievink, 2006).

Risk factors for non-specific mental health problems include (a) *direct exposure level to disaster* – degree of exposure (de Mel, McKenzie, & Woodruff, 2008; Norris et al., 2002; Wang et al., 2000), witnessing injury, death, or destruction (Ghaffari-Nejad, Ahmadi-Mousavi, Gandomkar, & Reihani-Kermani, 2007; Thomas, 2006), and direct threat of disaster (Thomas, 2006); (b) *participation in rescue and cleanup* (Dirkzwager et al., 2004; Huizink et al., 2006; Slottje et al., 2007; Spinhoven & Verschuur, 2006); (c) *media exposure* (Ford, Adams, & Dailey, 2007; Thomas, 2006; Wayment, 2004); (d) *characteristics of the disaster* – mass violence/intentional man-made event rather than an accidental or a natural disaster (Norris et al., 2002; Thomas, 2006); (e) *indirect consequences of disaster* – having a child with a severe injury (Dorn, Yzermans, Spreeuwenberg, & van der Zee, 2007), having a close one affected by disaster (Slottje et al., 2007), relocation or residential problem (Dirkzwager et al., 2006; Foster, 2002; Ghaffari-Nejad et al., 2007; Soeteman et al., 2007; Thomas, 2006), or community destruction (Thomas, 2006); (f) *proximity* – proximity to disaster (Foster, 2002; Thomas, 2006), being in the disaster-affected area/city at the time of disaster (Ghaffari-Nejad et al., 2007; Remennick, 2002; Smith et al., 1999; Soeteman et al., 2007), working near the disaster site (Trout et al., 2002); interestingly, some research has found signs of distress in geographically distant groups immediately after disaster, but with no change in ongoing moods (Whalen, Henker, King, Jamner, & Levine, 2004); (g) *alcohol problems since disaster* – alcohol dependence or problems (Adams, Bocarino, & Galea, 2006a, 2006b; Gaher, Simons, Jacobs, Meyer, & Johnson-Jimenez, 2006), or ongoing/increased alcohol use (Ford et al., 2007; Pfefferbaum et al., 2002); (h) *events since the disaster* – negative life event (Adams et al., 2006a), secondary stressors (Norris et al., 2002), post-disaster traumatic effects unrelated to disaster (Adams et al., 2006a); (i) *demographics* – female gender (de Mel et al., 2008; Dorn, Yzermans, Spreeuwenberg, et al., 2007; Ford et al., 2006; 2007; Norris et al., 2002; Thomas, 2006; Wayment, 2004), age <64 years or disability (Ford et al., 2006), minority race or ethnicity (de Mel et al., 2008; Ford et al., 2006; Norris et al., 2002; Thomas, 2006), low–medium socioeconomic status or education level (Dirkzwager et al., 2006; Ghaffari-Nejad et al., 2007), living in a developing country, middle age (Norris et al., 2002); (j) *pre-disaster psychopathology* – pre-disaster psychological problems (Dirkzwager et al., 2006; Norris et al., 2002; Soeteman et al., 2007; Wayment, 2004), pre-disaster victimization by intimate partner violence (Frasier et al., 2004), pessimism (van der Velden et al., 2007a), previous traumatic or stressful event exposure (Thomas, 2006; Wayment, 2004); (k) *social factors* – weak or deteriorating psychosocial resources (Norris et al., 2002), lower level of social support (Trout et al., 2002), less post-disaster help (Wang et al., 2000), post-disaster social strain (Wayment, 2004); (l) *other* – perceived similarity to victims (Wayment, 2004), perceived risk (Foster, 2002), having sleep problems post-disaster (Ford et al., 2006), loss of a first-degree relative during previous earthquakes (Ghaffari-Nejad et al., 2007); conversely, chronic illness was not a risk factor for mental health problems (van den Berg et al., 2006).

Many of these risk factors for mental health problems after disaster may be risk factors for mental health problems, in general. For example, van der Velden et al. (2007a) found that pessimistic victims were at higher risk for mental health symptoms after disaster than optimistic victims, but so were pessimistic non-victims. Few studies looked at protective factors for psychopathology. Protective factors include older age (>65), marriage (Ford et al., 2007), and collective helping behavior for women (Wayment, 2004). As with risk factors, some of these protective factors may be protective against mental health problems, in general, rather than in specifically in the post-disaster setting.

Some authors have attempted to quantify the contribution of each of these risk factors to psychopathology. Soeteman et al. (2007) found that pre-disaster psychological morbidity was the strongest predictor of psychological problems after the Enschede Fireworks Disaster, while Wang et al. (2000) found that post-disaster variables were as important to psychosocial outcomes as pre-disaster vulnerability after an earthquake in China. The evidence appears mixed; clearly there is support for relationships between psychopathology and pre-disaster conditions, exposure level to disaster, and events occurring after disaster.

Time appears to be the biggest contributor to recovery from mental health problems after disasters. In a study of micro-enterprise owners following the 2004 Tsunami, de Mel et al. (2008) found that mental health recovery was dependent largely on time, rather than on economic recovery. The longevity of disaster impact varies widely by study – different measurement tools and study designs may account for much of this variation. In addition, very few studies follow participants past 2 years post-event; those that do often rely on administrative records, rather than self-reported symptomatology, which may result in a reduced effect size. Moreover, one would expect longevity to vary by disaster type and severity. A recent review found that man-made disasters may have psychological impacts up to 6–14 years after disaster, while natural disasters typically have mental health impacts up to 3 years post-event (Thomas, 2006).

Sleep problems. Two studies we reviewed examined sleep problems; both involved the Enschede Fireworks Disaster. Dirkzwager et al. (2006) found exposed children aged 4–12 had larger post-disaster increases in sleep problems presented to family practitioners at both 1 and 2 years than unexposed children. Grievink et al. (2007) found much the same with self-report surveys – severe sleep problems were more than twice as likely in affected residents than controls at both 3 weeks and 18 months post-disaster; however, sleep problems did decrease in the affected group between 3 weeks and 18 months. Evidence from these two longitudinal studies both showed evidence of decline in problems over time.

Somatic complaints and medically unexplained symptoms. In disaster literature, somatic symptoms include such complaints as headaches, faintness or dizziness, pains in heart or chest, lower back pain, nausea or upset stomach, muscle soreness, dyspnea, hot or cold spells, numbness or tingling, lump in throat, feeling weak, and heavy feelings in arms or legs (Slottje et al., 2008). The implied cause of somatic symptoms is psychological – the physical manifestation of psychological distress.

Medically unexplained symptoms (MUPS) may have environmental, somatic, physical, or multiple origins, although they are commonly attributed either to the somatization of psychological disorders or to the misinterpretation of normal bodily sensations (Spinhoven & Verschuur, 2006). In the post-disaster setting, it may be difficult to disentangle the effect of environmental exposures and psychological distress in the epidemiology of these symptoms, especially for cleanup workers who may suffer toxic exposures over a prolonged period of time. We present a review below on MUPS and somatic symptoms with this limitation in mind.

There is evidence of somatic symptoms in both rescue/cleanup worker samples and the general population. Elevated physical symptoms and fatigue were reported by rescue workers after the Bijlmermeer Air Disaster (Slottje et al., 2008; Spinhoven & Verschuur, 2006; van den Berg et al., 2008), as much as 8.5 years later (Slottje et al., 2006). Almost half of those workers with physical complaints 8.5 years later attributed their symptoms to the disaster (Slottje et al., 2006).

The impact of psychopathology on somatic symptoms, even within the same disaster, is mixed. The Slottje study (2008) found symptoms to be independent of post-traumatic stress symptoms, while the Spinhoven study (2006) found elevated and persistent fatigue to be associated with higher psychopathology. Police officers and firefighters exposed to the air disaster had more physical and mental health complaints than unexposed workers, but no significant differences in lab outcomes (Hg, leukocyte, platelet), chemical outcomes (K, creatine, alanine, aminotransferase, alkaline phosphatase, gamma-glutamyl transferase, TSH, C-reactive protein, ferratin), or urinanalysis (protein) (Huizink et al., 2006). After the Enschede Fireworks Disaster, PTSD 18-month post-disaster predicted vascular problems diagnosed by a family practitioner up to 2 years later (Dirkzwager et al., 2007). Another study found anxiety and depression were associated with number of physical symptoms in survivors of the fireworks disaster (van den Berg, Grievink, Stellato, Yzermans, & Lebret, 2005). Residents of Enschede who visited a specialized mental health institution (MHI) after the fireworks disaster had more health problems, including MUPS, before the disaster and had increased health problems presented to a GP after the disaster, compared to their own baselines and non-MHI survivors (den Ouden et al., 2005). While there is likely a relationship between disaster-related psychopathology and somatic symptoms, the path of that relationship is unclear.

Risk factors for somatic symptoms/MUPS include (a) *rescue/cleanup activities* – rescuing people, supporting injured victims, searching for or identifying victims or remains, cleanup, security, or surveillance activities (Slottje et al., 2006, 2008);

(b) *direct and indirect consequences of disaster* – witnessing the disaster scene or having a close one affected by disaster (Slottje et al., 2008); (c) *pre-disaster vulnerabilities* – victimization by intimate partner violence (Frasier et al., 2004), pre-disaster psychological problems (van den Berg et al., 2008); (d) *emotional reaction to disaster* – panic attack (Adams et al., 2006a), perceiving the disaster as very bad (Slottje et al., 2006); (e) *post-disaster events* – negative life events and traumatic events (Adams et al., 2006a), lower quality of life (Spinhoven & Verschuur, 2006); (f) *demographic factors* – female gender or immigrant status (van den Berg et al., 2008); (g) *other* – tendency to be less reassured by a doctor (Spinhoven & Verschuur, 2006).

Adolescents affected by the Enschede Fireworks Disaster had significant increases in MUPS after disaster, compared to non-affected adolescents at both 1- and 2-year follow-up (Dirkzwager et al., 2006). Adult residents of Enschede also had a higher prevalence of physical symptoms than residents of an unaffected city up to 4 years after the disaster (van den Berg et al., 2005). On the other hand, rescue workers involved in the same disaster had increased non-specific ill health during the first year post-disaster, but returned to baseline levels after 3 years (Morren et al., 2007). The Slottje study above (2008) was conducted an average of 8.5 years after the Bijlmermeer Air Disaster. The literature suggests disaster-related somatic symptoms may last years to decades. A study of cleanup workers after the Chernobyl Disaster found radiation exposure level to be associated with somatic symptoms even after 18 years (Loganovsky et al., 2008).

The decision to present symptoms to a health-care provider is not dependent on impairment or distress, but rather on persistence of symptoms (van den Berg et al., 2007). Intrusions, avoidance, depression, anxiety, and sleep problems were perpetuating factors for physical symptoms (van den Berg et al., 2008), suggesting a psychopathological role in persistence of symptoms.

Post-traumatic stress disorder. As one might expect, post-traumatic stress disorder (PTSD) is the most commonly studied specific mental health outcome in disaster victims (see also Davis, Tarcza, & Munson, Chapter 5). In this section, we include studies that look at PTSD symptomatology (e.g., avoidance, intrusive thoughts, hyperarousal) and those looking at diagnoses of PTSD. Research includes samples from both rescue and cleanup workers and the general population as well as special populations, such as children (Hoven, Duarte, & Mandell, 2003) and those with chronic illness (Hyre et al., 2007).

Risk factors for PTSD after disasters include (a) *direct exposure of disaster* – direct exposure or exposure severity (Hoven et al., 2003; Neria, Nandi, & Galea, 2008), physical injury (Hoven et al., 2003; Maegele et al., 2005), and number of injuries (North et al., 2005); (b) *rescue and cleanup* – participation in rescue, recovery, or cleanup activities (Neria et al., 2008), being caught in a cloud of dust during rescue work (Mauer et al., 2007); (c) *emotional reaction to disaster* – feeling very distressed during disaster (Parslow, Jorm, & Christensen, 2006), both emotion-focused and problem-focused coping strategies (Chung, Farmer, Werrett, Easthope, & Chung, 2001), subjective appraisal at the moment of trauma (Hoven et al., 2003), and probable perievent panic attack (Pfefferbaum, Stuber, Galea, &

Fairbrother, 2006); (d) *indirect consequences of disaster* – for children, losing a family member, knowing someone who was injured or killed, living with a surviving parent with PTSD (Hoven et al., 2003), death or injury to a family member or friend (North et al., 2005), evacuation (Parslow et al., 2006), late evacuation and evacuation to a shelter or being displaced for >3 months (Hyre et al., 2007), living in an area with worse destruction (Armenian et al., 2000), family financial burden/loss (Armenian et al., 2000; F. H. Chou et al., 2007); (e) *characteristics of disaster* – human-made or technological disasters compared to natural disasters (Neria et al., 2008); PTSD prevalence after natural disaster 3–90%, man-made accidents 52–60%, shooting spree ~60.4%, war up to 87%, and terrorism ~66% (Hoven et al., 2003); (f) *behavior after disaster* – binge drinking, alcohol dependence (Adams et al., 2006b), increase in drinking post-disaster (Adams et al., 2006b; Pfefferbaum et al., 2002), alcohol consumption, hazardous alcohol consumption, change in alcohol consumption in either direction (Simons, Gaher, Jacobs, Meyer, & Johnson-Jimenez, 2005), incident drinking problems, increased use of cigarettes, or marijuana (Vlahov et al., 2002, 2006); (g) *proximity* (Foster & Goldstein, 2007; Neria et al., 2008; Smith et al., 1999); (h) *pre-disaster mental health* – pre-disaster victimization by intimate partner violence (Frasier et al., 2004), pre-disaster neuroticism (Parslow et al., 2006), pre-disaster psychiatric disorder (North et al., 2005); (i) *other mental health outcomes* – anxiety symptoms (Hoven et al., 2003), poorer mental health (Parslow et al., 2006), sleep disturbance (Chou et al., 2007); (j) *other* – media exposure (Hoven et al., 2003), for hemodialysis patients, less experience with treatment and missing three or more treatments (Hyre et al., 2007); (k) *demographics* – female gender (Hoven et al., 2003; North et al., 2005; Parslow et al., 2006), for children, younger age (Hoven et al., 2003), black race (Hyre et al., 2007), low-income level (Armenian et al., 2000), and lower education (Parslow et al., 2006).

Some researchers have tried to quantify the relative contributions of risk factors on PTSD symptomatology. Parslow et al. (2006) concluded that disaster-exposure factors were more strongly associated with PTSD symptoms than pre-trauma measures. Two recent meta-analyses of research on PTSD concluded that events occurring during or after traumatic events were more important risk factors for PTSD than pre-event characteristics (Brewin, Andrews, & Valentine, 2000; Ozer, Best, Lipsey, & Weiss, 2003). However, there is evidence that risk factors before, during, and after disaster play a role.

Other studies examined severity of PTSD symptomatology, finding similar results to the above. Post-disaster alcohol dependence (Adams et al., 2006b), death and destruction in city of residence (Goenjian et al., 2001), and radiation exposure level as a cleanup worker (Loganovsky et al., 2008) were all associated with increased severity of symptoms.

Several studies have found protective factors for PTSD symptomatology. Armenian et al. (2000) showed the importance of social factors in protection against PTSD – being with someone else at the moment of the earthquake and making new friends following the earthquake was protective for PTSD diagnosis. Victims of the Chi-Chi earthquake who had changes in their social networks after disaster were more likely to report PTSD (Chou et al., 2007). A study on the Nairobi and

Oklahoma City bombings found that victims in Nairobi who attended religious services more frequently were less likely to experience PTSD than those who attended religious services less frequently; this was not the case, however, for Oklahoma City (North et al., 2005). Risk and protective factors for psychopathology following disaster may based on culture.

As with non-specific mental health, the most important factor in the amelioration of PTSD may be time. Studies in the general population *on an average* show that PTSD prevalence decreases as time goes on (Chou et al., 2007; Grievink et al., 2007), but there is also evidence of a bifurcated path, with some individuals going into remission and others suffering sustained or worsened symptomatology as time goes on (North et al., 2002). Severe exposures may be associated with greater PTSD in the years and decades following disaster (Grievink et al., 2007; Nandi et al., 2004; Tucker et al., 2007). Loganovsky et al. (2008) found cleanup workers after the Chernobyl Disaster had greater PTSD symptomatology than controls even 18 years later. A recent review concludes that PTSD in children generally decreases over time, but without complete recovery (Hoven et al., 2003). Risk factors for persistence of PTSD symptomatology include the severity and duration of exposure (Hoven et al., 2003), functional impairment and seeking mental health treatment shortly after disaster (North et al., 2002), as well as post-disaster conditions, such as unemployment and high work stress (Nandi et al., 2004).

Depression. Depression is also commonly studied in post-disaster settings. In this section we include studies that look at depression symptomatology as well as diagnoses. Research includes samples from both rescue and cleanup workers and the general population as well as special populations, such as adolescents (Goenjian et al., 2001) or emigrants (Foster & Goldstein, 2007).

The prevalence of depression after disaster ranged from 9.4% for New York metropolitan residents (Person, Tracy, & Galea, 2006), to 18% for Pentagon employees after September 11, 2001 terrorist attack (Jordan et al., 2004), to 52% for Ministry of Health workers in an earthquake-affected region (Armenian et al., 2002). Risk factors for depression in the post-disaster setting include (a) *direct disaster exposure* – being directly affected, including being in the World Trade Center at the time of attacks, friend or relative killed, being injured, loosing possessions, property, or job, or being involved in rescue efforts (Loganovsky et al., 2008; Person et al., 2006); (b) *emotional reaction to disaster* – perceived radiation risk (Foster & Goldstein, 2007), having a perievent panic attack (Person et al., 2006); (c) *proximity* (Foster & Goldstein, 2007); (d) *indirect consequences of disaster* – living in an area with worse destruction, total material loss to family (Armenian et al., 2002); (e) *behavior since disaster* – alcohol dependence (Adams et al., 2006b), incident drinking problems, increased use of cigarettes, alcohol, or marijuana (Vlahov et al., 2002, 2006); (f) *demographics* – female gender (Armenian et al., 2002), female gender in the United States but not in Kenya (North et al., 2005), low-income, especially in neighborhoods with income inequality (Ahern & Galea, 2006); (g) *pre-disaster events* – pessimism (van der Velden et al., 2007a), experiencing multiple life stressors in the year prior, having been exposed to previous trauma (Person et al., 2006); (h) *events since disaster* – experiencing multiple secondary stressors (Person et al., 2006); (i) *other* – prior experience with earthquakes (protective, Knight, Gatz, Heller, & Bengtson, 2000), sleep disturbance (Chou et al., 2007).

As with PTSD, social factors offered protection against depression. Being with someone at the time of disaster and receiving assistance or support after disaster were protective for depression after the 1988 Armenian earthquake (Armenian et al., 2002). Interestingly, Armenian et al. (2002) found that *any* alcohol use after disaster was also protective against depression. This resonates with the findings of Simons et al. (2005), who concluded that any change in alcohol use (either positive or negative) resulted in increased risk of PTSD. Perhaps it is not alcohol use in general, but rather drastic changes in alcohol use as a result of disaster that are associated with psychopathology. It is also possible that post-disaster psychopathology, even at the sub-syndromal level, may predict changes in alcohol use in an attempt to self-medicate.

Severity of post-disaster depression was predicted by radiation risk perception and being diagnosed with a Chernobyl Disaster-related health problem (Bromet & Havenaar, 2007), as well as living in a city with worse Hurricane death and destruction (Goenjian et al., 2001). Again, depressive symptomatology is seen to decrease over time, although not to baseline levels (Grievink et al., 2007). Longevity of depression symptomatology may last years to decades (Bromet & Havenaar, 2007; Foster, 2002; Foster & Goldstein, 2007). There was still a dose–response relationship between proximity to Chernobyl and depressive symptoms 14–15 years later for immigrants to the United States (Foster & Goldstein, 2007). Eighteen years after the Chernobyl Disaster, cleanup workers showed higher rates of depression than controls (Loganovsky et al., 2008). Longevity of effects may be lower in those not directly affected by the disaster – Reijneveld, Crone, Verhulst, and Verloove-Vanhorick (2003) found that depression problems in schools affected by a café fire had returned to a control level by 12 months (Reijneveld et al., 2003).

Mental health problems associated with victimization are likely associated with biological changes in victims. Olff et al. (2006) found that survivors of the Enschede disaster with major depressive disorder had flatter salivary cortisol curves over the course of the day than healthy survivors and also tended to use more tobacco per day (Olff et al., 2006). They concluded that smoking may be an important palliative coping style and may mediate the relationship between the traumatic stress and the hypothalamic–pituitary axis.

Anxiety. One study found anxiety problems to be more prevalent than depression or PTSD after disaster; a survey of Pentagon employees that found 7.9% PTSD and 17.7% depression prevalence also found 23.1% of employees had symptoms of panic attack and 26.9% had symptoms of generalized anxiety 1–4 months after the attack (Jordan et al., 2004). Dirkzwager et al. (2006) found post-disaster increases in anxiety problems in affected adolescents were 2–3 times greater than for an unaffected group, while depressive symptoms were no different between affected and unaffected groups. Following the Chernobyl Disaster, severity of anxiety symptoms were associated with risk perception (Bromet & Havenaar, 2007; Foster & Goldstein, 2007), proximity, greater radiation exposure (Foster & Goldstein, 2007), and being diagnosed with a Chernobyl Disaster-related health problem (Bromet &

Havenaar, 2007). Like the other psychopathologies discussed, anxiety symptoms have been shown to decrease over time, sometimes to baseline levels (Reijneveld et al., 2003; Reijneveld, Crone, Schuller, Verhulst, & Verloove-Vanhorick, 2005), sometimes remaining higher than control levels (Grievink et al., 2007).

Behavioral problems. Risk factors for parent-reported behavioral problems included high-intensity exposure to September 11, 2001 terrorist attack (e.g., seeing people jumping out of windows, seeing dead people), synergistically when in combination with a previous history of trauma (Chemtob, Nomura, & Abramovitz, 2008). Reijneveld et al. (2003) also found greater behavioral problems (especially aggressive behavior) in schools affected by the Volendam café fire, compared to unaffected schools; however, they saw a decrease to control level after 12 months (Reijneveld et al., 2005). Interestingly, one study found fewer post-September 11, 2001 terrorist attack parental reports of behavioral problems 4 months after the attack, although authors hypothesized that this difference was due to decreased parental sensitivity (Stuber et al., 2005). This study was different from the Chemtob study in that it involved a community sample, rather than a sample of only children who were directly affected by the attacks. One might expect parents of directly affected children to be more sensitive than those in a sample of individuals who were largely unaffected.

Suicidality. The evidence about suicidality after disasters is mixed. Suicidality appears to be most problematic in individuals involved in cleanup work and those who were most severely affected by disaster. There is evidence for increased suicidality in cleanup workers after the Chernobyl Disaster, with Loganovsky et al. (2008) showing greater suicidal ideation in cleanup workers than controls, and Rahu et al. (1997) noting an excess death by suicide during 6.5 years of follow-up, accounting for nearly 20% of all deaths in Estonian workers. Victims of the 1999 Taiwan earthquake who lost a co-resident or family member, was injured, or had property loss were nearly 50% more likely than non-victims to commit suicide following the earthquake (Chou et al., 2003).

Daily functioning – social and occupational. Disaster-related mental illness has a significant impact on victims' ability to function in both personal and occupational capacities. Studies investigating the impact of mental illness on work often look at sickness absences – the advantage of this measure is its objectivity. Self-reports of functioning, on the other hand, may also reflect changing subjective appraisal as a result of mental health symptoms. Our results are presented below with that warning in mind.

It appears that the effects of disasters on worker productivity are high in the months following disaster, but decline to baseline or control levels thereafter. Belonging to a mental health risk group (PTSD, depression, panic attack, generalized anxiety, alcohol abuse) was correlated with reduced self-reported daily functioning for Pentagon workers 1–4 months after September 11, 2001 terrorist attack (Jordan et al., 2004). Exposure to September 11, 2001 terrorist attack was associated with both lower-quality workdays and greater workday loss for workers in New York City 1 year post-disaster, but less so at 2 years; other risk factors for productivity loss included PTSD and depression, history of traumatic events, and negative life events (Boscarino, Adams, & Figley, 2006). Similar results were shown with rescue workers involved in the Enschede Fireworks Disaster, with length of sickness absence nearly doubling in the first 6 months after disaster, but decreasing slowly thereafter (Dirkzwager et al., 2004). Morren et al. (2007) show the prevalence of absences specifically due to psychological problems among rescue workers increased in the first 18 months after the Enschede Fireworks Disaster, compared to control group, and declined thereafter.

Around 40% of survivors of the Oklahoma City and Nairobi bombings reported impairment of functioning with family, friends, or work 6–10 months after the bombing. Coping mechanisms may be socially influenced. Survivors of the Nairobi bombing were more likely to report turning to family and friends, participating in a support group, or relying on religious support to cope with their experience, while survivors of the Oklahoma City bombing were more likely to report taking medication, drinking alcohol, and seeing a psychiatrist (North et al., 2005). For older adults exposed to the 1993 Midwest floods, higher levels of pre-flood social support were associated with having received and provided social support within the first 60 days after the floods (Tyler, 2006). Like many psychological outcomes, impairment following disaster is related to pre-disaster, post-disaster, and disaster-exposure variables.

The relationship between mental illness and functional impairment may be mediated by coping mechanisms. In a sample of Oklahoma City bombing victims receiving support services, increased alcohol use was associated with functional impairment (Pfefferbaum & Doughty, 2001). Worksite crisis interventions may have a beneficial effect on both mental health and functional outcomes, including reduced risk for binge drinking and alcohol dependence, PTSD symptoms, major depression, somatization, anxiety, and global impairment (Boscarino, Adams, & Figley, 2005).

Infectious Disease

The literature on infectious disease outcomes after disaster is limited. We found very little original research in the area, in stark contrast to an abundance of preparedness guidelines, editorials, and commentary. This dearth of published research may be due, in part, to the focus of published literature on disasters occurring in high-income or developed nations, specifically the United States (Norris et al., 2002; Uckay et al., 2008), where infectious diseases may be less problematic due to extensive public health infrastructure and health system resources. Original research in this area commonly uses medical records or administrative data. The majority of articles we reviewed deal with floods and storms, which makes legitimate sense given the nature of infection.

Below we briefly discuss the evidence for epidemics following disaster and the contribution of infectious disease to disaster mortality. Next, we review the impact of infectious disease on the health system. We close the chapter by discussing the different sources of infection in a post-disaster setting and particular species and conditions of concern.

Epidemics. A recent review indicates that there is little evidence for epidemics of disease following geophysical disasters (Floret, Viel, Mauny, Hoen, & Piarroux, 2006). No severe outbreaks occurred in the aftermath of the 2004 Tsunami or Hurricane Katrina, where the majority of the peer-reviewed literature lies. Yet infections are a frequent consequence of disasters – primarily skin, wound, and respiratory infections (Uckay et al., 2008). Diarrheal diseases are a common indirect result of disasters that disrupt sanitation or water quality (Watson, Gayer, & Connolly, 2007).

Infectious disease mortality. Baker et al.'s trimodal model (1980) of trauma deaths predicts an excess of "late stage" deaths after mass trauma due, in part, to sepsis; however, there was little evidence of this after 2004 Tsunami (Nishikiori et al., 2006a). A recent review of geophysical disasters indicates that epidemics rarely contribute significantly to the death toll after disaster (Floret et al., 2006).

Respiratory and wound infections after disaster may be implicated in deaths, although the mortality rate varies greatly by pathogen. For instance, none of the presentations for "cold" led to death following the Hanshin-Awaji Earthquake, while 80 of 619 cases (13%) of pneumonia resulted in death (Tanaka et al., 1999). Of 14 cases of wound infections of *Vibro vulnificus* following Hurricane Katrina, there were five deaths; the cause of these deaths, however, is not reported and underlying conditions were implicated in increased risk of severe *Vibro* infection in the majority of these patients (Engelthaler et al., 2005). In other situations, disaster-related outbreaks have shown far lower mortality than is usual for the pathogen. A tetanus outbreak following the 2004 Tsunami in Aceh, Indonesia, showed a 17% mortality rate, compared to a usual expected mortality of 50% for adults and 80% for children in developing countries (Jeremijenko, McLaws, & Kosasih, 2007).

Impact on health system. The impact of infectious disease visits on health systems following disasters varies widely. Respiratory diseases, in particular, may represent a significant proportion of hospital visits. Hospitals in Japan saw an increase in illness-related admissions over the 15 days after the Hanshin-Awaji earthquake – a third of which were for respiratory disease (including pneumonia, cold, asthma, and other; Tanaka et al., 1999). Infectious disease represented 8.4% of diagnoses at the Red Cross Field Hospital after the 2004 Tsunami (Guha-Sapir et al., 2007). Another study showed infectious diseases were detected in 85% of hospital patients after flooding in Mozambique (Kondo et al., 2002). Respiratory illnesses represented 15% of emergency department visits following Hurricane Floyd, according to the CDC (cited in Llewellyn, 2006). Especially in natural and unintentional manmade disasters, risk of infectious disease will be somewhat dependent on chance in terms of disaster timing, location, and severity of damage.

Demand for infectious agent-related supplies is often high after disasters. The National Disaster Medical System Special Operations Response following Hurricane Andrew reported supplies of tetanus antitoxin and antibiotics were depleted within 24 hours of the Hurricane (Llewellyn, 2006). Following Hurricane Iniki and Andrew, tetanus vaccination and antibiotics were in the top five drugs prescribed (Nufer & Wilson-Ramirez, 2004). After the Bam earthquake, top prescriptions by emergency medical assistance teams included cold preparations (8%) and anti-bacterials (11.2%) (Sepehri & Meimandi, 2006).

Blood donations have been shown to increase after disasters (Glynn et al., 2003; Sonmezoglu et al., 2005). However, the number of donations confirmed positive for HIV, Hepatitis C, and Hepatitis B has been shown to increase in some circumstances (Glynn et al., 2003), largely explained by an excess of first time and lapsed repeat donors, but not in others (Sonmezoglu et al., 2005).

Sources of Infection

Soil and water. Watson et al. (2007) summarize the convincing evidence for diarrheal disease outbreak/clustering due to contaminated water after disasters, with reports from Bangladesh, West Bengal, Mozambique, Indonesia, Pakistan, the United States, Mumbai, Argentina, Russia, Rio de Janeiro, and Taiwan following floods, an earthquake, and storms. Kondo et al. (2002) reported a spike in diarrheal illnesses with simultaneous deterioration in drinking water quality after major flooding in Mozambique.

In another review, Uckay et al. (2008) found frequent reports of infections with gram-negative bacteria, such as *Aeromonas* and *Vibrio* species, after the Indian Ocean Tsunami, indicating a marine source of infection; moreover, atypical fungal and mycobacterial infections in immunocompetent patients suggest traumatic inoculation at the disaster site. After Hurricane Katrina, wounds infected with *Vibrio* species were also noted, with 6 of 24 cases resulting in death (Todd, 2006). Unusual fungal infection due to airborne dust has been documented following an earthquake in southern California (Watson et al., 2007). Lastly, a tetanus outbreak was noted after the 2004 Tsunami in Aceh, Indonesia, likely due to immersion of superficial wounds during the tsunami (Jeremijenko et al., 2007).

Vector borne disease. Outbreaks of malaria following flooding have been seen in Costa Rica, Peru, Mozambique, Sudan, Haiti, but not in Indonesia following the 2004 Tsunami (Ivers & Ryan, 2006; Kondo et al., 2002; Morgan, 2004; Watson et al., 2007). Dengue outbreaks are documented after monsoon rains and flooding in India, Thailand, Brazil, Indonesia, and Venezuela; heavy rain and flooding may be associated with arboviral diseases and lymphatic filariasis around the world (Ivers & Ryan, 2006). Lastly, an increase in triatomine bugs, the vector for Chagas disease, was documented in the 6 months following Hurricane Isadore in Mexico, where the maximum increase was along the path of the hurricane (Guzman-Tapia, Ramirez-Sierra, Escobedo-Ortegon, & Dumonteil, 2005).

Hospital-acquired disease. Evidenced for hospital-acquired infections includes the presence of multiply-drug-resistant species and multi-methicillin-resistant *Staphylococcus aureus* (MRSA) following the 2004 Tsunami and Hurricane Katrina, as well as correlation of multi-drug-resistant bacteria frequency with hospital stay duration (Uckay et al., 2008). On the other hand, Todd (2006) reported that the pattern of MRSA infections found in displaced children after Hurricane Katrina indicated a community source, rather than more invasive hospital strains. Resistant infections are likely acquired from both hospital and community environments.

Person-to-person/crowding. There is evidence for disease outbreaks or clusters due to crowding of displaced populations. The only true outbreak after Hurricane Katrina was a norovirus outbreak at a temporary shelter in Texas (Todd, 2006), which is spread through person-to-person or fomite contact. Measles clusters have been found in the Philippines, Aceh Indonesia, and Pakistan, after tsunami, volcano eruption, and earthquake; meningitis infections among displaced persons in Aceh Indonesia and Pakistan have also been documented (Watson et al., 2007). Moreover, food shortages and malnutrition in temporary shelters may increase vulnerability to infection (Kondo et al., 2002). Dead bodies, on the other hand, pose little risk of infection or epidemic following disasters (Ligon, 2006; Morgan, Ahern, & Cairncross, 2005; Watson et al., 2007), nonetheless workers handling dead animal and human remains should use precautions (Ligon, 2006).

Conditions and species of concern. Wound infections are a serious concern for those suffering injury during disaster (Ligon, 2006; Llewellyn, 2006). Common diseases of concern include tetanus (Jeremijenko et al., 2007; Ligon, 2006; Uckay et al., 2008; Watson et al., 2007), *Aeromonas* and *Vibrio* species (Ligon, 2006; Llewellyn, 2006), necrotizing fasciitis, and mycobacterium infections (Llewellyn, 2006). Microbiological assessment of 17 seriously injured tourists returning home identified common and uncommon multi-resistant pathogens (Maegele et al., 2005). Gram-negative bacteria were common in this group, as well as victims after tornadoes in Georgia and the United States (Uckay et al., 2008).

Acute respiratory infections (ARI) are another concern in the post-disaster setting (Ligon, 2006). ARI may be a major cause of illness in displaced populations especially, with increases in ARI seen in Nicaragua following Hurricane Mitch, in Aceh following the tsunami, and in Pakistan following an earthquake (Watson et al., 2007). One study found over two-thirds of children in a post-tsunami relief camp had an ARI (Jayatissa et al., 2006). Upper respiratory tract infections in those same 17 injured tourists returning home were found to contain a high rate of multiply-resistant species (Maegele et al., 2005). Maegele (2006) found that all of those tourists suffered near drowning involving aspiration of immersion fluids, marine, and soil debris; all patients displayed signs of pneumonitis and pneumonia, while several had severe sinusitis. Upper respiratory infection was in the top five chief complaints and top five diagnoses following Hurricanes Andrew and Iniki (Nufer & Wilson-Ramirez, 2004), and respiratory viral diseases were common after Hurricane Katrina (Uckay et al., 2008).

Diarrheal diseases are an important consequence of disasters. One study showed 17.9% of children in a post-tsunami relief camp had diarrhea (Jayatissa et al., 2006). Cholera, *Escherichia coli*, Salmonella, *Cryptosporidium parvum*, leptospirosis, and Hepatitis A and E are all possible causes of diarrheal disease after disasters (Ligon, 2006; Llewellyn, 2006; Morgan et al., 2005; Sur, Dutta, Nair, & Bhattacharya, 2000; Watson et al., 2007). Many diarrheal outbreaks may not be due to one specified pathogen (Uckay et al., 2008).

Chronic Disease

We reviewed nearly 40 articles on the impact of disasters on chronic diseases, including cross-sectional, cohort, and case studies as well as review articles. Our article base included samples from the general population and from rescue and cleanup personnel. By the very nature of chronic disease, studies often had longer follow-up than many other topic areas. As a result, the longitudinal cohort is a common design. Because many of these studies involve self-reported symptomatology, this area may represent the effects of long-term mental health as well as physical outcomes of disaster exposure. Where possible, we try to tease apart these effects.

In this section, we investigate the health effects of disasters across organ systems. We begin by reviewing the impact of disaster on cardiovascular health, followed by a brief discussion of diabetes and arthritis. Next, we discuss respiratory health, kidney and urinary health, and neurological effects. We review reproductive and developmental health effects of disasters, followed by musculoskeletal problems and cancer. Lastly, we discuss specific problems and conditions caused by particular exposures. Again, this is not an exhaustive list of all research on these topics, but rather an overview of the common areas of research.

Cardiovascular health outcomes. In this section, we include both cardiovascular outcomes (incident disease and death) and risk factors for cardiovascular disease, including hypertension, cholesterol, blood pressure, heart rate, vascular problems, and autonomic reactivity. Some studies examine self-reported symptomatology as well as objective measures. For example, over 8 years after the Amsterdam Air Disaster, exposed police and fireworkers were more likely to report cardiovascular complaints than unexposed workers; however, they had no significant differences in blood count or chemical values, with the exception of increased monocytes (Huizink et al., 2006).

The impact of disasters on cardiovascular health may depend on exactly what is being measured. For example, one study found no correlation between earthquake-related experiences and blood pressure or cholesterol; however, disaster experiences did predict resting heart rate (Bland et al., 2000). Autonomic reactivity (heart rate, diastolic/systolic and mean arterial blood pressure) and development of new vascular problems were both sensitive to disaster exposure, even years later (Dirkzwager et al., 2007; Tucker et al., 2007).

The relationship between cardiovascular health and disaster exposure may also be mediated partially by stress. Risk factors for cardiovascular problems are primarily related to indirect consequences of disasters, including having a child who was burned (Dorn, Yzermans, Guijt, & van der Zee, 2007); disaster damage, loss of possessions, or total loss (Armenian, Melkonian, & Hovanesian, 1998); financial loss, increased distance from family and friends, and decreased visiting due to relocation (Bland et al., 2000). Some demographic factors predicted vascular problems, including lower SES and female gender (Dorn, Yzermans, Guijt, et al., 2007). Bland et al. (2000) did not find support for mediation of the relationship between earthquake experience and resting heart rate by psychological stress.

There may be a life-course effect of stress on cardiovascular risk – all the way back to fetal development. Adults who were exposed to a Dutch Famine in late gestation had reduced glucose tolerance; those exposed in early gestation had a more atherogenic lipid profile, higher fibrinogen concentrations, lower factor VII concentrations, a higher BMI, and more often rated their health as poor; those exposed in mid gestation had increased obstructive airway disease (Roseboom et al., 2001).

Diabetes. There is some evidence that disaster-exposed individuals have higher rates of diabetes later in life (Armenian et al., 1998; Pesatori et al., 2003). Risk factors for diabetes after earthquake included loss of possessions and disaster-related damage (Armenian et al., 1998). Endocrine effects may, however, be sex specific. For example, female victims of dioxin exposures (but not men) were more likely to develop diabetes in the 20-year follow-up (Pesatori et al., 2003).

Arthritis. Earthquake victims with new arthritis diagnoses in the 4 years after earthquake were more likely to sustain greater loss of possessions and disaster-related damage than those without arthritis, matched for age and sex, controlling for education, and body mass index (Pesatori et al., 2003). Although this finding would seem to imply mediation by emotional problems and/or somatization, one might imagine additional confounding variables, as well.

Respiratory health. Respiratory problems represent one of the most studied chronic health effects of disasters. Much of this information comes from rescue and cleanup workers, who often sustain more severe exposure to airborne particulates and other lung irritants for a more prolonged period of time than the general population. Following September 11, 2001 terrorist attack, workers involved in rescue, cleanup, and recovery suffered reduced pulmonary function (Banauch et al., 2006), increased respiratory symptoms (Tao et al., 2007), cough, and lung function abnormalities (Skloot et al., 2004). Following the Enschede Fire Disaster, rescue and cleanup workers suffered increased respiratory symptoms (Dirkzwager et al., 2004) and excess sick leave due to respiratory problems (Morren et al., 2007).

Respiratory problems have been reported in civilian populations as well. Ten years after the Union Carbide gas leak, respiratory symptoms were more common and lung function more reduced who were living closer to the plant (Beckett, 1998). A review of the health effects of this disaster found evidence for radiological changes to the lungs, respiratory symptomatology and impairment, with progressive decline in lung function over 2 years of follow-up. This same disaster was found to have respiratory and mucous membrane symptoms 9 years after the explosion by Dhara et al. (2002); risk factors for these symptoms included proximity to the plant, duration of exposure, and physical activity following exposure.

For disasters with a more time-limited exposure, respiratory damage may be more reparable. After the Volendam café fire, adolescent survivors had increased respiratory symptoms 1 year after the fire, but not after 4 years (Dorn, Yzermans, Spreeuwenberg, Schilder, & van der Zee, 2008).

Kidney and urinary health. The evidence on kidney and urinary problems as a result of disaster varies by disaster type. Workers exposed to the Amsterdam Air Disaster showed had similar kidney function parameters as unexposed workers 8 years later (Bijlsma et al., 2008) and no differences in urinanalysis 8.5 years later (Huizink et al., 2006). Exposure to the Union Carbide industrial accident, on the other hand, was associated with urinary burn 9 years later (Dhara et al., 2002).

Neurological problems. Neurological health of those directly exposed to disaster, particularly chemical exposures, may suffer. Neurological and neurobehavioral problems have been associated with exposure to the Union Carbide gas leak (Dhara & Dhara, 2002), in rescue workers after the Enschede Fireworks Disaster (Morren et al., 2007), and in those exposed to the Tokyo Sarin attack (Nishiwaki et al., 2001). Specifically, backward digit memory span tests acted in a dose–response manner with exposure to Sarin gas (Nishiwaki et al., 2001). In a review of the health effects of the Chernobyl Disaster, Dhara and Dhara (2002) report evidence of impaired auditory and visual memory, attention response speed, associate learning, and motor speed and precision, with some tests showing a dose–response effect.

Reproductive and developmental health. In our review, reproductive health problems were reported by two articles, both investigating industrial accidents. Dhara and Dhara (2002) found evidence for menstrual cycle disruption, leukorrhea, dysmenorrhea, miscarriage, and both perinatal and neonatal mortality for women affected by the disaster; furthermore, animal experiments show that MIC has fetotoxic effects in mice. After the Seveso accident, men with greater blood-dioxin levels fathered significantly more girls than boys up to 20 years after the accident (Mocarelli et al., 2000).

The research on reproductive health behavior following disasters is limited and largely restricted to displaced women. Poverty, isolation, overcrowding, and the arrival of military, relief, construction, and transport personnel may contribute to increased risk of STI transmission in the aftermath of disaster (Carballo, Hernandez, Schneider, & Welle, 2005). A study in the country of Georgia found that women with PID were more likely to be internally displaced (due to conflict) than not, even after controlling for their lifetime sexual partners, IUD or condom use, induced abortion history, gynecological exam history, and STI history (Doliashvili & Buckley, 2008). After Hurricane Katrina, women were less likely to have multiple sex partners and less likely to be attending family planning services or using birth control, compared to before (Kissinger, Schmidt, Sanders, & Liddon, 2007). Kissinger et al. (2007) also found that nearly 20% of young women in a local family planning study had difficulty accessing necessary family planning care in the 5–6 months following Hurricane Katrina (Kissinger et al., 2007). This is not surprising given over 85% of these women had lived in three or more places in that time span and both of the family planning clinics where subjects were recruited were flooded and either moved or closed down completely.

Research on the developmental impact of disasters focuses on two main routes of effect – in utero chemical or radiological exposures and the effects of maternal stress on the developing fetus (sometimes acting in concert). Researchers have found no evidence of cognitive impairments in children exposed in utero or at a young age to the Chernobyl Disaster (Bromet & Havenaar, 2007; Taormina et al., 2008). Nor was there evidence of increased under-five mortality in the 5 years following the disaster (Gruber et al., 2005). Zichittella et al. (2004) also found no additional infant or post-neonatal mortality after the Chernobyl Disaster. Interestingly, evacuee mothers in the Taormina study were almost three times as likely to report their children having memory problems as controls, stressing the need for objective measures of chronic health.

The Quebec Ice Storms in 1998, on the other hand, had a negative impact on cognitive and language development of children exposed in utero as well as perinatal outcomes, infant temperament, and physical development, specifically for those exposed in the second trimester (King & Laplante, 2005). This is in contrast with the Roseboom study (2001) on cardiac outcomes, which showed exposure in late gestation to be most important; this difference is reflective of different developmental programming periods for different organ systems.

Though the evidence is still mixed, there is some support for the impact of in utero disaster exposure on adult mental health. One study looked at disaster-associated antisocial personality disorder (ASPD), examining the effects of prenatal nutritional deficiency due to an intentional man-made famine during World War II. Neugebauer, Hoek, & Susser (1999) found that men exposed to severe nutritional deficiency in the first or second trimester had 2.5 odds of ASPD as men unexposed to nutritional deficiency. Neugebauer did not find any effect of third-trimester exposure, suggesting fetal programming at specific points in time.

Another study in our review looked at non-affective psychosis and maternal flood-related stress (Selten, van der Graaf, van Duursen, Gispen-de Wied, & Kahn, 1999). Unfortunately, psychotic disorders are fairly rare and they did not separate their sample by trimester of exposure, which the Neugebauer study (1999) showed to be important. They found that those exposed to maternal flood stress in utero were 1.8 times as likely to have non-affective psychosis disorders in adulthood, however, the difference did not achieve statistical significance at the 95% confidence level (95% CI: 0.9–3.5).

Given the power of disaster-related stress to alter the sex ratio of children born in months following disaster, likely through excess fetal death (Catalano, Bruckner, Gould, Eskenazi, & Anderson, 2005), the concept of fetal-determined vulnerability for adult mental illness is not implausible. None of our reviewed articles examined biological mechanisms for observed effects.

Musculoskeletal problems. Chronic musculoskeletal problems have been reported following the Enscede Fireworks Disaster (den Ouden et al., 2005; Dirkzwager et al., 2004; Morren et al., 2007), the Amsterdam Air Disaster (Deeg, Huizink, Comijs, & Smid, 2005), the Volendam Café Fire (Dorn et al., 2008), and the Union Carbide Accident (Dhara & Dhara, 2002; Dhara et al., 2002).

Survivors of the Enschede Fireworks Disaster who visited a mental health institution after disaster (possibly a proxy for exposure status) had an increase in musculoskeletal problems presented to GPs in the year following crash, compared to before, but returned to baseline by 2 years (den Ouden et al., 2005). Rescue workers in the Enscede Disaster had greater musculoskeletal problems presented to an occupational physician up to 2 years after disaster compared to before; they also had greater absences from work during the first year post-disaster, but had returned to baseline by before year 2 (Dirkzwager et al., 2004). Morren et al. (2007) found rescue workers had greater sick leave for musculoskeletal problems in the first year post-disaster and remaining higher than controls until 3 years post-disaster.

Older persons living closest to the Bijlmer Air Disaster were experienced health decline above normal aging-associated decline; the effect was most obvious in interview-rated mobility (Deeg et al., 2005). Adolescent survivors of the Volendam Café Fire had increased GP-reported musculoskeletal problems in the first year after disaster, but not in later years (Dorn et al., 2008). Exposure to the Union Carbide Accident was associated with musculoskeletal problems, including muscle pain, joint pain, and bone pain (Dhara et al., 2002); the neuromuscular-toxic property of MIS is supported by animal studies (Dhara & Dhara, 2002).

Cancer. Chemical and radiological exposures are of particular interest to cancer researchers. Patients who received 224Ra injections for bone tuberculosis and ankylosing spondylitis in the 1940s and 1950s suffered increased risk of cancers system wide (including cancers of the bone, connective tissue, breast, thyroid, liver, kidney, pancreas, uterus, and bladder) in the 12–21 years following "treatment" (Spiess, 2002). Exposure to the dioxin TCDD following the Seveso Accident was associated with increased risk of morbidity and mortality from lymphoemopoietic neoplasm and cancers of the digestive and respiratory systems (Pesatori et al., 2003). A cancer incidence study from 1987 to 1992, 8 years after the Union Carbide Accident, found no evidence of increased risk for cancer of the lung, oropharynx, or oral cavity due to gas exposures; however, the authors note that more time may be necessary for the effect to show (Dikshit & Kanhere, 1999).

Specific problems and conditions. Exposure to Union Carbide incident associated with persistent respiratory and ocular problems (Dhara & Dhara, 2002). Bhopal Eye Syndrome, coined by Andersson et al. (1990), includes full resolution of the initial interpalpebral superficial erosion, increased risk for eye infections, hyperresponsive phenomena, and possibly cataracts.

Spanish Toxic Oil Syndrome (TOS) is a condition caused by ingestion of rapeseed oil denatured with aniline – a disaster taking place in Spain in 1981 – characterized by fever, rash, eosinophilia, pulmonary edema, and myalgia. Recent research has shown that impaired acetylation, and the genetic polymorphisms associated with it, mediated susceptibility to TOS (Ladona et al., 2001; McCredie & Willert, 1999). This may have implications for other disasters as well – genetic vulnerability may play a role in both occurrence and severity of symptoms after disaster.

Health Behavior

We reviewed over 25 articles on the impact of disasters on health behavior, including cohort, case-control, cross-sectional, ecological, and other study designs (e.g., key informant interviews). Our article base included samples from the general population and from disaster relief personnel. Surveys were by far the most common data sources for studies looking at most health behaviors, with the exception of child abuse for which administrative data were used. Much of the research in this area examines short-term effects of disasters. In this section, we review findings related to substance use, including alcohol, drug abuse, and tobacco. We also discuss the impact of disasters on child abuse and domestic violence.

Alcohol. Alcohol use and misuse after disasters has been widely studied with mixed results. Outcomes of interest included alcohol consumption, change in use, alcohol problems, alcohol dependence, hazardous alcohol consumption, and binge drinking. Much of the research we reviewed was in the United States with a focus on September 11, 2001 terrorist attack. Moreover, research on this topic is often cross-sectional, which does not allow researchers to determine the temporality of "cause" and "effect" – this is particularly problematic with the association between mental health status and alcohol use. Some authors refer to alcohol use/misuse as a risk factor for mental health problems after disaster, while others postulate that alcohol use/misuse is a coping mechanism brought on by poor mental health. It is likely that causality operates in both directions, in concert with mediating and moderating factors.

There is evidence for increased prevalence of alcohol problems after disaster. Researchers have shown a disaster effect on excessive alcohol consumption, increased alcohol use, and increased prevalent drinking problems after the Volendam Café Fire (Reijneveld et al., 2005), Oklahoma City bombing (Smith et al., 1999), and September 11, 2001 terrorist attack (Vlahov et al., 2006), respectively. Various measures of alcohol use/misuse were associated with (a) *exposure factors* – greater exposure (Boscarino, Adams, & Galea, 2006); injury, peritraumatic reaction, worry about safety (Pfefferbaum et al., 2002); degree of exposure for women (Vetter, Rossegger, Rossler, Bisson, & Endrass, 2008); grief and PTSD symptoms (Pfefferbaum & Doughty, 2001); conversely, sensory exposure and interpersonal exposure were not associated with increased alcohol intake (Pfefferbaum et al., 2002); (b) *proximity* – attending school where many students were affected (Reijneveld et al., 2003, 2005), living in the affected city (Smith et al., 1999); (c) *post-disaster mental health* – partial PTSD, sub-syndromal PTSD, PTSD severity, depression, and poor mental health status (Adams et al., 2006b); negative affect, mediated by coping motives (Gaher et al., 2006); grief, post-traumatic stress, trouble functioning (Pfefferbaum et al., 2002); receipt of peer support (protective, (Ford et al., 2006)); hyperarousal and intrusion symptoms (Simons et al., 2005); symptoms of PTSD and depression (Vetter et al., 2008; Vlahov et al., 2002, 2006); endorsement of emotional reactions and functional difficulties (Pfefferbaum et al., 2008).

The bulk of the research in this topic investigates the association between poor mental health and alcohol use/misuse. Some researchers have found mental health symptoms to be more strongly associated with alcohol use/misuse outcomes than disaster-exposure characteristics (Pfefferbaum & Doughty, 2001; Pfefferbaum et al., 2002), while others have found a lack of association between psychopathology and alcohol, after controlling for exposure level (Boscarino, Adams, & Galea, 2006). Interestingly, poor mental health may be associated with not just increased alcohol use (Adams et al., 2006b; Pfefferbaum et al., 2002; Vlahov et al., 2002), but also decreased use (Pfefferbaum et al., 2008), or both (Simons et al., 2005). Increased alcohol use was also protective for physical health, in the Adams study (2006b). As with the mental health section, many of these proposed risk factors may, in fact, apply to substance use in general, rather than only in a post-disaster context.

Drug abuse. Research on drug abuse after disasters is a bit more diverse than that on alcohol use, with research taking place following September 11, 2001 terrorist attack and the Oklahoma City bombing, the Chi-Chi and Bam Earthquakes, and the 2004 Indian Ocean Tsunami. Outcomes of interest include substance use, abuse, and dependence as well as cannabis use, specifically. There was one study on recovering substance users.

Evidence for a disaster effect on drug abuse is mixed, with researchers finding and increase (near doubling) on drug abuse/dependence following the Chi-Chi Earthquake (Chou et al., 2007), but not following the Volendam Café Fire (Reijneveld et al., 2003, 2005). Reineveld et al. did, however, find a disaster effect on alcohol use, indicating that alcohol may be more sensitive to the impact of disasters than drug abuse, for obvious reasons (e.g., accessibility, social acceptability, cost, etc.). Risk factors for substance use after disasters include degree of exposure, PTSD symptomatology (Vetter et al., 2008), PTSD, and depression (Vlahov et al., 2002). As with alcohol use, both exposure characteristics and post-disaster mental health have been supported as potential "risk factors" for substance use.

The effect of disasters on drug abuse is most prominent in the immediate time frame. During the 29 hours of the New York City Blackout, 911 emergency calls for drug- or alcohol-related emergencies actually decreased (Freese et al., 2006). In the days following September 11, 2001 terrorist attack, patients in recovery programs reported difficulty getting to their treatment due to interrupted public transport (Frank et al., 2006). In this same study, one of two residential recovery programs, half of the methadone programs, and over half of the drug-free outpatient programs reported an increase in positive urine toxicology following September 11, 2001 terrorist attack. Over half of opium abusers in and around the city during the Bam earthquake reported withdrawal symptoms due to a disturbed supply and half of these reported their symptoms to a medical provider, asking for morphine or another analgesic (Movaghar et al., 2005).

In short, to the degree that disasters disturb normal life for the average person, they also disturb normal life for drug users and those in recovery – sometimes by restricting use, but other times putting them at a greater risk of relapse. We did not see any research dealing with incidence of new drug problems after disaster, which would be of interest.

Tobacco. As with alcohol use, smoking has been posited as both a coping mechanism to deal with mental health problems following disaster and a contributor to worsening mental health. Directionality of association is as much a problem with tobacco as it is with alcohol.

There is evidence for increased smoking and additional initiation up to 18 months following disasters (Smith et al., 1999). Risk factors for increased tobacco consumption include traumatic disaster experience (Parslow & Jorm, 2006), denial of emotional reactions and functional difficulties (Pfefferbaum et al., 2008), peritraumatic reaction, grief, worry about safety, and trouble functioning (Pfefferbaum et al., 2002). Pfefferbaum et al. (2002) also found that sensory exposure and interpersonal exposure were not associated with increased tobacco intake after the Oklahoma City bombing.

Evidence on the effect of PTSD on tobacco consumption is mixed, with Parslow and Jorm (2006) finding no independent effect of PTSD, beyond disaster traumatic experience in bushfire-exposed young adults, while Pfefferbaum et al. (2002) found that post-traumatic stress was associated with increased smoking after the Oklahoma City bombing. Vetter et al. (2008) found that severity of PTSD symptoms increased odds of tobacco consumption, and Vlahov et al. (2002) found a smoking association with both PTSD and depression. The directionality of this relationship between post-disaster psychopathology and tobacco consumption is unclear.

In one of the few studies looking at the biology behind disaster stress and addiction, Olff et al. (2006) found that survivors of the Enschede Fireworks Disaster with depression tended to use more tobacco per day and also tended to have a flatter diurnal cortisol curve than health controls of survivors with PTSD. The authors conclude that smoking may actually mediate the relationship between the post-disaster depression and the hypothalamic–pituitary axis.

Child abuse and domestic violence. Child and spousal abuse have serious consequences for population health and well-being. Tragically, there is evidence that disasters may cause an increase in child abuse. The evidence in this field of research is mainly ecological – from administrative records – rather than etiologic. Child abuse reports in affected counties were disproportionately higher 3–6 months after Hurricane Hugo and the Loma Prieta Earthquake, compared to other years; however, there was no significant difference after Hurricane Andrew (Curtis, Miller, & Berry, 2000). Likewise, hospital admissions for inflicted traumatic brain injury in young children (shaken baby syndrome) increased 6 months after Hurricane Floyd in affected regions, compared to pre-disaster, with no corresponding increase in counties less affected by the disaster; levels returned to baseline thereafter (Keenan, Marshall, Nocera, & Runyan, 2004).

The evidence on intimate partner violence (IPV) following disasters is mixed. Frasier et al. (2004) found no significant increase in IPV after Hurricane Floyd, although the study did have some non-response issues (with nearly 1/3 of their sample refusing response to a question about lifetime IPV). Another study conducted 7–9 months after Hurricane Katrina found IPV rate was three times the United States baseline for displaced persons living in group trailer parks in Mississippi and Louisiana (Larrance, Anastario, & Lawry, 2007).

Conclusion

We have reviewed the literature about the range of public health consequences of disasters here. As is clear from this review, collectively experienced traumatic events influence the health of populations across a range of health indicators. The literature about the scope of these consequences is vast. Yet there remain substantial gaps in our understanding of the consequences of these events, with the literature about particular health indicators often providing conflicting evidence. Some of this lack of clarity may be due to the complexity of mass traumatic events, with the impact of these events being heterogeneous across groups comprising populations. While we can draw general inference about the population health consequences of disasters, such inference must be drawn cautiously with due recognition that the net result of one mass traumatic event may be different than other comparable disasters in different contexts. Future work in this field may fruitfully consider this complexity, developing models that can help predict how the interplay between the mass traumatic event and the context that is affected contribute to changes in population health. Such work may provide guidance for intervention that can mitigate the consequences of future events.

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