LANDSLIDES

The Nepal Earthquake 2015 and associated avalanches are stark reminders of the complexity of management of a large magnitude crisis of this nature. We are currently creating a new edition of the reference text ***Koenig and Schultz's Disaster Medicine: Comprehensive Principles and Practices***, which will be released this fall. The authors for a new chapter on landslides are Iain TR Kennedy, David N Petley, and Virginia Murray. Although our book is not yet finalized, we offer our colleagues a complimentary copy of the latest iteration of the landslides chapter to facilitate the education of health care providers and emergency managers on the front lines right now. Our goal is that this product will enhance understanding of landslides and improve outcomes for patients involved in this tragedy. This up-to-date, evidence-based reference is meant to serve as just-in-time knowledge for application to a real-life event. Please accept this resource with our compliments.

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Landslides

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Overview

Mass movements of dry materials, commonly referred to as landslides occur frequently, and are increasing around the globe. While technical and geological aspects of landslides are well documented, details of the health and social impacts, and the challenges of rescue and recovery from these disasters are less well researched.

After defining landslides, including classification types and common features, this chapter describes their epidemiologic features. Found everywhere there are slopes, landslides are particularly common around the Himalayan belt, Central America, Caribbean, and in the Pacific, especially the Philippines and Indonesia. Data suggest there were over 80,000 deaths attributable to landslides in one seven-year period[12].

Direct causes of mortality are typically related to suffocation or asphyxiation from becoming entrapped in the landmass; however other landslide effects are less clearly explained. Mental health consequences are the best described, with high rates of Post Traumatic Stress Disorder (PTSD) and major depressive disorder[21,22,23]. The evidence suggests that landslide survivors may have worse mental health outcomes than the survivors of other disasters, notably floods[22,24.] Physical health outcomes include direct injuries, which can result in crush syndrome, and indirect effects, including increases in infectious diseases, notably malaria.

They keys to reducing the medical and health effects of landslides are disaster risk reduction and mitigation strategies. This chapter describes projects of different scales in variable locations – from the comprehensive system in Hong Kong, to low cost local projects in the Caribbean. These case study descriptions demonstrate that disaster risk reduction measures are possible in any setting.

Finally this chapter calls for further research into the impacts of landslides and the policies and procedures for immediate response and recovery. Compared to other disaster types, these areas have been relatively neglected, and would benefit from better documentation and analysis. Findings from such studies would help improve the preparation for and response to landslides.

Current State of the Art

Definition

Landslides are defined as the “downhill and outward movement of slope-forming materials under the influence of gravity.”[1] They include a wide variety of phenomena, including rockfalls, debris flows, rock avalanches and soils slides, but exclude avalanches primarily consisting of snow and/or ice. Landslides are commonly triggered by intense or prolonged rainfall; earthquakes; snowmelt and human activity, although a small proportion result from forces acting within the slope and have no external trigger. Research into the mechanisms and impacts of landslides is extensive and detailed; Clague and Stead provide a 2012 state-of-the-art review.[2] However, investigations of the health and social consequences of landslides remain scarce. Research in these areas is urgently needed given the incidence of landslides is increasing with time.[3] This trend is likely to continue due to a combination of population increases (especially in Asia), migration to poorly-planned communities on steep slopes on the margins of urban areas, increases in rainfall intensity, and the conversion of forest land to agriculture.

Landslides are important both for their ubiquity - instances have been recorded in every global environment in which slopes are present – and for the role they play in increasing the impact of other hazards. During the 2008 Wenchuan (Sichuan) earthquake in China, nearly 200,000 landslides were triggered[4], directly killing over 20,000 people[5]. In the aftermath of the earthquake, rescue and recovery operations were severely hampered by the blockage of roads by landslides[6]. Given the short time window for rescuing victims trapped in buildings, landslides effectively increase the mortality rate from the primary hazards. Finally, considerable resources had to be diverted from rescue operations towards mitigating landslides that had blocked river channels, which created unstable lakes that threatened over a million people in the event of a catastrophic collapse of the barrier[7].

Types of landslides and their characteristics

The nature of the impacts caused by landslides is closely related to their mechanisms of movement. Landslides are commonly classified according to the materials from which they are formed (generally subdivided into rock, debris and soil) and the dominant nature of the movement (typically falling, sliding or flowing) (Table 1)[8]. In the context of landslide impacts it is also useful to consider rates of movement. Some very large landslides (often with masses in excess of a billion metric tons) travel at rates in the order of millimeters per year, and provide no direct threat to life, while a single free-falling 1 kg block can be fatal. However, in general, larger landslides cause greater levels of fatalities, especially when rates of movement are high. For example, 80% of deaths caused by landslides in Italy resulted from rapid events, such as debris flows and mudflows. However, when slower moving landslides do cause fatalities, the number of lives lost in each event tends to be higher than for the more rapid events. This is likely due to unanticipated building collapses[9].

As landslides often contain dense materials like rock, soil or debris mixed with water and travel at high speeds, human bodies are extremely vulnerable to their impacts. Survival usually requires either protection from a hard structure, such as a building or vehicle, or that the victim remains on the surface of the landslide. When unprotected victims become incorporated into the landslide, mortality is very high, such as in the Beichuan Middle School event where there were over 800 victims and no reported survivors (Figure 1).

While landslides are ubiquitous in areas with slopes, their highest rates of occurrence are in areas with high relief, steep gradients, weak materials and energetic triggering events. Highest rates of landsliding are recorded in mountains through the Alpine–Himalayan belt; in tropical volcanic areas such as the Indonesian archipelago and the Philippines; and in steep areas, even if the total elevation is low, affected by tropical cyclones (such as Taiwan, Hong Kong and southwestern China). Finally, human activities are important in determining patterns of occurrence of landslides. In many cases, people increase landslide occurrences. For example, landslides are common on reservoir banks created by large dams.[10] Furthermore, in Nepal, landslide occurrence has been greatly increased by the construction of poorly-designed and engineered rural roads[11]. On the other hand, in Hong Kong a major program of slope management and engineering over a 30-year period has probably reduced landslide occurrence to significantly lower than its natural background rate.

Landslide epidemiology

Data on the impact of landslides in terms of global loss of life over a seven-year period (2004-2010) are available in the Durham Fatal Landslide Database, compiled by Petley[12]. Investigators collected information on a daily basis through disaster management agency datasets, newspaper reports, scientific papers and local correspondents. The researchers report a total of 80,058 deaths (estimated error -5/+20%) [11]. Of these, 47,736 were attributable to landslides triggered by earthquakes, with the majority of the remainder being associated with intense rainfall events. This analysis excluded morbidity data, although numbers of injured persons associated with each landslide were recorded for rainfall-induced landslides. Fatality data are collected for earthquake induced landslides, but numbers of injuries are not known as this information is not recorded by agencies responding to such events. As the physics of seismically-induced and other landslides are the same, and the vulnerable populations are also similar, the ratio of deaths to injuries may be broadly similar.

To date, no systematic quantitative analysis has been undertaken of injury versus fatality rates for landslides. Researchers performed an analysis of the Durham Fatal Landslide Database for rainfall-induced landslides. Globally, the data indicate there were 32,322 fatalities and 9,408 reported physical injuries for the 2620 landslide events in the database, a 77.5% mortality rate. This rate, which is unusually high when compared with other hazards, is a consequence of the extremely violent physical processes associated with landslide events.

Haiti has the highest mortality rate (99.8%) and Norway the lowest (32.6%), suggesting that availability of well-equipped rescue teams and high quality medical care both at the landslide sites and in the prehospital and hospital environments might be a critical factor in determining this ratio. It is likely that, if similar resources were available in poor countries as are available in the more developed world, then the mortality rate from landslides would be reduced. This pattern is reproduced on a continental basis (Figure 2). The highest mortality ratio is recorded in the Caribbean; in this case the data are dominated by the ratio in Haiti. High ratios are also recorded in Central and South America, and Africa. The lowest ratio is recorded in Europe, reflecting the availability of high quality medical care and rapid emergency response. The low ratio in central Asia may signify the continued existence of disaster management agencies begun in the Soviet era. The low ratio in SE Asia could be explained by the influence of the Philippines and Indonesia, both of which have comparatively strong disaster management agencies, providing a rapid response to landslide accidents.

The spatial distribution of the landslide impacts is heterogeneous, with hotspots located along the Alpine–Himalayan belt (especially in the mountainous areas of India, Pakistan, Nepal, Bhutan, and Bangladesh), Central America, the Caribbean, the Andes (especially in Colombia), the Philippines, and Indonesia (Figure 3). This reflects a combination of causal factors for landslides and vulnerable populations.

Data regarding the economic costs of landslides are lacking, but would likely show a reverse pattern to mortality ratios, with the highest monetary losses occurring in mountainous areas of developed countries with significant financial assets. For example, the Bingham Canyon copper mine landslide in April 2013 in the U.S. state of Utah is expected to inflict net economic losses in excess of $500 million U.S., primarily through lost production in the mine and the costs of excavating the 160 million ton landslide mass.

Table 1: The simple landslide classification based on movement mechanism and material type.

From Special Report 176: Landslides: Analysis and Control. Varnes, D., Chapter 2: Slope Movement Types and Processes, Figure 2.1. Copyright, National Academy of Sciences, Washington, D.C., 1978. Reproduced with permission of the Transportation Research Board.

Mechanism of movement			**Type of material**		
			Bedrock	Engineering soils	
				Predominantly fine	Predominantly coarse
Falls			Rockfall	Earth fall	Debris fall
Topples			Rock topple	Earth topple	Debris topple
Slides	Rotational		Rock slump	Earth slump	Debris slump
	Translational	Few units	Rock block slide	Earth block slide	Debris block slide
		Many units	Rock slide	Earth slide	Debris slide
Lateral spreads			Rock spread	Earth spread	Debris spread
Flows			Rock flow	Earth flow	Debris flow
			Rock avalanche		Debris avalanche
			Deep creep	Soil creep	
Complex and compound			Combination in time and/or space of two or more principal types of movement		

Figure 1. Beichuan Middle School Landslide, China, 2008. Unprotected victims were incorporated into the landslide, resulting in over 800 victims with no survivors. © David Petley http://blogs.agu.org/landslideblog/2009/03/25/beichuan-photos-of-the-aftermath-of-a-natural-catastrophe/

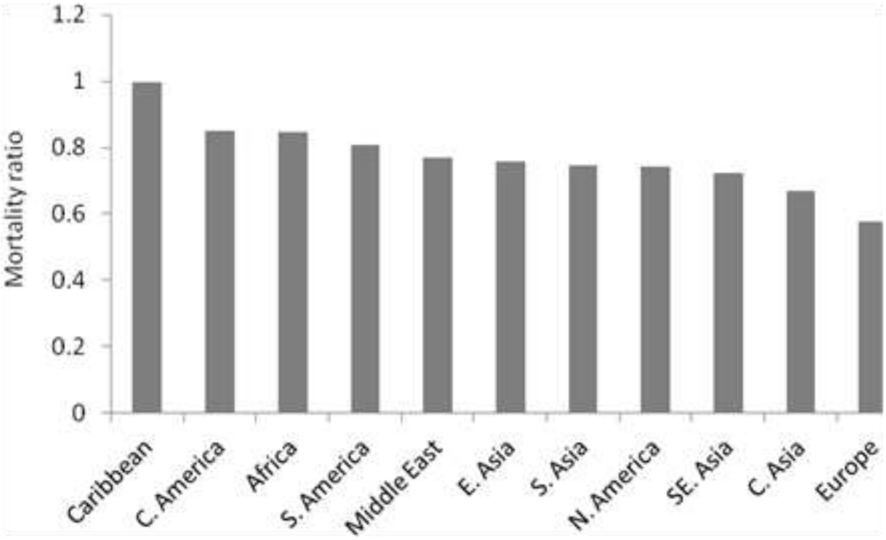

Figure 2. Durham Fatal Landslide Database for 2004-2010 landslide mortality ratios by continent (Petley personal communication, 2013)

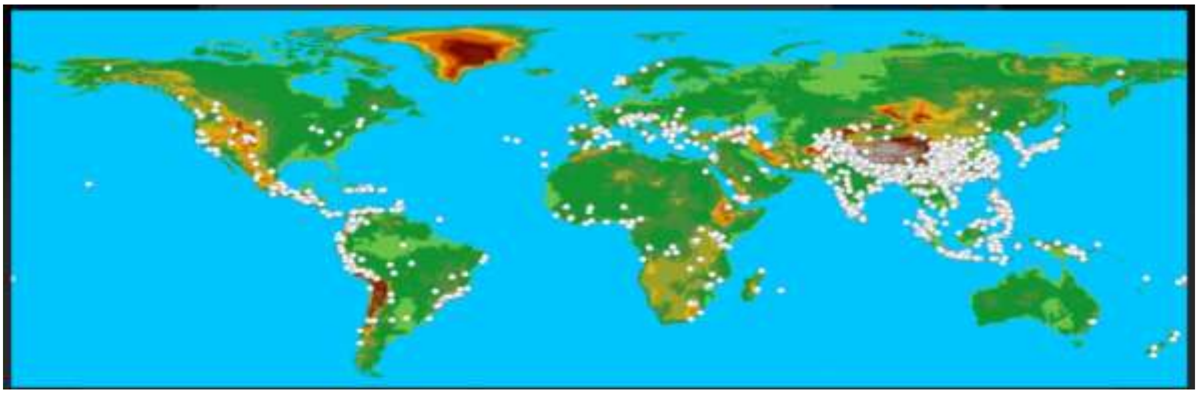

Figure 3. In 2004–2010, fatal landslides (white dots) were concentrated in southwestern India, eastern Asia, Central America and the Caribbean. (Petley, personal communication, 2013)

Health Impacts

As described earlier, a large proportion of direct physical health impacts of landslides are deaths. The most detailed study of a single event[13] examined risk factors for 43 fatalities during debris flows in Chuuk, Micronesia in 2002. The predominant cause of death was suffocation caused by being buried in the landslide (39/43), with one victim suffering blunt trauma including severe head injury. Three people died later of traumatic injuries, one of which was complicated by sepsis. On the day of the event, 48 survivors were treated in the emergency department with minor injuries, consisting mainly of lacerations and contusions, with concussions and fractures seen less commonly. A further 43 survivors were admitted to the hospital due to their injuries[13].

In this event, being under the age of 15 was a statistically significant risk factor for increased mortality. Awareness that landslides had recently occurred in the vicinity, and being aware of hazard warning signs, such as ‘rumbling water’, lowered mortality risk. However, no association between the size of the landslide or the slope angle and its impact on health was found.

Even when the victim is not buried by the landslide, injury can be sustained from being struck by rocks or other debris[14]. Landslides also cause indirect health impacts by destroying road and rail links; for example, there are reports of fatalities caused by vehicles striking landslide debris[15].

Because of the significant weight of debris, landslide survivors are susceptible to crush syndrome, which is characterised by rhabdomyolysis, renal failure and hyperkalaemia[16]. In severe cases, crush syndrome leads to development of multi-organ pathologies and ultimately death. Although crush syndrome is a common cause of death after disasters, it is treatable, particularly if detected early. Fluid resuscitation and dialysis are mainstays of treatment[17] (see Chapter 38).

Post disaster infectious diseases

As with other disasters, landslides are associated with outbreaks of infectious diseases. As landslides tend to destroy infrastructure such as housing and community facilities, temporary facilities are used. These facilities can promote infectious disease. For example, a study of a post-landslide camp in Eastern Uganda found there was insufficient access to clean water or latrines, which was exacerbated by many residents using a river water source, despite it being contaminated. There was significant burden of infectious disease, with 8.8% of respondents reporting a household member having diarrhea. However, respiratory infections (58.3% of respondents) and malaria (47.7% of respondents) were more common[18].

Increase in malaria incidence has been reported elsewhere, including during landslides after the 1991 Costa Rica earthquake. Depending on the region of the country, peak monthly reported rates were between 1,600% and 4,700% higher than the pre-earthquake rates. Landslides were a key factor in this, as they induced deforestation and changes in river flow patterns, which in turn increased mosquito breeding[19].

Landslides can also directly pollute water supplies through disruption of normal waste management systems and the transportation of soil and other materials into water courses. For example, after a landslide in the Karnaphuli Estuary, Bangladesh in May 2007, there was a rise in bacterial growth, including a ten-fold increase in faecal coliforms. There was also an upsurge of *Vibrio cholerae* populations, though this was smaller than after the preceding typhoon[20].

The Psychosocial Effects and Impacts on Mental Health

Landslides can significantly impact psychosocial and mental health. Mental health, particularly PTSD, is the most-studied health impact from landslides. Although some of the literature is old, and the diagnostic criteria have changed several times since their publication, they demonstrate that PTSD and major depressive disorder (MDD) are common among landslide survivors in settings as diverse as Italy, Mexico, Puerto Rico, and Taiwan.

A controlled prevalence study after the 1998 landslide disaster in Sarno, Italy, demonstrated that survivors were twenty times more likely than members of a control group to suffer from PTSD (27.6% v 1.4%). One year after the disaster, PTSD symptoms were nearly universal in the population of Sarno, with 90% of the study sample displaying PTSD symptoms relating to intrusive experiences.[21]

In 2010, Typhoon Morokot triggered landslides across much of southern Taiwan, killing 650 people. Diagnostic interviews with 277 adolescents displaced by landslides found 25.8% of the adolescents had PTSD three months after the disaster. Female gender, being injured during the landslide, and bereavement as result of the disaster were all associated with increased PTSD risk[22].

Researchers also studied the effects of a variety of factors on suicide risk in this population. Factors associated with a direct effect on increased suicide risk were female gender, higher frequencies of experiences of being exposed to disasters, PTSD, and MDD. High perceived levels of family support were found to have a protective effect. These data, however, may not be applicable to other populations as they describe a small group of adolescents who survived some of the worst effects of the disaster[23].

Landslides have been reported to have more severe psychosocial impacts than other disaster types. The authors of the Taiwan study contrasted the prevalence of PTSD in their cohort of 25.8% with a prevalence of 4.5% in a similar cohort after a 1999 earthquake in Greece. Similarly, after an extreme rainfall event in Mexico in 1999, a longitudinal study of people from a locality affected primarily by landslides was compared with people from an area affected by flooding. The landslide survivors had higher prevalence of PTSD (46%), as measured by diagnostic interviews six months post-disaster, compared to the group exposed to flooding (14%). Although the prevalence dropped faster in the landslide survivors, the rate remained higher than for the flooding group (19% vs. 8% at the end of a two-year follow up period)[24]. While both studies have confounding factors, the type of disaster may account for some of these differences.

Separate from psychological, social impacts were also measured for the Mexico event[25]. Subjects who experienced landslides were more likely: to have been bereaved (60.0% vs. 12.8%); to have lost larger amounts of property (58.5% vs. 44.2%); to have new interpersonal conflicts (29.8% vs. 19.4%); or to have had changes in social networks (social withdrawal) (71.2% vs. 60.9%) than those from flood affected areas. These factors reduce community resilience. Women generally perceived they had received less social support than did men.

The role of social support in families was also studied after landslides in Puerto Rico in 1985. Alcohol use, depression and total psychiatric symptomatology were found to be higher when there was a lower level of emotional support. Examining the role of family support, contrary to the authors' hypothesis, single and married parenthood did not affect level of symptoms, whereas those without spouses or children had the highest levels of alcohol use. [26].

The 1985 Puerto Rica landslide event was compared to that of survivors of a flood and resultant chemical release in the U.S. city of St Louis in 1982-1983, where there was a different pattern of psychosocial response. In St Louis, married parents not directly exposed to the disaster fared best, while married parents who were exposed to the disaster, and single parents regardless of their exposure status, had similar levels of psychological symptom logy. The variable exposures of the two groups, methodological differences, and unknown confounders may account for the disparity in psychosocial response; however, the distinctive cultural responses of the two groups may also have contributed[26].

A further study of the 1985 Puerto Rico disaster highlighted the importance of the role of cultural norms in disaster response. Investigators used modified diagnostic interviews to assess the prevalence of "*ataques de nervios*" (literally 'attack of nerves'). While described in the paper as a "Puerto Rican popular category of distress," and considered to be culturally "normal" in that community, some of the accounts of survivors' *ataques de nervios* symptoms appear sufficiently serious to suggest they would meet diagnostic criteria for acute stress reactions or other psychological disorders[27]. In fact, survivors who described *ataques de nervios* were more likely to have a mental disorder such as PTSD or major depressive disorder[28].

Risk Perception

The perception of disasters is mediated by a number of factors, including the type of disaster, previous experience with disasters, gender (e.g., men consider hazards less risky than women), and length of education (in years) [29]. Researchers describe that survivors of landslides report higher negative perceptions of control and impact from these events than survivors of floods.

The complexity of risk perception is demonstrated in the high landslide risk area of La Paz, Brazil. Known risk, a lack of trust in city officials, a "culture of silence," vested interests and political implications of alternate strategies resulted in the building of housing, much of it illegal, on high-risk slopes around La Paz. Nathan showed that the occupation of dangerous slopes can be explained as a rational attempt by local people to build resilience to political and social threats, which they perceive as being greater risks than landslides[30].

In their 2001 study of a landslide in a U.S. National Park, De Chano and Butler demonstrated that the risk perception of those not caught in a landslide does not change after the event, even with respect to the locations where landslides might occur.[31] However, perceptions of the authorities' response to the disaster can change. After a 2000 landslide in Stoze, Slovenia, public distrust of later interventions from national agencies was compounded by poor communications, conflicting advice, and lack of enforcement (for example by, ordering evacuation but not enforcing it)[32].

Mental models, which vary in complexity and accuracy, help individuals perceive risks of activities that have not yet occurred. The mental models for flash floods are more developed than those for landslides[33]; possibly because the physical processes for landslides are less well understood by the public. As personal experience, use of multiple sources of information and higher levels of fear about the hazard lead to better mental models, educational materials on landslide risk should draw on personal experience and be visually impactful, including the use of pictures of previous local disasters.

Risk mitigation/reduction measures

Landslide risk management is challenging. In more developed countries, large amounts of resources are spent engineering slopes against failure along transportation lines. For example, railway corridors usually consist of a combination of embankments, which can fail, undercutting the line, and cuttings, which can generate landslides that cover the track. Therefore, sophisticated techniques have been developed to investigate, design, manage and monitor slopes. These techniques are also widely used along highways in urban areas and to protect mountain communities. Failure rates of engineered slopes are low where these techniques are used, and high levels of safety result.

This is best illustrated by Hong Kong, which has the world's most successful slope management program. In response to a series of landslides in the early to mid 1970s, claiming almost 200 lives, the Hong Kong administration established the Geotechnical Control Office (now the Geotechnical Engineering Office), to manage slopes. A variety of techniques have been used to manage the risk, including:

- Relocation of the most exposed communities;
- Upgrading of manmade slopes;
- Enforcement of strict design codes;
- Accreditation of engineering and geological specialists;
- Development of a landslide warning system;
- Management of natural catchments likely to generate debris flows;
- Public awareness and information campaigns.

As a result of these techniques, summarized by Hencher and Malone in 2012,[34]] there has been a dramatic reduction in loss of lives from landslides in Hong Kong, with only three fatalities having occurred in the last decade.

Similar risk mitigation measures for landslides have been identified by communities in other settings. Researchers studying the response to the Stoze, Slovenia landslide disaster proposed simple legislation. This required clarifying agency responsibilities, sharing best practices, using local hazard assessment experts in area response teams, development of early warning systems, preparation of effective evacuation plans, and inclusion of disaster risk and response reduction into school curricula as a means of improving local and national interventions.

In Thailand, the installation of community early warning systems, first aid training, evacuation drills, and health education programs helped improve psychological well-being and adaptation (as a human coping mechanism) of the local population[35]. These risk mitigation measures therefore improve the resilience of communities to landslide disasters.

Comprehensive landslide management programs are extremely expensive, even for areas as small as Hong Kong, so are usually not practicable at the national scale. High mountain areas face additional challenges since the slopes are often too large or too remote to allow management in this way. For example, the 2010 Attabad landslide in Northern Pakistan had a volume of about 60 million m^3. In this case, management is best achieved through a combination of monitoring coupled with relocation of the most threatened communities and infrastructure when necessary. Landslide hazard mapping can help planners to prevent inappropriate development, although this assumes planning authorities are capable of enforcing the resultant regulations.

Work since 2004 in the East Caribbean covering communities containing unplanned housing, predominantly St. Lucia and Dominica, has demonstrated local implementation of affordable risk reduction strategies. Where implemented, slopes which had previously failed under lower rainfall levels were stable against a 1-in-4 year 24-hour storm and a 1-in-50 year 15-day rainfall. There were additional benefits in economic improvements, government relationships, and community resilience. This program included an organizational framework which provided engagement with vulnerable communities that allowed them to take ownership, gave project guidance, provided employment by engaging contractors from within the community, and built self-esteem[36].

Disaster response and recovery

The emergency response to landslide disasters is usually led by fire and rescue teams. However, there is little guidance available as to the most appropriate ways to search for trapped victims. The location of a victim within a landslide depends upon the nature of the movement. Fall events tend to engulf a victim in situ, whereas slides tend to push victims ahead of the main body of the landslide. Landslides undergoing flow type movement tend to incorporate victims into the mobile mass, rendering locating them much more difficult.

Without a structure to protect a victim, survival time for an individual who is engulfed by the mass is likely to be short, so response must be rapid. A depth of only 30 cm of beach sand can be sufficient to prevent lung inflation.[37] Hence, with a mass of about 2.5 tons per square meter, wet soil or rock may be fatal at shallow depths. After movement ceases, water within the landslide tends to percolate to the base of the slide, which becomes saturated, potentially drowning victims. The same process can lead to drying out of the upper surface of the landslide, making excavation more difficult. Rescues are often delayed by the need to safeguard the rescue team. Landslide events are frequently followed by subsequent failures; it is not unusual for these to be larger than the original collapse. These secondary collapses are caused by over-steepening of the slope by the initial failure, or because the failed block has split into two or more sections that fail sequentially. In the case of debris flows, 20 or more repeat events may occur during a single rainfall[38]

Almost all landslides leave scars that initially spall rocks or small failures. It is extremely difficult to identify whether these indicate another large failure is imminent, even for experienced landslide practitioners. Fire and rescue teams need to seek specialist advice and unique monitoring equipment to ensure safety is maintained[39]. Nonetheless, people are successfully rescued from within landslides, especially when protected within a well-constructed building. Extraction of victims is very challenging. The weight of landslide material can make it difficult to move by hand; mechanical excavators are better suited for this task, but their use is complicated when the location of buried victims is unknown. Rescue teams must balance speed against the risk of injuring a victim. It is difficult to ensure this balance is achieved.

Delay in use of specialist search and rescue teams, with advanced search technology such as acoustic listening and sonar devices, costs lives. In 2006, there was a five-day delay in obtaining technical support for search and rescue to a large landslide in the Philippines. Buildings, including a school, were displaced about 500 meters down slope before engulfing victims, such that initial search efforts were focused in the wrong area. In this period, the water table rose and drowned people who might have been saved if technical support had been available at the start of the response[40].

The expectations after landslides of residents of affected areas and those of response and recovery personnel can be very different. A study from Taiwan showed rescuers and survivors agreed that finance and reimbursement of loss should be the highest priority, and public information the lowest. However, residents felt patient care and supportive activities were the second and third priorities, while rescuers believed command and control was the second priority followed by patient care, with supportive activities being the second lowest priority. Residents were more likely to prioritize housing, food and sanitation.

These findings suggest responders are more focused on the immediate rescue phase, and may be less concerned with post-disaster recovery, whereas survivors concentrate on recovering losses. Responders should be sensitive to these motivations when assessing needs of the affected community[41].

Early integration of recovery in the response phase has been shown to lead to better outcomes. A case study examines the impact of a series of landsides in Guatemala that buried a town, including directly impacting the local hospital[42]. The hospital was operational within 16 days of the disaster at a temporary site. Describing the incident and the three phases of response, the factors that promoted successful movement from disaster response to recovery included an early shared vision of the recovery process. Local control of funds, good links with external aid agencies, and key personnel being invested in the project also improved the transition to recovery.

In addition to victims of the event, the psychosocial wellbeing and mental health of rescue workers and their families is at risk during and after disasters. Rescue work is labor-intensive and hazardous, and can be complicated by stressors, including fatigue, frustration, fear for personal safety, personal knowledge of the victims, and media exposure. Programs of psychological support that include on-scene and longer term follow up for individuals and families are beneficial.[43] However, there is no evidence that single session individual psychological debriefing is beneficial and it may even increase rates of PTSD.[44] (See Chapter 9)

Recommendations for Future Research

Geological and engineering aspects of landslides are well understood. Further research is needed on the health impacts of landslides, and how to minimize them. The most effective means of search and rescue and strategies for disaster risk reduction for landslides are additional areas where data from scientific studies may help improve response.

Routine collection of information on non-fatal medical and health effects of landslides would allow a better assessment of health burden, allowing investigation of injuries and mental health impacts. Basic studies, such as that reporting on the 2002 event in Micronesia[13], can be performed to gain a much greater insight into the human impact of landslides. Examination of the cause of death could also be carried out through retrospective review of post-mortem data.

Further research into health impacts will help inform rescue and recovery operations, and ensure providers have the necessary tools to maximize survival rates. More research on how best to integrate response and recovery phases, while concurrently meeting the needs and expectations of local populations, would also be valuable. As described in this chapter, there has already been exemplary landslide risk reduction and mitigation work, including community education and leadership, carried out in a number of different settings, with variable risk and resource levels. Further detailed reporting of these programs would allow the trialling of good practice in other areas to demonstrate portability of disaster risk reduction measures for landslides. Additionally, results of studies of disaster risk reduction and mitigation from other disasters could be better leveraged to identify best practices for landslide events.

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