International Journal of Epidemiology 1998;27:459–465

Fatal and hospitalized injuries resulting from the 1994 Northridge earthquake

Corinne Peek-Asa, Jess F Kraus, Linda B Bourque, Dushyanthi Vimalachandra, Jenny Yu and Jackie Abrams

Background The Northridge earthquake struck Los Angeles on 17 January 1994, originating from a previously unknown thrust fault. The earthquake measured 6.7 on the Richter scale and caused extensive damage to buildings, utilities and roadways. This report describes injuries occurring in the Northridge earthquake which resulted in death or hospital admission.

Methods Earthquake-related deaths were identified by the Los Angeles Department of the Coroner. All 78 hospitals in Los Angeles County were screened for earthquake-related admissions and were found in 16 of them. Coroner's records and medical records from the 16 hospitals were individually reviewed to identify earthquake-related injuries and to obtain information about the injury.

Results A total of 171 earthquake-related injuries was identified in Los Angeles County, 33 were fatal and 138 required hospital admission. Injury rates were approximately equal by gender and increased significantly with increasing age. Most of the fatalities were due to building collapse, and most of the hospital-admitted injuries were caused by falls or being hit by objects. Motor vehicle injuries and burns were also common causes of injury. Head and chest injuries were common among fatalities, and extremity injuries were the most common among those admitted to a hospital.

Conclusion Earthquakes cause injuries through many mechanisms, and a clearer understanding of these pathways can help focus prevention strategies. Research combining comprehensive surveillance with risk factor assessment can help identify behaviours and circumstances increasing the risk of injury in an earthquake.

Keywords Injury, disaster planning, epidemiology, risk factors

Accepted 16 September 1997

During the past 20 years, natural disasters have claimed more than 3 million lives worldwide, affected at least 800 million people, and resulted in property damage exceeding $500 billion.[1] Natural disasters often strike quickly and without warning, leaving little time for evasive action. Earthquakes are currently the most unpredictable and potentially severe of natural disasters. They have caused at least 1.3 million deaths between 1900 and 1988 and an estimated 20 000 deaths between September 1993 and the end of 1995.[2,3] An average of 16 earthquakes leading to death occur throughout the world each year, with many more leading to injury and property damage.[2] Individual earthquakes over magnitude 7.0 in China, the Philippines and Japan have reported thousands to hundreds of thousands of deaths.[4–6]

The Southern California Injury Prevention Research Center, UCLA School of Public Health, CHS 78-076, 10833 Le Conte Ave, Los Angeles, CA 90095-1772, USA.

Fault systems throughout California have had significant seismic activities causing extensive damage to concentrated population centres. In 1933, an earthquake of 6.3 magnitude on the Richter scale struck Long Beach, California killing 120 people and seriously injuring an estimated 300 more.[7] In 1971, a 6.5 magnitude earthquake occurred in Sylmar, California causing 58 deaths and up to 1000 injuries.[7,8] In 1989 the Loma Prieta earthquake, measuring 7.1 on the Richter scale, struck Northern California killing 63 individuals and injuring an estimated 3700.[9,10]

At 4.31 a.m. on 17 January 1994, the morning of Martin Luther King Day, an earthquake of magnitude 6.7 struck in the San Fernando Valley of Los Angeles. The earthquake, known as the Northridge earthquake, was caused by a previously unidentified thrust fault lying at least 9 miles under the valley floor. Earthquake activity was felt from Las Vegas to San Diego. The effects were immediate, including fires, downed power lines and traffic signals, property and road damage and severe

injuries.[8,11] Structural damage was reported to more than 12 000 homes, businesses, schools and hospitals, leaving many people homeless for extended periods.[11] The total estimated damage has exceeded 40 billion dollars, and even several years later buildings remain unrepaired and insurance settlements in dispute.[12]

Epidemiologists have suggested that enumerating the incidence of injuries and describing the activities which lead to injury during earthquakes are important in the development of prevention measures.[13,14] Researchers have hypothesized associations between injuries and seismic intensity, building characteristics, and activities of the individual, yet specific risk estimates are rare.[3,15,16] This study describes fatal and hospitalized injuries which occurred as a result of the Northridge earthquake. Individual medical records and coroners reports were used to identify causes and types of injuries.

Methods

The objective of this research was to identify and describe all fatal and hospitalized injuries which occurred as a result of the 1 January 1994 Northridge earthquake. Hospitalized injuries were defined as those that resulted in hospital admission between 17 January and 31 January 1994 and did not result in death. Only deaths and hospital admissions due to physical injury which occurred in Los Angeles County were included in the study population.

Injuries were defined as earthquake-related if the injury was due to consequences of earthquake activity. This included injuries from structural failure, being struck or trapped by objects dislocated during the shaking, falling during the earthquake, and sequelae of earthquake damage such as traffic control failure and clean-up injury.

Fatal injuries

Earthquake-related deaths were identified by the Los Angeles County Office of the Coroner. The Coroner's case definition included deaths such as cardiac events that did not involve a physical injury; this analysis includes only those deaths in which a physical injury was incurred. Autopsy reports were individually reviewed to determine the cause of death, injuries sustained and activity at the time of injury.

Because of the large number and the extreme severity of many fatalities, complete autopsies on all cases were not always possible. Of the 33 injury deaths, 60.6% did not have a complete autopsy and a complete list of injury diagnoses was not available.†

Hospitalized injuries

All 78 hospitals in Los Angeles County were screened to determine if there were any earthquake-related injury admissions between 17 and 31 January 1994. The screening procedure included the following steps: an interview with the Emergency Department Director, an examination of Emergency Department Logs, and an examination of discharge data. Of the 78 hospitals screened, 16 with earthquake-related admissions were identified. These 16 hospitals included three Level I and four Level II Trauma Centers, and nine hospitals with Emergency Departments. Medical records for all injury admissions in these hospitals were individually reviewed to identify earthquake-related injuries. Two additional Level I Trauma Centers were included to verify the accuracy of the screening process. No earthquake-related injuries were found in these two hospitals.

Injury coding

Injuries were coded using the Abbreviated Injury Severity (AIS) scale.[17] The AIS is a comprehensive taxonomy of individual injuries which denotes body region, type of anatomic structure, nature and severity of injury. The severity index ranges from 0 (no injury) to 6 (unsurvivable injury). The Injury Severity Score (ISS) estimates overall body trauma and is calculated by squaring and summing the three highest severity scores from different body regions. An ISS score of 76 indicates a non-survivable injury. An ISS of 99 is assigned when information is not detailed enough for severity coding.

Building inspection data

Buildings in which injuries occurred were linked to building inspection data purchased from the Los Angeles City Department of Building and Safety. The inspection data included all inspections made in Los Angeles City through October 1995. The injury information was linked to the Building and Safety database by injury address. Of the 171 earthquake-related fatalities and hospitalized injuries, addresses for 29 were unknown, 35 occurred outside the Los Angeles city limits and, therefore, could not be linked. Thirteen individuals not injured in a building were excluded. Of the remaining 94 people, 57 injury addresses were linked to the available building data and 37 injury addresses were not found in the building database.

Analysis

Injury rates were derived for Los Angeles County using data from the 1990 Census. Chi-square tests and odds ratios were calculated using SAS software.[18]

Results

Earthquake-related fatality and hospitalized injury rates

A total of 171 fatal and hospitalized earthquake-related injuries were identified in Los Angeles County for a rate of 1.93 per 100 000 residents. The hospitalized injury rate of 1.56 per 100 000 residents was 4.1 times the fatality rate of 0.37 per 100 000 residents (95% confidence interval [CI] : 2.81–5.99) (Table 1).

The rate of earthquake-related injuries for females was slightly but not significantly higher than that of males (risk ratio [RR] 1.20, 95% CI : 0.89–1.63). This pattern is unusual when compared with other types of injuries, such as motor vehicle crashes and homicides, where males have much higher rates than females.

There was a dramatic increase in earthquake-related injury rates with increasing age (Table 1). Compared with those aged 0–19, those aged 60–79 were 10.9 times more likely and those age 80 and above were 34.6 times more likely to sustain an earthquake-related injury. This trend was more pronounced for hospitalized than for fatal injury, with 75.8% of hospitalized and 31.2% of fatally injured over the age of 65.

† Six (18%) of the fatalities had a complete autopsy, seven (21%) had some internal examination, and 20 (61%) had external exams only. The 20 individuals who did not have a complete autopsy had multiple unsurvivable injuries.

Table 1 Earthquake-related injuries and population rates of injury. Fatal and hospital-admitted injuries, Northridge earthquake, 1994

	Earthquake-related injuries	Population[a]	Rate per 100 000 Los Angeles County residents	Rate ratios and (95% CI)
Total	171	8 863 164	1 93	n/a
Severity				
Fatal	33	8 863 164	0 37	1.00
Hospitalized	138	8 863 164	1.56	4.10 (2.81–5.99)
Gender				
Male	78	4 421 398	1.76	1.00
Female	93	4 441 766	2.09	1.20 (0.89–1.63)
Age[b]				
0–9	5	1 384 014	0.36	1.00[c]
10–19	5	1 223 397	0.41	1.00[c]
20–39	55	3 797 209	1.45	3.78 (1.93–7.41)
40–59	44	1 910 925	2.25	5.87 (2.95–11.68)
60–79	36	859 369	4.19	10 92 (5.42–22.01)
80+	25	188 498	13.26	34.58 (16.61–71.99)
Race				
White, non-Hispanic	102	3 618 850	2.81	1.00
Hispanic	38	3 351 242	1.13	0.40 (0.27–0.59)
African American	6	934 776	0.64	0.23 (0.10–0.52)
Asian/Pacific Islander	12	907 810	1.32	0.47 (0.26–0.85)
Other	3	50 486	5.94	T.S.[d]
Unknown	11	n/a	n/a	n/a

[a] Population for Los Angeles County, 1990 Census estimates.

[b] One injured individual had an unknown age and date of birth and is excluded from age rates

[c] The age groups 1–9 and 10–19 are combined for rate ratio estimation so that equal groups are compared. The combined denominator is 2 607 411.

[d] T.S. = Cells too small

Table 2 Cause of injury for earthquake-related fatal and hospitalized injuries, Northridge earthquake, 1994

Cause	Fatal (No. = 33) No. (%)	Hospitalized (No. = 138) No. (%)	Risk ratio for fatal outcome (95% CI)
Hit/trapped by building parts	22 (71.0)	11 (8.0)	8.36 (4.52–15.49)
Hit/trapped by objects	0 (0.0)	21 (15 2)	Undefined
Motor vehicle	5 (15.2)	4 (2.9)	5.23 (1.48–18 41)
Burns/electrocution	2 (6.1)	10 (7.3)	0.84 (0.19–3.64)
Fall	4 (12.1)	77 (55.8)	0.22 (0.09–0.55)
Cutting/piercing	0 (0.0)	7 (5.1)	Undefined
Other	0 (0.0)	8 (5.8)	Undefined

Earthquake injury rates were highest for White, non-Hispanic residents. The lowest earthquake injury rates were among African Americans, with an RR of 0.23 (95% CI : 0.10–0.52) compared to Whites. Hispanic and Asian Americans also had a significantly lower risk of earthquake injury. This pattern reflects the demography of the region closest to the epicentre.

Cause of injury

Injuries caused by falling buildings or building parts were the most common cause of fatal injury, and were 8.36 times more likely to cause fatal than hospitalized injury (95% CI : 4.52–15.49) (Table 2). Hospitalized injuries caused by falling buildings or building parts included eight individuals (5.8%) who were hit by beams or plaster and three (2.2%) who were hit by chimneys. Being hit or caught between objects, such as furniture, caused no fatal injuries, but was a frequent cause of hospitalized injury. Among the 21 hospitalized who were hit or caught by objects, 16 (11.6%) were struck by household objects or furniture, two (1.4%) were hit by falling glass, one (0.7%) was hit by an unknown household object, one was caught between two machines in a workplace and one was crushed by people fleeing a building.

Earthquake-related motor vehicle injuries were 5.23 times more likely to result in fatality than hospitalized injury (95% CI : 1.48–18.41) (Table 2). Two fatal and two hospitalized motor vehicle injuries were caused by collapsed or damaged roadways

Table 3 Injury event characteristics of earthquake-related fatal and hospitalized injuries, Northridge earthquake, 1994

Characteristic	Fatal (No. = 33) No. (%)	Hospitalized (No. = 138) No. (%)	Significance
Injury date			
1/17/94	33 (100.00)	123 (89.1)	
1/18/94–1/20/94	0 (0.0)	8 (5.8)	$\chi^2 = 3.14$
1/21/94–1/25/94	0 (0 0)	4 (2.9)	$P = 0.08$
1/26/94–1/31/94	0 (0.0)	3 (2.2)	
Days between injury and death or admission			
0	27 (81.8)	86 (62.3)	
1	3 (9.1)	21 (15.2)	n/a
2–4	2 (6.1)	16 (11.6)	
5+	1 (3.0)	15 (10.9)	
Place of injury			
Inside	26 (81.3)	108 (92.3)	$\chi^2 = 3.39$
Outside	6 (18.8)	9 (7.7)	$P = 0\ 07$
Unknown	1 (n/a)	21 (n/a)	
Injury involved structural failure			
Home	22 (66.7)	12 (8.7)	$\chi^2 = 52.4$
Roadway	2 (6.1)	2 (1.4)	$P < 0\ 01$
Utilities	1 (3.0)	2 (1.4)	
Other	0 (0.0)	2 (1.4)	
No structural failure	8 (24.2)	119 (86.9)	

and the remaining motor vehicle injuries were due to other causes such as traffic control failure. Falls were the leading cause of hospitalized injury but less frequent among fatalities (RR: 0.22; 95%CI : 0.099–0.55). Burns and electrocutions were equally likely in the two groups (RR: 0.89; 95% CI : 0.19–3.64).

Injury event characteristics

All 33 of the fatal injuries occurred on the day of the earthquake with 27 (81.8%) of these deaths occurring within minutes of earthquake onset (Table 3). Of the remaining fatalities, three survived up to 24 hours, 2 survived for up to 4 days, and one death occurred 8 days following the injury. Among the hospitalized, 89.1% of the injuries occurred on the day of the earthquake although injuries related to the earthquake continued to occur until 30 January 1994. Although 62.3% of the hospitalized sought care on the day that the injury occurred, 15.2% delayed seeking care for 1 day, 11.6% delayed seeking care for 2–4 days, and 10.9% did not seek care until more than 5 days after the injury.

A slightly higher proportion of fatal than hospitalized injuries occurred outside, although the majority of all injuries occurred indoors. The causes of injury indoors and outdoors differed. Indoor injuries involved structural failure of buildings, being hit by objects and falls. Of the individuals injured outside, nine were in motor vehicle crashes, five were falls and one was fatally electrocuted.

Twenty-five of the fatalities (75.8%) and 18 of the hospitalized injuries (13.0%) were caused by a structural failure. Over 66% of fatalities, but only 8.7% of hospitalized injuries, involved a structural failure of the home. Failure of roadway structures and utilities caused three (9.1%) fatalities and four (2.8%) hospitalized injuries. The 'other' category consists of one injury caused by a falling beam in a parking garage and a fall from a window.

Injury patterns

The average ISS of 63.6 for fatally injured is almost 10 times the average of 6.6 for those hospitalized (Table 4). The ISS for fatalities ranged from 4 to 76 and for severe fatal injuries from 1 to 26. The fatal injury with an ISS of 4 resulted from complications of a hip fracture.

Among fatalities, 26 (78.8%) had unsurvivable injuries with an ISS score of 76 (Table 4). The most common cause of death ($n = 22$) was a combination of asphyxia and body compression during building collapse. Two motor vehicle crashes and two burns also led to ISS scores of 76. Eighty-seven per cent of the hospitalized had an ISS of less than 16, indicating mild to moderate injury. Only three individuals sustained injuries with an ISS over 25, which included one head injury from being hit by a boulder, one person with broken ribs and chest trauma from a fall, and one severe burn.

The head was the most commonly injured body region among fatalities (48.5%), followed by thoracic injuries (42.4%) (Table 5). Abdominal and lower extremity injuries were also common among fatalities. It should be noted that injury patterns by body region for fatalities may be underestimated because autopsies were not complete for 60.6% of cases.

Injuries to the lower extremity were diagnosed in 74 of the 138 (53.6%) hospitalized individuals (Table 5). Femur fractures were the most common lower extremity injury, followed by

Table 4 Injury Severity Scores for fatal and hospitalized earthquake-related injuries, Northridge Earthquake, 1994

ISS Score	Fatal (No. = 33) No. (%)	Hospitalized (No. = 138) No. (%)	Significance
1–8	1 (3.0)	75 (54.4)	
9–15	0 (0.0)	45 (32.6)	
16–24	0 (0.0)	6 (4.3)	
25–39	2 (6.1)	3 (2.2)	
40–75	2 (6.1)	0 (0.0)	
76	26 (78.8)	0 (0.0)	
99[a]	2 (6.1)	9 (6.5)	
Average[b]	63.6	6.6	$P < 0.001$

[a] 99 = unknown severity

[b] Average excludes ISS of 99.

Table 5 Number and per cent of individuals sustaining injury in each body region, severe earthquake-related injuries, Northridge Earthquake, 1994[a]

Body region	Fatal[b]	Hospitalized
Lower extremity	6 (18.2)	74 (53.6)
Upper extremity	2 (6.1)	26 (18.8)
Spine	2 (6.1)	18 (13.0)
External	8 (24.2)	14 (10.1)
Head	16 (48.5)	10 (7.2)
Face	5 (15.2)	5 (3.6)
Chest	14 (42.4)	3 (2.2)
Abdomen	7 (21.2)	3 (2.2)
Neck	0	0.0

[a] Individuals are included in every region in which an injury was sustained, thus individuals with injuries in multiple regions will be represented more than once

[b] Injured regions for fatalities are underestimates because 20 of the 33 individuals did not receive complete autopsies.

pelvic fractures. Upper extremity injuries were sustained by 26 (18.8%) individuals with fractures of the humerus and radius being the most common upper extremity injury. Eighteen (13.0%) individuals had spinal injuries which consisted predominantly of lumbar burst fractures from falls. Fourteen individuals (10.1%) had burn injuries (external region) which ranged in severity from AIS level 1 to 3. Head injuries were sustained by 10 (7.2%) hospitalized individuals and were most frequently from falls or being hit by heavy objects. Three individuals sustained thoracic injuries.

Building inspections

Of the 57 injuries linked to building inspection data, 33 (57.8%) were non-fatal and 24 (42.1%) were fatal (Table 6). Seventy-five per cent of the fatalities which were linked to the building database had reported building damage, compared with 27.3% of buildings in which hospitalized injury occurred. Injuries most often occurred in apartment complexes which were the location for 17 of the 24 fatal and 15 of the 33 hospitalized injuries. Sixteen of the 17 fatal injuries in apartments occurred in one complex known as Northridge Meadows, which was later demolished. The other apartment complex in which a fatality occurred did

Table 6 Damage inspections and building type among fatal and severe earthquake injuries in Los Angeles City, Northridge Earthquake, 1994

Building type	Fatal		Hospitalized	
	Number inspected	Number (%) reporting damage	Number inspected	Number (%) reporting damage
Single family residence	6	2 (33.3)	11	3 (27.3)
Apartment complex	17	16 (94.1)	15	1 (6.7)
Condominium	0	n/a	2	2 (100)
Garage	0	n/a	1	1 (100)
Hotel	1	0 (0.0)	0	n/a
Office	0	n/a	1	0 (0.0)
Retail establishment	0	n/a	2	1 (50.0)
Entertainment establishment	0	n/a	1	1 (100)
Total	24	18	33	9 (27.3)

not report any damage on building inspection although the medical records indicated injuries due to building collapse. Building damage was reported in 6.7% of the apartment complexes in which hospitalized injuries occurred.

In five of the 30 buildings in which no damage was reported, the medical or coroner's record indicated that structural damage led to injury. Three of these people died of a combination of asphyxiation and body compression and indicated a collapsed building, one was injured in a falling doorway, and one was injured by falling structural debris. It is difficult to explain why three asphyxiation and body compression deaths in which the coroner's record indicated building collapse were listed in buildings receiving an inspection indicating no damage. One possible explanation could be an error in the reporting of the injury address. However, this also indicates that injury can be caused by structural failure which does not lead to complete building collapse or failure of building integrity, such as falling chimneys and doors.

Discussion

In the 1994 Northridge earthquake there were approximately four hospitalized injuries for every fatal one, which is similar to previous estimates.[2] Both fatal and hospitalized injury rates were particularly high among the elderly. Possible factors exacerbating injury among the elderly may include an inability to move quickly to avoid falling objects or to vacate buildings, as well as decreased tolerance to injury insults.

Entrapment from building collapse has been identified as the biggest risk factor for fatality in an earthquake and our findings support this conclusion.[5,16] However, neither entrapment nor structural collapse was a major predictor of hospitalized injury. The primary risk factors for serious injuries were falls and being hit by objects. Structural failure was a factor in 75.8% of deaths but only 13.1% of hospitalizations. These results indicate many causes of earthquake injuries, especially those not leading to death.

Injury severity scores for fatal and hospitalized injuries, which for most causes of injury show a continuous distribution over the range of values, was bimodal with very little overlap. Most fatalities had multiple non-survivable injuries from building collapse, indicating that survival after the building collapsed was unlikely. Severities for hospitalized injuries were on the lower spectrum of the ISS scale, with 54.5% of hospitalizations having a score less than 9. There is an indication that many individuals delayed seeking care for their injuries, and this trend may explain why some injuries on the lower end of the severity spectrum led to hospitalizations.

Secondary disasters following earthquakes, including fires, landslides or floods, have been identified as greatly increasing the lethality of an earthquake.[19] Fires were the only secondary disaster reported from the Northridge earthquake, and burns accounted for 6.1% of fatalities and 7.3% of hospitalized injuries. Fire-related injuries may have been minimized because most fires occurred in non-residential buildings which were sparcely populated during the earthquake and because fires were quickly controlled.

Most injuries in the Northridge earthquake, both fatal and hospitalized, occurred inside buildings. This finding reflects the location of most of the population during the onset of the earthquake and is not necessarily an estimate of the potential for injury. However, the types of injuries occurring indoors do differ from those outdoors, which mostly involve traffic crashes.

The onset of the earthquake at 4.31 a.m. when most people were at home, may have played a role in saving lives. Injuries from mass exodus of buildings, traffic and road failures, and falling store inventories and machinery may have been avoided. Further research on earthquake timing and injury outcome is needed, however, because other researchers have found more serious injury in night earthquakes.[2]

Although an attempt was made to identify all fatal and hospital-admitted injuries resulting from the earthquake, some cases may not have been identified. The screening process may have failed to identify hospitals who admitted earthquake injuries although a validity check in two hospitals found no additional cases. Medical records were individually reviewed to identify the activity at the time of injury and earthquake-relatedness, but misclassification could have occurred if the medical record did not mention an activity related to the earthquake. Misclassification in the opposite direction, in which non-earthquake injuries were classified as earthquake injuries, is unlikely and these estimates are thus conservative.

The total number of injured people from the Northridge earthquake is unknown, but some estimates have been reported. The Los Angeles County Health Department found that in the 10 days following the earthquake 9196 people sought emergency care in a sample of nine hospitals, but the relation of these injuries to the earthquake is unknown.[20] Estimates of up to 1200 hospital-admitted earthquake injuries have been reported, but these estimates are not based on medical record review.[7,11,21] Based on these estimates, the number of fatal and hospitalized injuries requiring hospitalization may comprise a small proportion of the overall number of injuries. These diverse reports demonstrate the difficulty in determining the incidence of injury following a major disaster.

Detailed information about the number and causes of injuries from earthquakes is needed to improve and evaluate intervention measures. The findings of this research show that earthquake injuries have complex causal pathways which include many variables, both behavioural and environmental. Many potential points of intervention can be identified in these pathways. Research incorporating epidemiological risk factor evaluation with engineering and geological analysis and medical response information will be the most powerful approach to designing effective prevention programmes for the different environments in which earthquakes occur.

Acknowledgements

We would like to thank the many people at the participating hospitals with whose help this study could not have been completed. We also wish to thank Kim Shoaf from UCLA, Billie Weiss and Maya Mahue from the Los Angeles County Department of Health, Roger Trent from the California Department of Health Services, Lashmanan Sathyavagiswaran and Joe Muto from the Los Angeles Department of the Coroner, and Chris Shultz from Harborview/UCLA Medical Center.

This research was funded by the California State Department of Health and the Southern California Injury Prevention Research Center. The findings of this research reflect the opinions and conclusions of the authors.

References

[1] Schultz CH, Koenig KL, Noji EK. A medical disaster reponse to reduce immediate mortality after an earthquake. *New Engl J Med* 1996;**334:** 438–44.

[2] Alexander D. The health effects of earthquakes in the mid-1990s. *Disasters* 1996;**20:**231–46.

[3] Smith GS. Research issues in the epidemiology of injuries following earthquakes. In: *International Workshop on Earthquake Injury Epidemiology for Mitigation and Response* Baltimore, MD, 1989 61–81.

[4] Sheng, CY. Medical support in the Tangshan earthquake: a review of the management of mass casualties and certain major injuries. *J Trauma* 1987;**27:**1130–35.

[5] Roces MC, White ME, Dayrit MM, Durkin ME. Risk factors for injuries due to 1990 earthquake in Luzon, Philippines. *Bull World Health Organ* 1992;**70:**509–14.

[6] Yoshimura N, Makayama S, Makagiri K, Azami T, Ataka K, Ishii N Profile of chest injuries arising from the 1995 Southern Hyogo Prefecture earthquake. *Chest* 1996;**110:**759–61.

[7] Langness D. *The Northridge Earthquake. Planning and Fast Action Minimize Devastation.* California Hospitals 1994;**8:**8–10.

[8] Cowen AR, Denney JP. *Earthquake.* Emergency Medical Service 1994; **23:**58–64.

[9] Pointer JE, Michaelis J, Saunders C *et al.* The 1989 Loma Prieta earthquake: impact on hospital patient care. *Ann Emerg Med* 1992; **21:**1228–33.

[10] Haynes BE, Freeman C, Rubin JL *et al.* Medical response to catastrophic events: California's planning and the Loma Prieta earthquake. *Ann Emerg Med* 1992;**21:**368–74.

[11] Carr SJ, Leahy SM, London S, Sidhu S, Vogt J. The public health response to Los Angeles' 1994 earthquake *Am J Public Health* 1996; **86:**589–90.

[12] Reich K. Quake called nation's most expensive disaster *Los Angeles Times,* March 13, 1997:B3

[13] Armenian HK. Methodologic issues in the epidemiologic studies of disasters. In: *International Workshop on Earthquake Injury Epidemiology for Mitigation and Response.* Baltimore, MD, 1989:96–106.

[14] Noji EK, Jones NP, Smith GS, Krimgold FR. Use of quantitative measures of injury severity in earthquake research. In: *International Workshop on Earthquake Injury Epidemiology for Mitigation and Response.* Baltimore, MD, 1989.39–60.

[15] Stratton JW. Earthquakes. In: *The Public Health Consequences of Disasters.* U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. Atlanta, GA, 1989:13–24

[16] Noji EK, Kelen GD, Armenian HK. The 1988 earthquake in Soviet Armenia: a case study *Ann Emerg Med* 1990;**19:**891–97.

[17] *Abbreviated Injury Severity Scale.* Des Plaines, IL: Association for the Advancement of Automotive Medicine, 1990.

[18] *Statistical Analysis Software, Version 6* Cary, NC: SAS Institute Inc., 1989.

[19] Coburn AW, Pomonis A, Sakai S. Assessing strategies to reduce fatalities in earthquakes. In: *International Workshop on Earthquake Injury Epidemiology for Mitigation and Response.* Baltimore, MD, 1989: 107–32.

[20] Weiss B. *Injuries in the 1994 Northridge Earthquake.* Los Angeles County Department of Health Services, Injury and Violence Prevention Program. Final Report to the Centers for Disease Control Los Angeles, CA, 1995.

[21] Durkin ME. Fatalities, nonfatal injuries, and medical aspects of the Northridge Earthquake. In: Woods, MC and Seiple W. (eds). *The Northridge, California, Earthquake of 17, January 1994.* California Department of Conservation, Division of Mines and Geology Special Publication **116:**247–54.