Morbidity and Mortality in The Loma Prieta Earthquake Earthquake: A Review of Recent Findings

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Abstract

In 1989, the *First International Workshop on Earthquake Injury Epidemiology for Mitigation and Response* was held at The Johns Hopkins University under the sponsorship of the National Science Foundation and the National Center for Earthquake Engineering Research. In this workshop, researchers representing a broad range of disciplines gathered to assess the state of the art in earthquake injury epidemiology, and to plot a course for future quantitative research in this important but often neglected area. Since that workshop, a number of significant earthquakes have occurred in the U.S. and elsewhere and have provided the opportunity for detailed follow-up on casualty. In this paper, a brief review of the findings to date of a detailed case-control study of morbidity and mortality during the Loma Prieta earthquake, partially funded by NCEER, will be given. As the full study is nearing completion at time of writing, only preliminary data are available, but more comprehensive results will be available within the next 12 month period.

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Objectives and Approach

The specific objectives of this study on morbitity and mortality in the Loma Prieta earthquake were to: assess the relative risk for physical injury associated with different physical environments, entrapment and personal behaviors in disaster and post-disaster phases; assess the relative risk for other potential risk factors for physical injury including pre-existing medical conditions and mobility, drug and alcohol use, and sociodemographic characteristics: estimate the absolute risk of physical injury mortality and morbidity associated with the earthquake in the County of Santa Cruz; and provide input data for casualty and loss estimation procedures for California and other areas of the U.S.

A secondary aim of this study was to determine if physically injured cases who sought treatment at a hospital were different from those who did not seek such care. Selection factors for treatment, such as injury severity, possession of health insurance, and sociodemographic characteristics were examined.

The approach to this research was to collect information on both injuries and risk factors through structured interviews. Injury information was also obtained from medical records and autopsy reports.

This research task is part of NCEER's Building Project. Task numbers are 88-4003, 88-6010, 89-4003, 90-4003, 91-6131, 92-6102 and 93-6102.

Introduction

Despite its apparent simplicity, obtaining reliable and accurate estimates of casualties associated with earthquakes has posed serious challenges. Such estimates have varied, in part, because there is no universally accepted definition of earthquake-related deaths and injuries. Furthermore, documentation of injuries has generally taken a lower priority than rescue and treatment activities in the face of disaster. The Loma Prieta earthquake was no exception. Initial press accounts put the total death toll in the hundreds (Shilts et al. 1989a; Shilts, et al. 1989b), an overestimate by a factor of three to four, and even the scientific literature could not agree on a total count, offering a range of 60 to 67 deaths (e.g., Anon 1990; McNutt 1990; CDC 1989; and USGS 1989). One year after the event, there was still no reliable information on morbidity (i.e., injury) associated with the earthquake (Jones et al. 1990b) This uncertainty still exists at the time of writing. The work described herein attempts to overcome these and other problems that have characterized previous research in this area.

While there have been clear advances in recent decades in most of the disciplines involved in earthquake casualty research, it is clear, with few notable exceptions (e.g., Glass et al. 1977), that epidemiologic methods have only recently begun to be applied to this area. Recent efforts have confirmed the assertion that there is much to be learned from the detailed analytical study of earthquake casualty. As society endeavors to reduce the consequences of natural disasters, appropriately directed and focused efforts are required. In the earthquake injury field, these efforts can be identified most readily through comprehensive and detailed epidemiologic study of events as they occur. A brief overview of epidemiology and its application to the study of earthquake injuries and structural engineering risk factors is given below. More details can be found in Wagner et al. (1994a).

Overview of Earthquake Injury Epidemiology

Epidemiology is the basic science underlying all public health prevention programs. A generally accepted definition of epidemiology is "The study of the distribution and determinates of health-related states or events in specified populations, and the application of this study to control of health problems" (Last 1988).

Epidemiologic studies can be divided into those which are *descriptive* or *analytical.* Descriptive studies (e.g., case series) are conducted when little is known about the causes of an injury or disease. These studies describe the patterns of injury or disease in populations according to demographic characteristics, such as age, sex and level of education; geographic location; and time period. While they are useful in generating etiologic hypotheses, descriptive studies cannot definitively demonstrate that a risk factor causes a particular ailment. Once clues become available, analytical studies (e.g., case-control) can be carried out to test hypotheses that suspected hazards cause a particular health condition. More details can be found in Wagner et al. (1994).

Earthquake injury epidemiology can be defined as the study of the distribution of death and injury in earthquakes and the causes of fatal or nonfatal injury. The causal mechanisms are difficult to elucidate precisely, as are the appropriate variables and indicators describing them. It is necessary to consider building construction types, and their performance during earthquakes, the influence of nonstructural components of buildings and building contents, occupancy and occupant behavior, emergency and rescue response, and medical treatment provided. These areas have not traditionally been the responsibility of any single field, but require the interaction of several disciplines. A rigorous epidemiologic approach to the study of earthquakes is based on the study of diseases/injury in whole populations, rather than studying a limited number of individual patients and their treatment (Last 1988; Lilienfeld 1980). As such, it seeks to determine risk factors or predict health outcomes that can then be used to develop sound principles for injury prevention in future events

Unfortunately, detailed epidemiologic studies of injuries in past events have not, in general, occurred. Thus, it is not clear exactly where prevention and treatment efforts and finances should be focused. If it is found, for example, that most severe injuries or deaths are resulting from inappropriate responses on the part of the victims, then education should be targeted as a priority item. If the interaction between building contents and occupants is causing high rates of injury, then more action needs to be taken to ensure proper anchorage of these contents. If a large number of people are dying because they are not being extricated quickly enough from collapsed buildings, then extrication techniques or rescue equipment need improvement. If a large number of people are dying after successful extrication from severely damaged or collapsed structures, then it is necessary to improve emergency treatment procedures.

The projects attempted under the sponsorship of NCEER, NSF , and the California Department of Health Services were the conduct of a case-series study, and a case-control study of injuries in the County of Santa Cruz associated with the Loma Prieta Earthquake of 1989 A brief outline of these studies and their findings to date is summarized below.

Accomplishments - The Loma Prieta Earthquake

On Tuesday, October 17, 1989 at 5:04 p.m. Pacific time, a magnitude 7.1 earthquake with an epicenter 10 miles northeast of Santa Cruz struck the northern California region. The County of Santa Cruz (CSC) was hard hit by the quake though it did not get the media attention of San Francisco and Oakland. The damage sustained warranted the assignment of the second highest intensity level assigned to the earthquake, i.e., MMI VIII, to much of the County. A case-control study of the risk factors for sustaining physical injuries in CSC associated with the Loma Prieta earthquake was initiated to study how the physical environments and personal behaviors of residents of CSC contributed to their risk of being physically injured or killed in CSC during the shaking of the main earthquake and in the subsequent 72 hours. The study is described briefly below. A more thorough discussion of the study methods can be found in Wagner et al. (1994b.)

Study Methods

Physical environments are characterized broadly as being inside a building, in or on a vehicle; or outside (in close proximity to a building or away from buildings entirely). Risk factors specific to each environment are also being explored Buildings are broadly classified as residential, commercial, industrial/farm, and public/institutional. For practical reasons (e.g., knowledge limitations of laypersons), the only attempt made through the questionnaire to infer structural type was through material description; this aspect is likely to require field follow up after preliminary data analyses. Within the building environment, hazards from structural and nonstructural components of buildings are distinguished from dangers posed by building contents. Behaviors of interest include the protection and rescue of oneself and other people, pets, or things, as well as clean-up activities in earthquake-damaged areas. Sociodemographic characteristics examined include age, sex, level of education, occupation, access to health insurance, etc.

The outcomes of interest are earthquake-related physical injuries that occurred during the shaking of the main earthquake (the disaster phase) and the subsequent 72 hours (the post-disaster phase). Injuries are characterized by their type, affected body parts, cause, and level of severity.

Information on both injuries and risk factors was obtained through a structured interview of cases and controls, or their proxies if necessary. Injury information on cases was also obtained from medical records and autopsy reports. Interviews were generally conducted by telephone. They were administered in English and Spanish. Interviews are a standard tool in epidemiology (Schlesselman 1982). They provide unique advantages over other methods of data collection for certain classes of information For example, interviewing individuals is the best method currently available to investigate human behaviors during an unanticipated event (such as an earthquake) in a large-sized sample.

To be eligible for the case-control study, participants had to have been living and present in CSC at the time of the earthquake. The case group consisted of those killed by the earthquake and those seen at an CSC hospital or flown by helicopter out of County for treatment of earthquake-related injuries. For comparison, a population-based random sample of current CSC residents was selected using a random digit dial of listed and unlisted residential telephones. The sample was divided into two groups: non-injured controls; and, injured controls, i.e., individuals who incurred an earthquake-related injury but were not treated at a CSC hospital or flown by helicopter to a hospital outside CSC. The non-injured controls were frequency matched to hospital and dead cases on general area of residence at the time of the earthquake. Three residential strata were defined by aggregates of contiguous zip codes in the County. Stratum 1 is the northern mountainous region of the County, stratum 2 is the coastal northern area of CSC (including the City of Santa Cruz) and stratum 3 is the southern part of the county (including the City of Watsonville). The goal was to interview two non-injured controls for each hospital or dead case.

The relationship between risk factors and earthquake-associated injuries and deaths is being evaluated for each of two time periods: 1) the disaster phase, the 15 second shaking period of the main shock, and 2) the post-disaster phase, defined as the next 72 hours.

Hospital and dead cases (or their proxies in the latter case) were interviewed from July 19, 1990 to March 31, 1991. Non-injured and injured controls were interviewed over the period of March 24, 1991 to August 31, 1991.

At the time of writing, most of the collected data have been coded and entered. Three basic types of analyses are being performed. First, hospital and dead cases are being compared to non-injured controls to assess the significant risk factors for injury. Second, hospital and dead cases are being compared to injured controls to evaluate the selection factors for seeking medical care among the injured. Third, several descriptive studies are being undertaken to assess the total morbidity and mortality in CSC associated with the earthquake.

Results

The proceeding data should be regarded as provisional since the data are still being validated and edited Final results will be published in the epidemiologic and engineering literature when available.

The hospital/dead case population consisted of 580 persons (or their proxies) targeted for interview. Of these attempted interviews, 483 (83%) were successfully completed, 31 (5%) were refusals, and 66 (11%) were lost to follow up (Jones et al. 1992). Of the 483 successful interviews, 286 were eligible for the case-control study.

In obtaining the random population sample, contact was attempted with 1880 households. Of these, only 7.4% refused to cooperate with the study. This low refusal rate among hospital/dead cases and the population sample is important, as it indicates that both study groups are likely to be representative of the populations from which they came. In all, 701 households were deemed eligible for the case-control study.

The data indicate that a significant proportion (108/701) of the population sample sustained some form of injury associated with the earthquake, even though they did not visit one of the CSC hospitals; of these 108 injured controls, 103 were eligible for the case-control study. This background rate of injury not reported to a hospital is of importance for disaster preparedness, as it must be factored into overall casualty estimates.

Table 1 presents an example from this study of the level of detail and organization of data needed to calculate estimates of the relative risk for exposures in a case-control study. The table presents the set-up of data for hospital/dead cases and non-injured controls by two potential risk factors, physical location and residence stratum when the mainshock began.

In table 1, the odds ratios for each stratum (which, in this example, represent the relative odds of being injured during the mainshock associated with being in a building when the shaking began) can be computed.

Loc. @ t_o	Hosp./dead cases				Non-inj'd controls			
	Stratum				Stratum			
	1	2	3	Tot	1	2	3	Tot
Bldg	*a*	*b*	*c*	*m1*	*q*	*r*	*s*	*o1*
Vehicle	*d*	*e*	*f*	*m2*	*t*	*u*	*v*	*o2*
Neither	*g*	*h*	*I*	*m3*	*w*	*x*	*y*	*o3*
Total	*n1*	*n2*	*n3*	*N1*	*p1*	*p2*	*p3*	*N2*

Table 1

Data set-up for analysis of respondent location (when main shock began) for hospital/dead cases injured during main shock and non-injured controls

The "odds ratio" ψ is defined as the ratio of the odds of injury in exposed individuals to the odds of injury in the unexposed. It is closely related to the rate ratio (Schlesselman 1982), and can be represented as

$$\Psi = \frac{P(I \mid E) / P(\bar{I} \mid E)}{P(I \mid \bar{E}) / P(\bar{I} \mid \bar{E})} = \frac{P(E \mid I) / P(\bar{E} \mid I)}{P(E \mid \bar{I}) / P(\bar{E} \mid \bar{I})}$$

where E represents exposure (in this case to a building), $\bar{E}$ nonexposure, and I, $\bar{I}$ represent injury and non-injury, respectively. The first term is the odds ratio sought, while the second represents quantities measurable in a case-control study; the two are equal by Bayes' Theorem. For stratum 1,

$$\frac{a / n1x(t+w) / p1}{(d+g) / n1xq / p1} = \frac{ax(t+w)}{(d+g)xq}$$

If the stratum-specific odd ratios are constant across strata, then it is appropriate to calculate a summary statistic. This is frequently accomplished using the Mantel-Haenszel estimate, a weighted average of the stratum-specific odds ratios (Mantel et al. 1959). If the stratum-specific odds ratios are not constant, then it is inappropriate to combine them. Instead, they should be presented separately with the interpretation that there is an interaction between the two risk factors (e.g., stratum and location at the moment the earthquake began)

Risk Factors for Injury

Some preliminary analyses have recently been completed (Wagner et al. 1994c; Wagner et al 1994d). A summary of some of the more significant results are presented below.

Event Phase

The risk of injury during the main shock, adjusted for area of residence within CSC, was computed using a stratified analysis (Wagner et al. 1994c). Injury risk was 2.87 higher for those in a building vs. other places when the earthquake began (95% confidence interval (CI) = 1.79-4.61). For those in a building, increased risk was associated with:

- damage to building components e.g., collapsing walls (OR=10.36; 95% CI=3.17-33.90);
- damage to contents e.g , falling furniture (OR=2 95; 95% CI=1.83-4.76);
- trying to rescue people (OR=2.49; 95% CI=1.63-3.82); or
- trying to exit a building (OR=1.93; 95% CI=1.30-2.91).

Decreased injury risk was associated with (during the shaking):

- standing under a doorway (OR=0.51, 95% CI=0.33-0.78); or
- holding on to something (OR=0.58, 95% CI=0.39-0.86).

Findings such as these can clearly help in devising future earthquake injury prevention strategies.

Post-Event Phase

The risk of injury during the post-event phase, adjusted for general area of residence within CSC, was computed using a stratified analysis (Wagner et al 1994d). An earthquake-related injury was reported for the post-event phase for 103 eligible cases. Using strict criteria, study investigators designated each injury as directly or indirectly related to the earthquake, or not having enough information to place it in either category.

For all injuries combined, increased injury risk during the post-event period was associated with factors considered directly related to the earthquake e.g.:

- rescuing or retrieving people, pets or things (OR=2.08; 95% CI=1.36-3.18);

- being trapped (OR=2.41; 95% CI=0.74-7 83); or

- being prevented or slowed from exiting a building due to earthquake-induced debris (OR=6.00; 95% CI=1.34-26.91).

Injury risk for these same factors increased for analysis restricted to injuries directly related to the earthquake (e.g., being trapped: OR=3.76; 95% CI=1.20-11.77) and became non-significant in the analysis of indirectly earthquake-related injuries.

These findings demonstrate the importance of classifying injuries by time period of occurrence and type of earthquake-related injury in order to properly characterize risks so that appropriate earthquake injury prevention strategies can be developed for both the event and post-event phases.

Relationship Between Injury and Building Type

A descriptive study was undertaken to describe the categories of injury associated with building types, and how the buildings are related to the causes of injury for a subset of injuries obtained in Santa Cruz County during the main shocks of the Loma Prieta earthquake (Porterfield et al. 1994). Preliminary results from the study indicate that there are differences in the distribution of building types associated with the location of cases at the onset of the shaking There are also differences in the distribution of how buildings relate to the causes of injury among the various building types.

In order to reduce the chances of being injured during an earthquake (if in a building when the shaking began), it is necessary to not only understand what types of injuries occur, but also what causes these injuries, and how the injuries are related to the structure or building the person was in at the onset of the earthquake. This descriptive study is a first attempt to relate building types to injuries. Although the nature of the study does not allow specific risk factors to be conclusively established (e.g., risk of being injured in specific building types), it will outline points of potential interest that should be examined in future studies.

Using interview data as a source of address information, a building survey was conducted by structural engineers in the County in the summer of 1992. Addresses were obtained (from case interviews) and validated through a careful evaluation of the (sometimes inconsistent) interview data. In all, a total of 543 sites were visited over a ten-day period. Structures were coded according a form which attempted to collect information compatible with the interview forms used in the case-control study and with ATC-13 classifications (ATC 1985) The primary purposes in collecting data were twofold: (1) to provide an expert and valid measure of structure-related risk factors for earthquake-related injuries and (2) to enable comparison of the experts' assessment to the interviewees' (i.e., lay persons') responses to the structure-related questions in the interview. The injury information on the interview was coded by trained nosologists using the ICD-9-CM (ICD-9-CM 1992). The specific ICD-9 codes were then broken down into nine broad injury categories: fractures, sprains (also includes dislocations and strains), intracranial, crushing, burns, penetrating, superficial, contusions, and other (includes unspecified injuries; injuries not elsewhere classifiable; and death — all of which were instantaneous). Each injury was also assigned a building relatedness code to describe the buildings' relation or possible relation in causing the injury. The cause of each injury (as related to a building) was assigned to one of the following categories: structural or nonstructural components, building contents, unspecified debris (possibly structural or nonstructural or building contents), neither structural or nonstructural components nor building contents, and unknown. Cause codes were assigned to each injury rather than each person. Thus, a person with multiple injuries could have his or her injuries assigned to different cause categories Presented herein are the preliminary results of a descriptive study that links the injury information (i.e., type of injury and building relatedness of injury) from the interview to the building type supplied through the engineering survey.

Cases selected for this descriptive study had to meet several criteria. (1) they had to be either killed by the earthquake or seen at a CSC hospital or flown by helicopter to an out of CSC hospital for treatment of earthquake related injuries, (2) they had to have been injured or killed during the main shaking of the earthquake, (3) they had to have been in a building when the shaking began Information on people injured after the main shock or who were not in a building when the shaking began will be presented at a later time. Currently 265 successfully interviewed people are thought to have met criteria (1) and (2) in the definition of a case. Of those 265, 238 (90%) were determined to have been in a building when the shaking began. The number of eligible people was further reduced from 238 to 210 for the following reasons (1) no exact address/location was given for the site at which the person was located when the shaking began, (2) a specific address was available from the interview, but the engineers could not find the site altogether, could not find a structure at the given location, or were unable to determine which was the appropriate structure at a site where several existed, and (3) the engineers were unable to observe the appropriate structure at a site due to physical barriers.

Table 2 shows the building type for the buildings in which each of the 210 cases was located when the shaking began. Since more than one person could have been injured at a single location, not all 210 structures are unique. Of the 210 possible structures, 191(91%) are unique. Ten structures (5 wood, 2 tilt-up, 1 reinforced masonry, 1 concrete) contained two cases when the shaking began, two (1 steel, 1 unreinforced masonry) had three cases and one (concrete) had six cases It is essential to keep in mind the fact that 70% of the cases were injured in wood buildings when interpreting the injury information contained therein.

Building Type	*# (%) of Buildings*
Steel	18 (9%)
Concrete	16 (8%)
Tilt-up	6 (3%)
Wood	145 (70%)
Reinforced Masonry	7 (3%)
Unreinforced Masonry	10(5)
Metal	5(2%)
Unknown	3(1%)
Total	210 (100%)

■ Table 2
Number (%) of Cases by Type of Building Occupied at Start of Shaking

A total of 487 injuries were reported in the 210 case interviews Table 3 shows the number (%) of injuries reported per building type. All of the combinations of injury categories and building types found in this study are presented therein Although some of the absolute numbers of injuries per injury class/building type category are too small to consider for meaningful analysis in this study, they may represent areas which need to be considered in the future. Unreinforced masonry buildings represent only 5% of the total buildings in the sample yet 25% of the intracranial injuries and 33% of the crushing injuries reported were associated with persons in unreinforced masonry buildings when the shaking began. Proxy interviews were completed for three dead cases in this study All three of these dead cases (included in the "other" injury cat-

	Type of Building								
Injury Type	Steel[4]	Conc.[5]	Tilt-up	Wood	RM	URM	Metal	Unkn.	Total
Fracture	4(9)	0(0)	1(2)	31(72)	1(2)	3(7)	2(5)	1(2)	43(100)
Sprain[6]	12(20)	5(8)	3(5)	35(58)	2(3)	0(0)	3(5)	0(0)	60(100)
Intracranial	1(8)	4(33)	1(8)	3(25)	0(0)	3(25)	0(0)	0(0)	12(100)
Crushing	0(0)	0(0)	0(0)	2(67)	0(0)	1(33)	0(0)	0(0)	3(100)
Burn	2(18)	0(0)	0(0)	9(82)	0(0)	0(0)	0(0)	0(0)	11(100)
Penetrating	0(0)	2(15)	1(8)	8(62)	1(8)	1(8)	0(0)	0(0)	13(100)
Superficial[7]	13(8)	14(9)	4(2)	117(71)	1(1)	12(7)	2(1)	1(1)	164(100)
Contusion	17(11)	16(10)	7(4)	103(66)	4(3)	3(2)	3(2)	4(3)	157(100)
Other[8]	2(8)	0(0)	0(0)	18(75)	1(4)	3(13)	0(0)	0(0)	24(100)
Total	51(10)	41(8)	17(3)	326(67)	10(2)	26(5)	10(2)	6(1)	487(100)

■ **Table 3**

Number (%) of Injuries by Injury Class, Building Type Occupied at Start of Shaking

egory) were in unreinforced masonry buildings at the start of the shaking. The distribution of building types in each of the injury categories does not always reflect the distribution of building types among the total number of buildings in the sample. Many factors contribute to this variable distribution.

The percentage of sprains, strains and dislocations due to structural or nonstructural components as well as the percentage of fractures caused by building contents are comparatively low (10% and 19%, respectively). A total of 43 (9%) of the injuries reported from the cases actually occurred outside (people were in a building when the shaking began but did not remain there for the entire event). Of the 43 injuries that occurred outside, 27 (63%) were caused by neither structural or nonstructural components nor contents. Many of these represent people who fell trying to get outside during the main shocks.

Table 4 represents the distribution of building types by building-relatedness of injury codes. It is essential to consider this distribution when ascertaining whether or not the building played a role in causing the injury. Those injuries caused by structural or nonstructural components are definitely building-related. Building-contents-related injuries are thought to possibly be building related because the performance of a structure will affect how the contents react in an earthquake. Those cases that were injured by neither contents nor structural or nonstructural components cannot be considered to have completely building unrelated injuries. Most of the injuries reported as unrelated to structural or nonstructural components, or contents, were falls. As with contents, the behavior of a building will have an effect on the way people react to the earthquake. It is thought that more falls, for instance, would occur in buildings that shake more. On the other hand, many factors (e.g., age, physical condition, sobriety) can alter the chances of someone falling and being injured by that fall. Therefore, deviations in the distribution of building-relatedness of injury codes per building type from the distributions of total building types in the sample should be noted, but a thorough analysis is beyond the scope of this paper.

Although the number of injuries in individual categories is often small it should be pointed out

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[1] Includes steel moment resisting frames, braced steel frames, steel frames with cast in place, concrete shear walls

[2] Includes concrete moment resisting frames, concrete shear wall buildings.

[3] Also includes dislocations and strains.

[4] Open wounds (i.e., lacerations)

[5] Includes unspecified injuries, injuries not elsewhere classifiable and instantaneous death.

Type of Building	Struct/ Nonstruct [1]	Contents [2]	Unspecified Debris [1] or [2]	Neither [1] nor [2]	Unknown	Total
	Building Related Cause of Injury					
Steel	10(20)	20(39)	6(12)	10(20)	5(10)	51(100)
Concrete	4(10)	19(46)	1(2)	12(29)	5(12)	41(100)
Tilt-up	6(35)	7(41)	1(6)	2(12)	1(6)	17(100)
Wood	28(9)	92(28)	78(24)	108(33)	20(6)	326(100)
RM	3(30)	2(20)	0(0)	4(40)	1(10)	10(100)
URM	20(76)	4(16)	0(0)	0(0)	2(8)	26(100)
Metal	0(0)	6(60)	0(0)	4(40)	0(0)	10(100)
Unknown	1(17)	4(67)	0(0)	1(17)	0(0)	6(100)
Total	72(15)	154(32)	86(18)	141(29)	34(7)	487(100)

■ **Table 4**
Number [%] of Injuries by Building Type and Building-Related Cause

that while only 15% of the total number of injuries were definitely caused by structural or nonstructural building components, 76% of the reported injuries that occurred in unreinforced masonry buildings were definitely caused by the structural or nonstructural components. All of the reported injuries associated with the three dead people were caused by either structural or nonstructural building components.

The distribution of contents-related injuries is very scattered. While concrete and metal structures have high percentages of contents related injuries (46% and 60%, respectively), wood buildings seem to have a significantly low percentage (28%) of injuries caused by contents. These figures should be considered when analyzing the overall relatedness of a building to specific injury categories.

The preliminary results of this component of the study show that there are differences in the distribution of building types associated with the location (of cases) at the start of the earthquake among the different injury categories. There are also differences in the distribution of how buildings relate to the causes of injury among the various building types

Conclusions

While a number of isolated studies of earthquake injuries had occurred prior to 1989, the International Workshop at Johns Hopkins made a significant contribution to establishing the field, identifying the critical elements, and defining the research needs The authors took advantage of the experience gained in the workshop to develop the case-series and case-control studies of injuries from the 1989 Loma Prieta earthquake described herein.

The study has already identified a number of important risk factors for injury, and as the analysis proceeds. will continue to provide data that are of value to emergency planners and the engineering community. While the results will provide a wealth of much-needed information, it should be emphasized that these results represent *one* event in *one* county in *one* state. Generalization of these data should be done with caution, and more data from other events are certainly needed. It is hoped that the lessons learned herein will make a contribution not only in the provision of raw data, but also in the lessons learned in conducting such a study. These lessons should facilitate more efficient studies in the future, and enable important gaps or potential improvements to be identified.

Personnel and Institutions

The case-series and case-control studies are a collaborative effort among The Johns Hopkins University, the California Department of Health Services (California's public health agency) and various consultants; the three CSC hospitals, Dominican Santa Cruz, AMI Community (Dominican and AMI Community have since merged), and Watsonville Community Hospitals; and the County of Santa Cruz Office of Emergency Medical Services and its consultants. Drs. Kirsten Waller, Alex Kelter and Roger Trent are the Department of Health Services principal personnel involved with the study. Jim Schneider and Lisa Angell, emergency medical care specialists, organized and directed the medical abstraction of hospital case records and provided ongoing advice and consultation to the study. Sayeed Choudhury contributed to the development of the engineering survey used by the site engineers to code buildings Dr. William B. Cross and Mr. Anqi Liu completed the engineering field work in CSC. Michelle Porterfield conducted the case-series analysis of the injury/building data.

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