LOSS ESTIMATION AND PROCEDURES

STUDY METHODS AND PROGRESS REPORT: A CASE-CONTROL STUDY OF PHYSICAL INJURIES ASSOCIATED WITH THE EARTHQUAKE IN THE COUNTY OF SANTA CRUZ

By Robin M. Wagner, Nicholas P. Jones, and Gordon S. Smith, The Johns Hopkins University; and Frederick Krimgold, Virginia Polytechnic Institute and State University

CONTENTS

ABSTRACT

A case-control study in progress is examining the risk factors for physical injuries associated with the Loma Prieta earthquake. The study explores how the physical environments and personal behaviors of residents of the County of Santa Cruz contributed to their risk of being physically injured or killed during the shaking of the main earthquake and in the subsequent 72 hours. This paper describes in detail the study design and methods. Information on risk factors and injuries was collected in the County of Santa Cruz through a structured interview and review of medical records during the field period, which ended in August 1991. The risk factors for physical injury examined include age of building, type of structure, occupant behavior, and sociodemographic characteristics. Preliminary results of the data collection efforts (for example, the number of cases and controls targeted for an interview and ascertained) are reported here. The collected data are currently being coded for data entry and subsequent analysis. Final study findings will be published when available.

INTRODUCTION

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 and Sward, 1989a, b), an overestimate by a factor of three to four, and even the scientific literature could not agree on a final total count, offering a range of 60 to 67 deaths (Journal of Emergency Nursing, 1990; McNutt, 1990; Morbidity and Mortality Weekly Report, 1989; and Plafker and Galloway, 1989). One year after the event, there was still no reliable information on injury morbidity associated with the earthquake (Jones and others, 1990). The work described below attempts to overcome these and other problems that have characterized previous research in this area.

This paper describes recent efforts made, since the Loma Prieta earthquake, to assess, both qualitatively and quantitatively, the morbidity and mortality associated with that event. This study, when complete, will not only provide useful information relative to this specific event, but will also augment substantially the literature available in disaster—specifically earthquake—epidemiology. As the research is still in progress, the material and data presented herein must be considered preliminary only. Unfortunately, since most of the efforts to date have focussed on study design, data collection, and coding, few quantitative data are available for presentation at this stage. Reported herein, therefore, are descriptions of the study design, implementation, and future plans, as well as preliminary assessments made from the data processed to date. Specifically the authors are unable to report injury rates, risk factors, and so forth, at this stage, owing to the ongoing status of the project.

PURPOSE OF STUDY

A case-control epidemiology study of the risk factors for physical injuries in the County of Santa Cruz, associated with the Loma Prieta earthquake, is being conducted Earthquake-related injuries that occurred during the shaking of the main earthquake and the next 72 hours are being examined. The study population is restricted to persons who were residents of the County of Santa Cruz and were physically present in the County at the time of the earthquake.

The specific primary aims of this study are:

1. To assess the relative risk for physical injury associated with different physical environments (for example, buildings, vehicles, outside), with entrapment, and with personal behaviors in the disaster and postdisaster phases of the Loma Prieta earthquake.
2. To assess the relative risk for other potential risk factors for physical injury including preexisting medical conditions and mobility, drug and alcohol use, and sociodemographic characteristics.
3. To estimate the absolute risk of physical injury mortality and morbidity associated with the Loma Prieta earthquake in the County of Santa Cruz.

A secondary aim of this study is to determine if physically injured cases who sought treatment at a hospital were different from those who did not seek such care. For example, selection factors for treatment that will be examined include injury severity, possession of health insurance, and sociodemographic characteristics

BACKGROUND AND SIGNIFICANCE

Earthquakes are one of the most feared natural disasters, causing injury and physical damage in developing and developed nations alike. Despite the fact that earthquakes have killed at least 1.3 million people in this century (Smith, 1990), they have received scant attention from epidemiologists.

PREVIOUS STUDIES

A critical review of the scientific literature on the causes of earthquake-related deaths and injuries leads to the following general conclusions. First, there is a paucity of epidemiological investigations of earthquakes, despite their great lethality (Smith, 1990). This dearth has arisen from inadequate funding and, until recently, from a relative lack of interest in the subject area by researchers (Tierney, 1990). Second, almost all of the published epidemiological studies on earthquake-related injuries are descriptive rather than analytical[1], precluding the ability to establish and quantify the magnitude of the relationship between significant risk factors and injuries. Only four earthquakes, prior to the Loma Prieta, have been examined through analytical studies of earthquake-related injuries: the 1976 Guatemalan (Glass and others, 1977); 1980 Italian (de Bruycker and others, 1983, 1985); 1988 Armenian (Armenian and others, 1992; Noji, 1990); and 1990 Philippine (Morbidity and Mortality Weekly Report, 1990) earthquakes.

Third, documentation of deaths and, in particular, nonlethal injuries is often incomplete in the aftermath of disaster,

[1]Descriptive injury studies investigate the experiences of injured or killed individuals only The background rate of exposure to the same hazards (for example, collapsing buildings) in the noninjured persons is not considered Analytical injury studies are superior to descriptive ones, in that they compare the experiences of injured persons to noninjured ones to identify and quantify significant risk factors for injury. Analytical studies permit researchers to test hypotheses that particular hazards are associated with injuries.

particularly in less-developed countries. Fourth, injuries are often vaguely and inconsistently defined in the previous epidemiological studies. For example, the definition of injuries may include conditions other than physical trauma (Sanchez-Carrillo, 1989), as well as any affliction treated after the disaster, whether or not it was earthquake-related (de Ville de Goyet and others, 1976). Investigators often employ different schemes to classify injury severity levels (Coulson, 1989). Fifth, most previous epidemiological studies of earthquakes have been conducted solely by health researchers, even though the topic calls for an interdisciplinary approach which draws on structural engineering, geology, architecture, epidemiology, and emergency medicine

The majority of studies on the risk factors for earthquake-associated injuries actually appears in the earthquake engineering literature. These studies have generally been executed along strict disciplinary lines without input from health professionals. Thus, despite their quantitative approach, these engineering studies do not employ standard epidemiologic methods or meet minimal criteria generally required by epidemiologists to accurately and reliably assess risks. For example, some surveys of earthquake victims are not based on random probability samples of a clearly defined study population (Arnold, 1986; Durkin, 1985 (San Fernando earthquake)); others do not report sufficient information to evaluate the sampling methodology (Mochizuki, 1988; Miyano and Mochizuki, 1988; Ohta and others, 1980; Ohta and Omote, 1977); still others sample highly select groups (Mochizuki and others, 1988)[2], making it difficult to generalize the results to the rest of the population. Many of these studies either do not report or have unacceptably low case ascertainment or survey response rates.[3] The survey instruments, when described, do not always appear to measure well the stated variables of interest (Ohta and others, 1977, 1980), although this may result from inadequate translations of the questionnaires published in the English-language scientific literature.[4]

Despite these limitations, the literature has identified a number of potentially important risk factors for injuries associated with earthquakes These include characteristics of the earthquake itself (magnitude, intensity, distance from the epicenter, time of day, and season), geological and topographic conditions (soil type, cliffs, or mountains), post-earthquake weather (rain which may cause landslides and extreme cold), the nature of the built environment (the degree of seismic resistance of buildings and other human engineered structures, such as bridges), the presence or absence of secondary hazards (fires, hazardous materials spills, tsunamis), sociodemographic features of the affected population (population density, age, and sex), and human behavior during and after the event (Stratton, 1989; Tierney, 1990). An extensive critique of the earthquake injury risk factor literature will be published later (Jones and others, 1993a).

CASE-CONTROL STUDY OF THE EARTHQUAKE

This study in progress aims to build and improve upon previous work. It is being conducted by an interdisciplinary research team which includes epidemiologists (including an injury specialist), an engineer, and an architect. As an analytical epidemiological study, it will be able to explore and refine hypotheses of the contribution of the built environment and behaviors to earthquake-related casualties. Physical injuries are clearly defined with respect to qualifying medical conditions, severity level, time of occurrence, and earthquake-relatedness. Risks posed by structural and nonstructural components of buildings are distinguished from those associated with building contents.

The County of Santa Cruz was chosen for study rather than other regions affected by the Loma Prieta earthquake for the following reasons. Although the media concentrated on the San Francisco Bay area, the earthquake was centered in the County of Santa Cruz and caused widespread damage and destruction in the County. The County of Santa Cruz also presented unique opportunities for ascertaining persons injured in the County. The County had a relatively small total population at the time of the earthquake (approximately 235,000). It was difficult to leave the County by ground transportation after the earthquake, since it is isolated by natural barriers (the Pacific Ocean and Santa Cruz Mountains), and the few roads leading out of it were inaccessible for days, owing to earthquake-induced damage. Furthermore, medical treatment options in the County were thought to be restricted to the County's three hospitals, since doctor's offices and clinics were reportedly closed for several days after the earthquake.[5]

[2]These researchers targeted college graduates because they thought respondents with higher education would have better memories than those with less schooling

[3]For example, results based on case ascertainment rates of less than 30 percent were reported for building occupants in the 1985 Mexico and 1986 San Salvador earthquakes (Durkin and others, 1988)

[4]The Ohta questionnaires were administered in Japanese but translated into English for publication.

[5]An exception to this is that one clinic, Salad Para la Gente, which sustained serious structural damage during the quake, set up an outdoor temporary clinic in the downtown Plaza of Watsonville following the quake The outdoor clinic provided limited services for minor injuries to a predominantly Hispanic clientele According to Salud's Director, Barbara Garcia, persons with serious injuries were referred to a County hospital.

PUBLIC HEALTH IMPACT OF THE STUDY

Injury prevention strategies can intervene at a number of different phases of an earthquake: the predisaster, disaster, and postdisaster phases (Noji and Sivertson, 1987). Interventions aimed at the predisaster phase prevent or limit people's exposure to the disaster; those directed toward the disaster phase limit the impact of the disaster while it is occurring; and those targeted at the postdisaster phase minimize the consequences of injuries incurred during the disaster. Examples of interventions for earthquakes include keeping people from living or working in seismically active regions and improving the design of buildings and (or) retrofitting them (for example, anchoring houses, bracing walls, and so forth) to prevent their collapse during the shaking (predisaster phase); instructing people on protective actions to take during the mainshock (disaster phase); and developing techniques to more rapidly rescue and treat victims trapped by rubble (postdisaster phase)

This case-control study will evaluate risk factors for the predisaster, disaster, and postdisaster phases. Thus, the lessons learned from this study can hopefully be used to design more effective injury prevention plans for future earthquakes.

Finally, this project is the first case-control study of earthquake-related injuries in a region in which many buildings have been designed or retrofitted to resist seismic forces. Thus, in contrast to the earlier studies which have concentrated on lesser developed nations, the results of this investigation are likely to be generalizable to future earthquakes in California and industrialized nations, such as Japan, which have well-conceived and enforced seismic building codes. This information should be valuable since there is a probability of approximately two-thirds that an earthquake at least as strong as the Loma Prieta earthquake will strike California in the next 30 years (U.S. Geological Survey, 1990).

PRELIMINARY STUDIES

BACKGROUND

This case-control study is one of several collaborative projects examining the health impacts of the Loma Prieta earthquake. The efforts of the participating research teams are being coordinated by the California Department of Health Services, the State's public health agency. This study builds on an ongoing descriptive, case-series study of the medical consequences associated with the earthquake in the County of Santa Cruz. The Johns Hopkins University team has played a leading role in the design and execution of both studies, in collaboration with California health authorities.

A major goal of the descriptive study is to determine the circumstances, causes, and nature of deaths and physical injuries requiring hospital treatment that occurred in the County of Santa Cruz and were associated with the earthquake. These cases are also part of the case-control study.

Hospital cases were identified by reviewing the medical records of all persons who visited the emergency room of any one of the three hospitals in the County of Santa Cruz—Dominican Santa Cruz, AMI Community, and Watsonville Community Hospitals[6]—for any reason in the 72 hours after the earthquake. County residents who were flown by helicopter to a hospital outside of the County were also identified as hospital cases. Helicoptered cases were identified through a review of the logs of all local helicopter ambulance services as well as through contact with the California Department of Forestry and Fire Protection. The latter agency used some of its helicopters to transport County residents to hospitals outside the County. Dead cases were identified by media reports and a visit to the County of Santa Cruz Coroner's Office. Dead cases and hospital cases whose medical records indicated they were "injured" or they visited the hospital for "unknown" (that is, unrecorded) reasons were targeted for a follow-up interview. Those with "unknown" diagnoses were targeted so as not to miss anyone who might have been injured.

The medical records of County of Santa Cruz hospital visitors were abstracted by 19 volunteers with medical training under the supervision of Santa Cruz County Office of Emergency Medical Services and Watsonville Community Hospital, collaborators in the project. Autopsy and coroner's reports were obtained from the Coroner's Office for the dead cases.

The interviewing phase of the descriptive study began on July 19, 1990, and was completed by March 31, 1991.

PRELIMINARY RESULTS OF THE DESCRIPTIVE STUDY

During the case ascertainment period (the 72 hours after the main earthquake), six persons died from earthquake-related physical injuries that occurred in the County. The three County of Santa Cruz hospitals recorded 1,057 visits to their emergency rooms, representing 990 persons (some people went to a hospital more than once in the 72 hours after the quake). Of these 990, 630 visitors (64 percent) had diagnoses of "injured" or "unknown." The remainder (36 percent) had "illness" diagnoses. A critical review of all the medical abstracts resulted in some of the "injured" or "unknown" persons to be judged ineligible (that is, not earthquake-related) whereas a few from the "illness" category had sufficiently ambiguous diagnoses to be included for an interview. This review resulted in 565 persons who

[6]Dominican has recently acquired AMI and converted it into a drug treatment center, nursing home, and intermediate care hospital.

Table 1.—*Distribution of target population of County of Santa Cruz hospital cases by hospital and medical outcome recorded on the medical abstract*

Hospital	Medical Outcome			
	Injury	Illness	Unknown	Total
Watsonville	215	4	33	252 (44.6 pct)
Dominican	193	0	14	207 (36.6 pct)
AMI	104	0	2	106 (18 8 pct)
Total	512 (90.6 pct)	4 (0.7 pct)	49 (8 7pct)	565 (100 0 pct)

Table 2.—*Distribution of ascertained County of Santa Cruz hospital cases that completed interviews as of December 26, 1990 by hospital and medical outcome recorded on the medical abstract**

Hospital	Medical Outcome			
	Injury	Illness	Unknown	Total
Watsonville	184	4	24	212 (45.6 pct)
Dominican	163	0	10	173 (37.2 pct)
AMI	79	0	1	80 (17.2 pct)
Total	426 (91.6 pct)	4 (0.9 pct)	35 (7.5 pct)	465 (100.0 pct)

* n=463 and n=2 for totally and partially completed interviews, respectively.

Table 3.—*Distribution of ascertained County of Santa Cruz hospital cases that refused to be interviewed as of December 26, 1990, by hospital and medical outcome recorded on the medical abstract**

Hospital	Medical Outcome			
	Injury	Illness	Unknown	Total
Watsonville	6	0	1	7 (23.3 pct)
Dominican	13	0	1	14 (46 7 pct)
AMI	8	0	1	9 (30.0 pct)
Total	27 (90.0 pct)	0 (0.0 pct)	3 (10 0 pct)	30 (100.0 pct)

* Includes final refusals (refusal conversion failed) (n=17) and refusals for whom refusal conversion process had not been completed (n=13).

visited a County of Santa Cruz hospital—including one of the six persons killed by the earthquake—or their proxies being targeted for an interview. Four additional persons were identified as injured and flown to an out-of-county hospital. Thus, the total pool of potential cases was 574 (565 County hospital cases (including 1 dead case) plus 5 other dead cases and 4 non-County hospital cases).

A total of 482 potential cases or proxies were interviewed (477 completed interviews and 5 break-offs), representing 83 percent of the total. Another 31 (5 percent) refused. About 11 percent were lost to follow-up.

Tables 1 and 2 show that the 465 County hospital cases who were interviewed as of December 26, 1990, (a final analysis is not yet available), were highly representative of the target population from which they came with respect to both medical outcome and hospital visited. Table 3 shows that refusals obtained as of December 26, 1990, were disproportionately higher than expected from the two north County hospitals (Dominican and AMI Hospital) and lower from the south County hospital (Watsonville). The reasons for this are unknown. However, Dominican Hospital acquired AMI in a highly publicized takeover during the interview phase, and this may account for some of the negative responses.

A more complete description of the case population and ascertainment methods is presented in the following section.

STUDY DESIGN AND METHODS

OVERVIEW OF METHODS

This case-control study examines how the physical environments and personal behaviors of the County of Santa Cruz residents contributed to their risk of being physically injured or killed in the County by the Loma Prieta earthquake. Physical environments are characterized broadly as being inside a building, in or on a vehicle, or outside (near a building or entirely away from one). Risk factors specific to each environment, such as collapsing chimneys or landslides, are also being explored. Within the building environment, hazards from structural and nonstructural components of buildings are being 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 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 postdisaster 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 the County at the time of the earthquake. The case group consisted of hospital and dead cases For comparison, a population-based sample of current County residents was selected using a random digit dial of listed and unlisted residential telephone numbers. The sample was divided into two groups: noninjured controls and population cases, the latter group comprising individuals who incurred an earthquake-related injury but were not treated at a County hospital or flown by helicopter to a hospital outside the County. The noninjured 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. The goal was to interview two noninjured controls for each hospital or dead case.

The injury status of individuals from the population sample was not determined in advance of the interview. Injury information collected in the interview was used to assign persons post-hoc to the appropriate category Based on the results of the pilot testing, 20 percent of the population sample was expected to have incurred an earthquake-related injury and thus qualify as population cases.[7] With such a background injury rate, it would be necessary to interview 2 5 members of the population sample for each hospital or dead case to achieve the desired 2:1 ratio of noninjured controls to hospital/dead cases. Population cases will be studied separately from hospital and dead cases.

Hospital and dead cases or their proxies were interviewed from July 19, 1990, to March 31, 1991. Noninjured controls and population cases were interviewed over the period of March 24, 1991, to August 31, 1991.

The collected data is currently being coded for data entry. Three basic types of analyses will be performed. First, hospital and dead cases will be compared to noninjured controls to assess the significant risk factors for injury. Second, hospital and dead cases will be compared to population cases to evaluate the selection factors for seeking medical care among the injured. Third, several descriptive studies will be undertaken to assess the total morbidity and mortality in the County of Santa Cruz associated with the earthquake.

TARGET POPULATION

The case-control study target population was the residents of the County of Santa Cruz at the time of the earthquake. The County is highly diverse with respect to geography and the demographic composition of its population. At the time of the earthquake, the County's population was approximately 235,335 (California Department of Finance, 1990). Approximately two-fifths of the population lived in one of the four incorporated cities—Santa Cruz, Watsonville, Capitola, and Scotts Valley—whereas the remainder lived in unincorporated areas of the County (table 4). The two major cities are Santa Cruz (n=51,082) and Watsonville (n=30,882) which are located in the coastal parts of north and south County, respectively.

The populations in the north and south County are quite distinct. The residents of north County are predominantly white and English speaking and have a relatively high socioeconomic status. Many are employed in the computer and electronics industries. Nearby Silicon Valley and tourism drive the local economy. A large university, University of California at Santa Cruz, draws many students and professionals to the area.

[7] This background rate is in keeping with the results of the case-control study of the 1988 Armenian earthquake, in which 30 percent of the selected controls were found to have been injured but not hospitalized (Armenian and others, 1992)

Table 4.—*Population characteristics of the County of Santa Cruz, January 1, 1990, estimates*

[Source: California Department of Finance (1990, p. 51)]

Location	Number (Percent) of People
Incorporated cities	
Santa Cruz (north County)	51,082 (22 pct)
Watsonville (south County	30,882 (13 pct)
Capitola (north County)	10,450 (4 pct)
Scotts Valley (north County)	9,460 (4 pct)
Total incorporated	101,874 (43 pct)
Unincorporated areas	133,461 (57 pct)
Grand Total	235,335 (100 pct)

In contrast, Watsonville has an agricultural economy with a large Hispanic population that fluctuates seasonally due to migrant farm workers Many of the Hispanics are poor, and an undetermined number are undocumented. A significant fraction of the Hispanic community lives in severely overcrowded dwellings; often two or three families live in a house designed for one family. Others live in converted garages, shacks and labor camps.

The County of Santa Cruz can also be categorized by geography Much of the County's population lives along the coastal regions in relatively urbanized cities. These coastal cities, running from north to south, include Davenport, Santa Cruz, Live Oak, Capitola, Soquel, Aptos, Rio del Mar, La Selva Beach, Freedom, and Watsonville. The rest of the population lives in the Santa Cruz Mountains, which run from the northwest to the southeast parts of the County. Cities in the mountains include Boulder Creek, Ben Lomond, Brookdale, Felton, Los Gatos, Mt. Herman, and Scotts Valley in the north, and Corralitos in the south The mountainous population itself is quite diverse and different from the coastal residents. The residents range from wealthy growers, commune dwellers, and artists to persons in communities as poor as Appalachia.[8] Most are white and generally very self-reliant—an attitude which may affect medical seeking behaviors.

Geography also serves to isolate the population from neighboring counties. The County is bounded by the Pacific Ocean and the Santa Cruz Mountains. Only a few highways lead out of the County, and some of these were closed for days after the earthquake due to landslides and other damage.

This geographic and demographic diversity is likely to have influenced the types of risk factors for injury and opportunities for medical treatment experienced by the population during and after the earthquake.

In fact, the catchment areas for the three County hospitals—the main source of hospital cases—have almost no overlap. Watsonville Hospital serves the south County area. Dominican and AMI are located about 1 mile from one another in the Santa Cruz city area and serve the north coastal and mountainous regions. This can be seen in table 5, which presents the distribution of target population of the County hospital cases by hospital visited in the ascertainment period and city of residence at the time of the earthquake. Almost all of the potential cases from Watsonville went to Watsonville Hospital (184 out of 191), whereas the vast majority of Santa Cruz residents went to either Dominican or AMI Hospitals (155 out of 158).

DEFINITION OF STUDY GROUPS

The case-control study consists of a case group, comprising hospital and dead cases, and a population sample, divided into noninjured controls and population cases. The hospital and dead cases are a subset of those from the descriptive study, having to meet more stringent requirements for entry into the case-control study. The eligibility criteria for both studies are summarized and compared in table 6. The study group definitions for the case-control study are described in the following two sections.

CASE GROUP: HOSPITAL AND DEAD CASES

Hospital cases were defined by the following criteria: (1) they were residents of the County at the time of the earthquake; (2) they were physically injured in the County during the shaking from the mainshock, or in the subsequent 72 hours as a result of the earthquake or its aftershocks; and (3) they were treated at a County hospital or were flown by helicopter to a hospital outside the County within 72 hours of the earthquake.

Dead cases met the following criteria: (1) they were residents of the County at the time of the earthquake and (2) they were killed in the County by physical injuries during the shaking from mainshock, or in the subsequent 72 hours as a result of the earthquake or its aftershocks.

[8]Personal communication from a number of local and Federal officials, including 1990 U S Census workers.

Table 5 —*Distribution of potential cases by hospital visited and city of residence*

Cities within County of Santa Cruz	Hospital			Total
	Watsonville	Dominican	AMI	
Aptos	8	22	6	36
Ben Lomond	4	1	0	5
Boulder Creek	0	2	4	6
Brookdale	0	1	0	1
Capitola	0	14	6	20
Corralitos	0	1	1	2
Felton	0	6	4	10
Freedom	11	0	0	11
La Selva Beach	3	0	0	3
Live Oak	0	0	6	6
Los Gatos	0	3	1	4
Mt Herman	0	0	1	1
Santa Cruz	3	102	53	158
Scotts Valley	0	5	4	9
Soquel	1	24	3	28
Watsonville	184	4	3	191
Zayante	0	0	1	1
Cities outside County of Santa Cruz	11	10	1	22
No residence information	36	6	8	50

To make the sampling frame for hospital cases and noninjured controls comparable, hospital cases were excluded if: (1) they lacked a home phone at the time of the interview or (2) they were living in institutional or commercial facilities at the time of the interview. These exclusion criteria will be waived if it can be determined from the interview that the case's condition is a consequence of the earthquake. For example, cases living in motels, shelters, or tents because the earthquake destroyed their homes are not excluded. The residential phone requirement will be waived for cases who usually had a home phone but who lacked one at the time of the interview because of earthquake-related circumstances.

POPULATION SAMPLE: NONINJURED CONTROLS AND POPULATION CASES

A random sample of current County of Santa Cruz residents was taken for comparison to the case group. This population sample comprised two groups, noninjured controls and population cases.

Noninjured controls were defined by the following criteria: (1) they were residents of the County when the earthquake occurred; (2) they were present in the County when the earthquake occurred; (3) they were alive at the time of the interview; (4) they were residents of the County at the time of the interview; and (5) they were not injured because of the earthquake in the ascertainment period.

Population cases satisfied criteria (1) through (4) used for the noninjured controls, plus two additional ones: (5) they sustained an earthquake-related injury during the ascertainment period and (6) as a result of these injuries, they did not seek treatment at a County hospital or were not flown by helicopter to a non-County hospital during the ascertainment period. Individuals who met the population case criteria and who sought treatment at other medical facilities (for example, private doctor's offices, clinics) were classed as population cases.

Table 6 —*Comparison of case and control definitions in the case-series and case-control studies*

Group Criteria	Case series study		Case-control study			
	Cases		Cases		Population sample	
	Hospital	Dead	Hospital	Dead	Population cases	Noninjured controls
Injured during shaking and (or) in next 72 hours in County	Yes	Yes	Yes	Yes	Yes	No
Earthquake-related injuries	Yes	Yes	Yes	Yes	Yes	NA
Visited a County hospital or flown by helicopter ambulance to out-of-county hospital	Yes	Sometimes	Yes	Sometimes	No	No
Resident of County at time of quake	Not required	Not required	Required	Required	Required	Required
Resident of County at time of interview	Not required	Not required	Not required	Not required	Required	Required
Had home phone at time of interview	Not required	Not required	Required[1]	NA[3]	Required	Required
Living in an institutional facility at time of interview	Included	Included	Excluded[2]	NA[3]	Excluded	Excluded
Alive at the time of the interview	Not required	Not required	Not required	Not required	Required	Required

[1]Cases without phones at the time of the interview will be included if their phone status was related to the earthquake (for example, they were institutionalized after their injuries, or they lived in temporary shelters because their homes were destroyed by the earthquake).

[2]Cases living in institutions at the time of the interview for reasons related to the earthquake will be included

[3]NA means "not applicable"

CASE ASCERTAINMENT (HOSPITAL AND DEAD CASES)

Hospital and dead cases in the case-control study are a subset of those in the case-series study. Thus, the former were ascertained in the same manner as the latter as described in the section, "Preliminary Studies."

As noted in that section, the review of medical records and helicopter logs resulted in 574 persons being targeted for an interview. Another five persons were ascertained in the process of tracing the cases who were identified from the medical records and helicopter logs. These five persons met the case definition and were interviewed. Thus, the final total population targeted for an interview was 579.

Reviews of the records of hospital and dead cases for whom an interview was obtained are underway to determine if they met the eligibility requirements for the case-control study. Preliminary results of this review are presented in the section, "Preliminary Progress Report on Case-Control Study."

POPULATION SAMPLE SELECTION PLAN

A population-based stratified random sample of current County residents was selected using a random digit dial of listed and unlisted residential phone numbers in the County. Selected individuals were screened for eligibility on the residency requirements (that is, living and present in the County at the time of the earthquake) before being enrolled.

As indicated above, the population sample included both persons who were not injured by the earthquake (noninjured controls) and those who were injured but did not go to a hospital (population cases). The injury status of enrolled individuals was not determined before the interview began. Thus, participants were assigned to the appropriate study group after the interview was completed.

To increase statistical power, an attempt was made to select two noninjured controls for each hospital or dead case. It was estimated that 20 percent of the County population and selected sample would have been injured (see discussion below). Thus, it was deemed necessary to choose 2 5 eligible individuals to achieve the desired 2:1 ratio of noninjured controls to hospital and dead cases.

Noninjured controls were frequency matched to hospital and dead case on general area of residence at the time of the earthquake, which is likely to be an important confounder (see section, "Target Population").[9] Matching closely on residential location was not done because this could result in overmatching on building type, a primary risk factor of interest.

In theory, residential strata should be as similar within and as different between strata as possible with respect to the geography and sociodemographic characteristics. This ideal was approximated by creating three strata of contiguous zip codes which were geographically distinct (table 7;

fig 1). Stratum 1 covered the north mountainous areas, where most of the County's mountain population lived. Stratum 2 corresponded to the north coastal region and included the cities of Santa Cruz, Capitola, Soquel, and Aptos. Stratum 3 covered the entire south County, including Watsonville, where most of the County's Hispanic population lived.

Noninjured controls were assigned to a stratum as part of the initial screening process. A random sample of listed and unlisted residential phone numbers for the County was computer generated.[10] Each number had an equal probability of being selected. Enrolled individuals were asked for their home zip code at the time of the earthquake before the interview began. Their answer determined the stratum into which they fell. Once the proper number of noninjured controls was selected for a stratum, additional persons initially selected from that stratum were not enrolled.

The matching information, home zip code at the time of the earthquake, was also obtained for hospital and dead cases from the questionnaire.

This sampling plan, unusual for a case-control study, was adopted because it was deemed both important and feasible. It was important because it would facilitate the study of persons injured by the earthquake who would not otherwise be ascertained as hospital and dead cases. The number of such persons was expected to be high. In the pilot test of the draft questionnaire—to refine the questions for inclusion in the final version—on a small random sample of County residents[11], it was found that 20 percent reported an earthquake-related injury of any severity level that was not treated at a hospital.[12] This rate, if borne out in the full-scale study, would translate into some 47,000 earthquake-related injuries in County residents.

The medical significance of injuries among population cases was also considered. Most population cases were expected to have minor injuries. However, the great majority

Table 7.—*Control selection strata by general area of residence in the County of Santa Cruz at the time of the earthquake*

Zip code	City
Stratum 1: North Mountainous County	
95005	Ben Lomond
95006	Boulder Creek
95007	Brookdale
95018	Felton
95030	Los Gatos
95041	Mount Herman
95066	Scotts Valley
Stratum 2: North Coastal County (predominantly nonmountainous)	
95003	Aptos
95010	Capitola
95017	Davenport
95060	Santa Cruz
95062	Live Oak
95064	UC Santa Cruz
95065	Santa Cruz
95073	Soquel
Stratum 3: South County	
95076	Watsonville
95019	Freedom

[9]A confounder (for example, residential stratum) for a risk factor of interest (for example, being in a building when mainshock began) can make it appear that there is a relationship between the risk factor of interest and the outcome of interest (for example, injury) when, in truth, there is none, and vice versa. Technically, a risk factor, C, is a confounder for the risk factor of interest, R, if: (1) C is an independent risk factor for the outcome of interest, I, and (2) C is distributed differently among the different levels or categories of R (for example, the distribution of residential stratum is different among those in a building and those not in a building when the shaking began), and (3) R does not cause C or vice-versa. One method to control or adjust for a confounder is to match cases and controls on that confounder. This is done when it is thought that a random sampling plan without matching may not produce enough cases and controls at each level of the confounder to examine the independent effect of other risk factors, holding the effect of the confounder constant, in the analysis phase. A disadvantage of matching is that one cannot examine the association between the confounder (for example, residential stratum) as a risk factor and the outcome of interest (for example, injury). Thus, in general, one tries to minimize the number of risk factors that are matched. In this study, matching on residential stratum was performed because this variable was thought to be a potential confounder, and a sampling plan was desired that would ensure an adequate number of cases and controls in each of the three strata. This matching will not preclude analyses of risks associated with other unmatched and potentially important risk factors (see section, "Purpose of Study"), including sociodemographic characteristics such as age, sex, and level of education.

[10]The telephone numbers were provided by the consulting firm Survey Sampling, Inc. (SSI) which had performed a Waksberg-like technique on all of the residential telephone prefixes in Santa Cruz County. SSI identified all "working blocks" of telephone numbers in the County. Details of the process will be provided in future reports.

[11]See section, "Questionnaire and Interview" for a brief description of the pilot testing procedures.

[12]An elevated background rate is consistent with the results of the case-control study of the Armenian earthquake, in which an even higher proportion (30 percent) of the selected controls was found to have been injured but not hospitalized (Armenian and others, 1992).