A case – control study of injuries arising from the earthquake in Armenia, 1988*

H.K. Armenian,[1] E.K. Noji,[2] & A.P. Oganesian[3]

The study attempts to identify predictors of injuries among persons who were hospitalized following the Armenian earthquake of 7 December 1988. A total of 189 such individuals were identified through neighbourhood polyclinics in the city of Leninakan and 159 noninjured controls were selected from the same neighbourhoods. A standardized interview questionnaire was used. Cases and controls shared many social and demographic characteristics; however, 98% of persons who were hospitalized with injuries were inside a building at the time of the earthquake, compared with 83% of the controls (odds ratio = 12.20, 95% confidence interval (CI) = 3.62–63.79). The odds ratio of injuries for individuals who were in a building that had five or more floors, compared with those in lower buildings, was 3.65 (95% CI = 2.12–6.33). Leaving buildings after the first shock of the earthquake was a protective behaviour. The odds ratio for those staying indoors compared with those who ran out was 4.40 (95% CI = 2.24–8.71).

Introduction

Much of the epidemiological information on earthquake injuries has been based on descriptive case studies (*1–5*). Current efforts to investigate earthquake-related morbidity and mortality are, however, attempting to correlate death and injuries with structural factors (*6–9*),[a] housing damage, victim behaviour (*10–14*), as well as other possible determinants. A number of the earthquakes that have been studied previously occurred in rural areas, and few epidemiological data are available from urban earthquakes (*15–19*). Better understanding about the factors associated with death and injuries in such settings is essential to determine the relief needs and the appropriate public health response (*20, 22*).[b] Only by understanding how and where people are injured in earthquakes can we recommend safer building designs and appropriate occupant behaviours to improve survival, and provide information to direct search and rescue efforts for potential survivors.

An earthquake that registered 6.9 on the Richter scale occurred in the northern part of Armenia at 11h 41 on 7 December 1988 (*22*). A total of 500 000 to 700 000 persons were made homeless, with an estimated 25 000 deaths. Of the 130 000 persons who were injured, 14 000 were hospitalized, primarily in Armenia itself.[c] In a joint project with the Ministry of Health of Armenia and the Johns Hopkins University, a number of epidemiological investigations of the earthquake survivors were developed. The first of these aimed at identifying predictors of injuries in persons who were hospitalized from the city of Leninakan. The present case–control study was conducted to compare individuals who were hospitalized because of injuries with controls who remained unscathed following the earthquake. The objective of the study was to increase understanding about the role of the physical setting (e.g., type

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[1] Professor and Deputy Chairman, Department of Epidemiology, Johns Hopkins University, School of Hygiene and Public Health, 615 North Wolfe Street, Baltimore, MD 21205, USA. Requests for reprints should be sent to this author.

[2] Assistant to the Branch Chief for Emergency Response, Health Studies Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health and Injury Control, Centers for Disease Control, Atlanta, GA, USA.

[3] Director, Republican Information and Computer Centre, Ministry of Health, Armenia.

[a] **Mochizuki, T. & Miyano, M.** A simplified failure model analysis of rural houses typical in East Turkey in aiming at countermeasures against human casualty due to an earthquake. In: *A comprehensive study on earthquake disasters in Turkey in view of seismic risk reduction.* Sapporo, Japan, Hokkaido University, 1983, pp. 87–129.

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[b] **Western, K.** *The epidemiology of natural and man-made disasters.* DTPH Dissertation. London, London School of Hygiene and Tropical Medicine 1972, pp. 1–123.

[c] *Report on international relief assistance for the earthquake of 7 December 1988 in the SSR of Armenia.* United Nations Disaster Relief Organization unpublished document UNDRO/89/6, 1989, pp. 1–35.

of building, location of occupants), occupant behaviour, and personal characteristics in earthquake-related injuries.

Methods

The study was begun in March 1989 and the data collection phase was finished in September 1989. The study population was defined as all persons who were hospitalized with injuries from the city of Leninakan as a result of the earthquake of 7 December 1988. A list of these patients, collected from discharge data from all the hospitals in Armenia, was available from the Ministry of Health, in Yerevan. However, case identification on the basis of the addresses given on the list proved to be impossible since the residences of most of the patients with injuries had been destroyed and they were living in makeshift housing or moved frequently to different places of residence. Because of these difficulties, the selection of cases and controls was limited to identification of individuals based on information provided by the neighbourhood polyclinics (primary care facilities which provide the entry point to the health services). From detailed maps of the city of Leninakan, a random city block was selected on each of the days of interviewing, and the neighbourhood polyclinic for the block concerned was contacted to identify the cases of hospitalized injuries caused by the earthquake. The name of each of the cases identified from these neighbourhood searches was checked against hospital discharge lists. For each of the cases, a control who had not been hospitalized with injuries was selected from another household in the same neighbourhood. An effort was made to match the controls and cases by sex and age within ±5 years. Since most of the interviewers, who were students, were employed for the summer months only, collection of data stopped in the autumn when the universities re-opened. Interviews of 189 cases and 227 controls were completed. However, 68 of the persons interviewed as controls had histories of injuries caused by the earthquake, but which did not necessitate hospitalization. These were studied as a separate group. Less than 1% of the total study population refused to be interviewed. After the variables of interest had been defined, a set of questions was formulated and a questionnaire was developed in Armenian and pre-tested on a sample of 14 cases and controls. The final questionnaire consisted of 67 questions and took about 30 minutes to administer. The questions covered sociodemographic information about the person and the family, where they were located and the position they adopted during the earthquake, injuries, rescue activities, details of health care following the earthquake, relief efforts and general health-risk behaviour. Each of the questionnaires was coded and put in computer format for processing and analysis. After simple frequency distribution analyses, the data for the cases were compared with those for the controls and odds ratios and confidence intervals were calculated. The analysis was unmatched, since a number of the cases were not matched to the controls, many of whom turned out to have been injured but not hospitalized. Multivariate analyses were performed using logistic regression.

Results

A number of the social and demographic characteristics of the cases and controls were similar. Thus, there were no significant differences between the two groups in terms of age, sex, distribution and educational background. Similarly, there were no differences for factors related to general health behaviour, such as smoking, exercise, and alcohol consumption (Table 1).

As shown in Table 2, 98.4% of the cases were inside a building at the time of the earthquake, compared with 83.0% of the controls, with an odds ratio of 12.20 and a 95% confidence interval of 3.62–63.79. The odds ratio for injuries for persons who were in a building with five or more floors compared to persons in lower buildings was 3.65 (range, 2.12–6.33) (Table 3). Also, the risk increased with

Table 1: **Distribution of the study groups, according to various characteristics**

	No. of hospitalized cases	No. of controls with:	
		No injuries	Mild injuries
Females	120 (63.5) [a]	95 (59.8)	42 (62.7)
Educational level			
<High school	29 (19.7)	21 (15.2)	14 (23.3)
High school	50 (34.0)	56 (40.6)	28 (46.7)
Technical college	40 (27.2)	31 (22.5)	7 (11.7)
University	27 (19.6)	21 (14.3)	10 (16.7)
Age group (years)			
<17	35 (18.5)	21 (13.2)	5 (7.4)
17–22	23 (12.2)	12 (7.6)	10 (14.7)
23–39	67 (35.5)	62 (39.0)	16 (23.5)
40–59	54 (28.6)	48 (30.2)	27 (39.7)
≥60	10 (5.3)	16 (10.1)	10 (14.7)
Smokers	42 (22.2)	36 (22.6)	14 (20.6)
Alcohol consumption	40 (21.1)	46 (29.1)	10 (14.7)
Regular exercise	81 (43.3)	59 (37.3)	22 (32.9)
Total	189	159	68

[a] Figures in parentheses are percentages.

Table 2: **Distribution of cases and controls, according to their location at the moment of the earthquake**

Location	No. of hospitalized cases	No. of non-injured controls
In a building	179 (98.4) [a]	132 (83.0)
In the street	3 (1.7)	27 (17.9)
Total	182 (100)	159 (100)

[a] Figures in parentheses are percentages.

Table 3: **Distribution of cases and controls, according to the number of floors in the building they occupied at the moment of the earthquake**

No. of floors	No. of hospitalized cases	No. of non-injured controls
≤4	91 (50.8) [a]	102 (79.1)
≥5	88 (49.2)	27 (20.9)
Total	179 (100)	129 (100)

[a] Figures in parentheses are percentages.

Table 4: **Distribution of cases and controls by location, according to the floor they occupied in the building at the moment of the earthquake**

No. of floors[a]	No. of hospitalized cases	No. of non-injured controls
1	30 (16.8) [b]	60 (46.9)
2–4	121 (67.6)	63 (49.2)
≥5	28 (15.6)	5 (3.9)
Total	179 (100)	128 (100)

[a] Odds ratios: floors 2–4 versus floor 1 = 3.84 (95% confidence interval (CI): 2.18–6.79); floors ≥5 versus floor 1 = 11.20 (95% CI: 3.62–37.03); Mantel-Haenszel weighted odds ratio = 4.95 (95% CI: 3.04–8.16).
[b] Figures in parentheses are percentages.

the number of the floor in the building (Table 4). The odds ratio for individuals who were on the second to fourth floors at the time of the earthquake, rather than on the first floor, was 3.84, while the odds ratio for those on the fifth floor or higher, rather than on the first floor, was 11.20.

The first reaction of individuals who were within a building at the moment of the earthquake, after the initial shock, was to run outdoors as a protective measure (odds ratio for staying indoors, 4.40; (range, 2.24–8.71)) (Table 5). A separate analysis was performed for the subgroup of cases and controls who had moved at all after the first shock. For this subgroup, the odds ratio for those who moved within the building compared with those who ran out of the building was 3.84 (range, 1.77–8.42).

Table 6 shows the odds ratios after a multivariate adjustment of these findings using logistic regression. The results indicate that this had no appreciable effect, except for location on the upper floors of the buildings, where the adjustment decreased the magnitude of the association.

Table 5: **Distribution of cases and controls, according to their reaction after the first shock of the earthquake**

	No. of hospitalized cases	No.of non-injured controls
Stayed indoors[a]	144 (90.0) [b]	88 (67.2)
Ran or jumped outdoors	16 (10.0)	43 (32.8)
Total	160 (100)	131 (100)

[a] Odds ratio for staying indoors = 4.40 (95% confidence interval: 2.24–8.71).

[b] Figures in parentheses are percentages.

Table 6: **Multiple logistic regression analysis, adjusting for age group and the variables shown**

Variable	Odds ratio	95% Confidence interval
≥5 floors in the building	3.45	1.76–6.74
Individuals located on floors:		
2–4 versus 1	2.60	1.42–4.75
5 versus 1	4.02	2.08–14.9
Stayed indoors versus ran outside	4.84	2.34–10.0

Discussion

Previous studies have stressed the importance of critically analysing earthquake data in order to develop methods for rapidly assessing health care needs and improving disaster relief (*1–5, 24, 25*). In the aftermath of the Armenian disaster, an opportunity arose for us to study the injuries in the city of Leninakan and to relate them to different types of buildings, occupant locations, and occupant behaviours.

There have been some attempts to correlate death and injuries in earthquakes with structural factors (*6–9*),[d] housing damage, victim behaviour

[d] See footnote *a*, p. 251.

(*10–14*), and other possible determinants of injury. Most of the previously studied earthquakes, however, occurred in rural areas, and except for the earthquake in Mexico City in 1985, little research has been conducted on a major catastrophic earthquake within an urban environment (*15–19, 26, 27*). Also, most studies have examined mortality and not morbidity. The present is the first case–control study that has focused on the determinants of injury in a major urban earthquake.

Among the factors that determine the number of people killed after a building collapses are entrapment, the severity of their injuries, how long individuals can survive without medical attention, the time taken to rescue them and the medical treatment they receive (*28, 29*).[e] A 1977 study of the Guatemalan earthquake concluded that deaths and injuries are critically dependent on the damage to housing and on the type of construction materials used (*7*). The most important findings of this study related to the significant differences between hospitalized cases and uninjured controls in terms of their location at the time of the earthquake and their behaviour immediately after the impact.

The most common cause of earthquake injury in Armenia resulted from vibration-induced failure of buildings, which entrapped victims (*30*). Such structures ranged from simple dwellings, with heavy roofing material, to large multistorey buildings which collapsed totally (*22, 31*). The structural engineering factors that lead to injury need to be addressed by improving building design and construction practices and by stringently implementing the building codes; also, initial occupant reaction during an earthquake could be taught and modified (*10*). Often it is assumed that during a major earthquake the ground motion will be too violent or the time will be too short for building occupants to pursue any actions that could affect their own survival or that of others. However, the few studies that have appeared suggest that occupants often have both the time and ability to take several actions before buildings collapse and that proper occupant action can be a decisive factor in either causing or preventing injury (*10, 12*). Education and training could therefore play a significant role in reducing earthquake morbidity and mortality; initial occupant actions following the first shock should, however, be based on a realistic appraisal of occupants' capabilities and actions during earthquakes. Studies suggest that many general beliefs about appropriate response can endanger rather than protect building occupants (*10*). Confusion about recommended first actions might arise because the relative efficacy of protective occupant actions is very much dependent on the seismic performance of specific building types (*13*).

Widely-accepted beliefs about how people react in earthquakes need to be re-examined; depending on the physical setting, some beliefs appear valid, others potentially fatal. Experience indicates that different types of building withstand earthquake shaking in quite dissimilar ways, thereby threatening occupants in different ways.[e] Thus, in San Francisco and Tokyo, whose buildings have a low probability of catastrophic collapse due to strict enforcement of building codes, and where there is some crowding of structures especially in central areas, the recommendation may be to stay indoors to avoid being struck by a rain of bricks on to pavements from unbraced balconies or ornamental parapets (*12, 32–36*). On the other hand, in countries with poor or nonexistent building codes, where the majority of the structures have the potential for catastrophic collapse, e.g., in Armenia, running out of doors at the first instant of the earthquake may represent the only chance of survival; however, this may be too simplistic. For example, in coastal towns of Peru that were affected by the catastrophic 1970 earthquake, people who rushed instinctively out into the wide streets at the first tremors escaped unscathed, and many of those trapped in the collapsed houses with flimsy roofs were rescued (*37*). In contrast, the people in the mountainous Callejon de Huaylas who reacted similarly to the first tremors were immediately buried in the narrow streets by tons of rubble bursting out from both sides under the weight of heavy town roofs. Also, in the parish of Venzone, hit by the 1976 Friuli earthquake in northern Italy, agile groups suffered more than the elderly or very young because they ran out into the narrow streets and were crushed by falling masonry (*38*). Clearly the development of sound guidelines indicating the best actions to take to reduce the likelihood of injury will require further careful studies of the location of injured and noninjured persons, correlated with specific geographical sites and building stock.

In Armenia, retrospective comparison of the behaviour of hospitalized, injured, and noninjured controls suggests that running out of the building decreased the injury rate. However, it is possible that many of the cases were unable to run out of the building because of their injuries, i.e., the injury itself could have influenced their behaviour. Our separate analysis of the subgroup of cases and controls who had moved at all after the first shock showed that those who were able to move and stayed in the building had an odds ratio of 3.84 for hospitalized

[e] **Coburn, A.W. et al.** *Factors affecting fatalities and injury in earthquakes.* Internal Report, Engineering Seismology and Earthquake Disaster Prevention Planning. Hokkaido, Japan, Hokkaido University, 1987, pp. 1–80.

injuries compared with those who ran out of the building. In Armenia, the early warning offered by preliminary tremors may also have been helpful in decreasing earthquake morbidity. Similarly, an earthquake in the Yugoslavian state of Montenegro in 1979 came in two shocks, with enough time between them for people to get outside their houses (*39*).

Although a building may still fail in an earthquake, injuries can be prevented or reduced if those parts of the building likely to be occupied by large numbers of people are designed in such a way that there is less risk of injury to the occupants. For example, one recommendation may be for structural engineers to design safe emergency exits, especially in taller buildings. However, in order to design an effective escape route, both behavioural and engineering factors need to be taken into consideration. Unfortunately, in many buildings the staircase is the weakest element when the ground shakes (*39*). Thus, high-rise apartment complexes are very dangerous in earthquakes, since they have few emergency exits, and vulnerable lifts and stairs. Clearly, proper occupant behaviour in earthquakes needs to be studied further in multidisciplinary investigations involving epidemiologists and structural engineers (*40, 41*).

Building types and structural systems have different collapse mechanisms when they fail under the influence of earthquake ground motion, and the type of building and collapse pattern affect occupant survival rates (*28, 42*). For example, in buildings that collapse quickly or that take a long time to evacuate a high proportion of occupants may be trapped. The few statistics that are available on reinforced concrete buildings show that about 90% of occupants are trapped by collapse of these structures.[f] This is probably due primarily to the difficulty of escaping from multistorey buildings. These observations are consistent with the results of our study, which showed that persons located on the lower floors of multistorey buildings were able to escape injury, or at least severe injury that required hospitalization. Thus, not only are the type of building and the occupant's behaviour important determinants of morbidity, but so also is the location of the victim at the time of the impact. Determining where people were located when they were injured or killed can provide valuable information to search and rescue personnel looking for potential survivors.

[f] **Spence, R.J.S. et al.** *Reducing human casualties in building collapse: methods of optimising disaster plans to reduce injury levels.* Cambridge University. Martin Centre for Architectural and Urban Studies, 1991, p. 25.

Study limitations

Although, the selection of the cases and controls in the study was far from ideal, it reflects some of the difficulties encountered in random sampling approaches in communities that have been almost totally destroyed by a disaster. However, comparison of the demographic characteristics of the cases with those of the total population of hospitalized patients from Leninakan indicated that for both groups a number of social and demographic factors were similar, which argues against selection or sampling bias for cases.

The possibility of interviewer bias also has to be considered since the case–control status of the study subjects was known to the interviewers. However, those controls who turned out to have minor injuries upon interview had characteristics that were more similar to those of the case group than to those of the controls. This speaks against interviewer bias. Finally, there were no differences between the case and control groups for a large number of variables that may have been thought to be earthquake-related but which were not.

Cultural factors and differences in building materials, practices, and patterns vary significantly in different countries, as do patterns of building use. Care must therefore be exercised in generalizing the results of the present study to other countries, particularly to industrialized countries (*23*). Despite these limitations, the results of the study have increased our understanding of the magnitude of the threats that different building types and occupant behaviours pose and have suggested practical guidelines to improve public awareness and protection in earthquake-prone parts of the world, e.g., educational programmes that focus on protective actions to take in earthquakes.

Conclusions

Our findings contribute to the overall process of developing a methodology for the investigation of the health effects of earthquakes. Studies such as this should help to guide building construction practices in earthquake-prone regions, suggest actions to be taken by occupants to prevent death and injury, and provide insights that will lead to the development of better earthquake-preparedness plans.

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Résumé

Etude cas-témoins des blessures consécutives au tremblement de terre d'Arménie, 1988

Dans cette étude, les auteurs ont cherché à déterminer les facteurs prédictifs de blessures chez les personnes hospitalisées à la suite du tremblement de terre survenu en Arménie le 7 décembre 1988. Ont été retenus comme cas 189 blessés hospitalisés dans un des dispensaires de quartier de Léninakan, et comme témoins non blessés 150 personnes provenant des mêmes quartiers. Un questionnaire par interview normalisé a été utilisé. Les cas et les témoins présentaient de nombreuses caractéristiques sociales et démographiques communes; toutefois, 98% des blessés hospitalisés se trouvaient à l'intérieur d'un bâtiment au moment du tremblement de terre, contre 83% des témoins (odds ratio = 12,20, intervalle de confiance à 95% (CI) = 3,62–63,79). Le odds ratio des blessures pour les sujets se trouvant dans un bâtiment ayant cinq étages ou plus, par rapport à ceux qui se trouvaient dans des bâtiments moins hauts, était de 3,65 (CI 95% = 2,12–6,33). Le risque de blessures était significativement plus élevé pour les personnes qui se trouvaient dans les étages les plus élevés lors du tremblement de terre. Le fait de quitter les bâtiments dès la première secousse constituait un comportement protecteur. Le odds ratio pour les sujets restés à l'intérieur par rapport à ceux qui sont sortis immédiatement était de 4,40 (CI 95% = 2,24–8,71).

Les résultats de cette étude épidémiologique contribuent au processus d'élaboration d'une méthodologie d'investigation des effets des tremblements de terre sur la santé. De telles études aideront à orienter les pratiques de construction dans les régions sismiques, à proposer des comportements permettant aux occupants d'éviter d'être blessés ou tués, et fourniront des indications qui permettront d'améliorer les plans d'intervention en cas de séisme en tenant compte des types de constructions usités dans la région.

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