

Deaths and Injuries due to the Earthquake in Armenia: A Cohort Approach

HAROUTUNE K ARMENIAN,* ARTHUR MELKONIAN,** ERIC K NOJI† AND ASHOT P HOVANESIAN**

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Background. This is the first population-based study of earthquake injuries and deaths that uses a cohort approach to identify factors of high risk. As part of a special project that collected data about the population in the aftermath of the earthquake that hit Northern Armenia on 7 December 1988, employees of the Ministry of Health working in the earthquake zone on 7 December 1988, and their families, were studied as a cohort to assess the short and long term impact of the disaster. The current analysis assesses short term outcomes of injuries and deaths as a direct result of the earthquake.

Methods. From an unduplicated list of 9017 employees, it was possible to contact and interview 7016 employees or their families over a period extending from April 1990 to December 1992. The current analysis presents the determinants of 831 deaths and 1454 injuries that resulted directly from the earthquake in our study population of 32 743 people (employees and their families).

Results. Geographical location, being inside a building during the earthquake, height of the building, and location within the upper floors of the building were risk factors for injury and death in the univariate analyses. However, multivariate analyses, using different models, revealed that being in the Spitak region (odds ratio [OR] = 80.9, 95% confidence interval [CI] : 55.5–118.1) and in the city of Gumri (OR = 30.7, 95% CI : 21.4–44.2) and inside a building at the moment of the earthquake (OR = 10.1, 95% CI : 6.5–15.9) were the strongest predictors for death. Although of smaller magnitude, the same factors had significant OR for injuries. Building height was more important as a factor in predicting death than the location of the individual on various floors of the building except for being on the ground floor of the building which was protective.

Conclusions. Considering that most of the high rise buildings destroyed in this earthquake were built using standard techniques, the most effective preventive effort for this disaster would have been appropriate structural approaches prior to the earthquake.

Keywords: cohort, deaths, disasters, earthquakes, injuries

A number of investigations have studied death and morbidity as a result of earthquakes using cross-sectional field survey techniques as well as case-control methods within the period immediately following the disaster.^{1–5} A number of these past investigations of earthquake related morbidity and mortality have reported associations of death and injuries with structural factors and damage.^{6–10} These investigations have identified injury and death prevention strategies under such circumstances as well as assisting in improving rescue, medical and public health action taken after an earthquake's impact.^{11–15}

An earthquake registering 6.9 on the Richter scale hit the northern part of the Armenian Republic of the Soviet Union at 11:41 a.m. on 7 December 1988.¹⁶ Between half-a-million and 700 000 people were made homeless, with deaths estimated at 25 000. More than 21 000 residences were destroyed.¹⁷ While definitive data is not available, it would appear that the population trapped in buildings following the earthquake could be estimated at between 30 000 and 50 000.¹⁸ Of the 130 000 people injured in this earthquake, 14 000 were hospitalized, primarily in Armenia.^{19,20}

As part of a special information project that collected data about the population in the aftermath of the earthquake, we initiated a number of epidemiological studies that would provide the necessary intelligence about structural risk factors and appropriate protective behaviour in the immediate period following an earthquake.^{21,22} A case-control study was conducted in the summer of 1989 in the city of Gumri (known as Leninakan at the

* Department of Epidemiology, School of Hygiene and Public Health, The Johns Hopkins University, School of Hygiene and Public Health, Department of Epidemiology, 615 N Wolfe Street, Baltimore, MD 21205, USA.

** Republican Information and Computer Center, Ministry of Health, Armenia.

† Centers for Disease Control and Prevention, Atlanta, GA, USA.

TABLE 1 *Frequency distribution of the study population by age, gender, and geographical location*

	Gumri		Spitak		Others		Totals
	N	%	N	%	N	%	N
Age							
0–10	1995	17.2	422	19.1	3509	18.4	5926
11–20	1747	15.1	412	19.4	3179	16.7	5338
21–30	2200	19.0	359	16.9	3502	18.4	6061
31–40	1878	16.2	356	16.8	3339	17.5	5573
41–50	1059	9.1	141	6.7	1554	8.2	2754
51–60	1553	13.4	227	10.7	2314	12.2	4094
61–70	840	7.3	143	6.7	1200	6.3	2183
>70	309	2.7	61	2.9	444	2.3	814
Gender							
Females	6140	53.0	1079	50.9	9956	52.3	17 175
Males	5441	47.0	1042	49.1	9085	47.7	15 568
Total	11 581	100.0	2121	100.0	19 041	100.0	32 743

time of the earthquake) involving 189 cases of hospitalized injuries and 156 controls who remained unscathed after the earthquake.²³ This case-control study identified a higher risk of injuries for those who were in taller buildings and who were located on the higher floors of these buildings as well as for those who were indoors during the earthquake. Based on these initial findings from the case-control study, a large scale cohort study was started to study these risk factors from a population perspective, to monitor the long-term health effects of one of the worst natural disasters of the 20th century on the health conditions of the affected population and to ascertain continuing needs for health services. This paper presents the findings of the cohort study as to determinants of deaths and injuries in the immediate post-earthquake period.

METHODS

A number of options were considered in selecting a population from the earthquake zone for long term surveillance and monitoring. The criteria for selecting such a population included representativeness, ease of follow-up, and the ability to identify the study population to the day prior to the earthquake through some type of listing. Following a search for an appropriate study population, it was decided to use the employees of the Ministry of Health living in the earthquake region on 6 December 1988, and their first degree families. Listings of these employees were obtained from payroll and personnel sections as well as from the Republican Information and Computer Center of the

Ministry of Health in Yerevan. Since the employees of the Ministry of Health and their families included people from a very broad sector of the population, they were probably representative of the larger group except for better access to medical care. Better access to medical care was actually considered an advantage for the follow-up part of this study. Due to our access to the personnel files of these employees, tracing was considered to be easier than for most other subgroups that were considered for the cohort. From an initial unduplicated list of 9017 employees, 7016 were located, primarily at their workplace, but some were also interviewed at home. Of the employees that we were not able to contact, 927 had moved outside the earthquake region with no follow-up address, 73 had died and their families relocated, 106 refused to be interviewed and for 895 names on the initial list no information was available about such employees or no contact could be established after a number of attempts. For each of the employees that could not be located, a special effort was made from their available colleagues to get information on the vital as well as migration status of the individual and their families. A comparison with the available information from the original listings revealed that people who could not be traced included a larger proportion of physicians and employees who were posted in the city of Gumri (Leninakan) compared to those that could be located. Table 1 has a listing of the study population by age group, gender and area of residence.

Following a definition of the variables of interest, a questionnaire was developed in Armenian and pretested in Armenia on a small sample of employees.

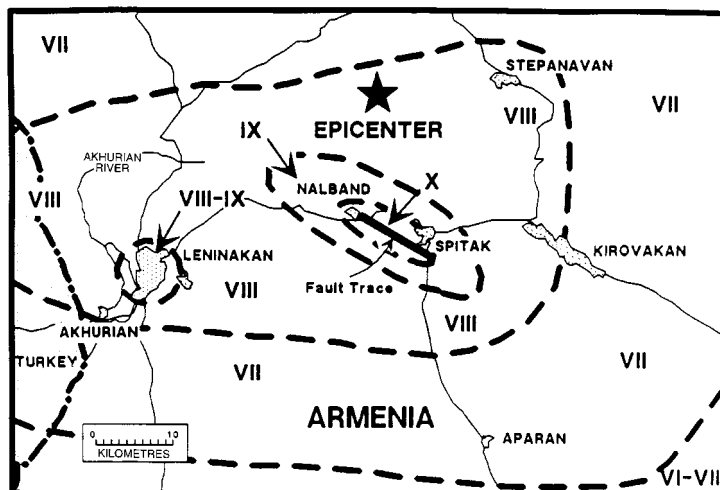


FIGURE 1 *Isoseismal map of the 7 December 1988 Earthquake Zone in Armenia*

The interviewers identified each of the employees from the original list and an interview was conducted at the workplace. For a few of these employees the interview was conducted at home when direct contact could not be established at the workplace following a couple of attempts. The employees were encouraged to check with the appropriate family members about information on the whereabouts of others if they were not very certain about the validity of their knowledge. Each of the questionnaires was coded and entered into a computer format for processing and analysis. Simple frequency distributions and cross tabulations provided an initial approach to the analysis. In order to adjust for the various factors, a multivariate logistic regression analysis was used. Age was introduced in the models as a continuous variable. In addition to the adjustments, various other multivariate models were used to test potential interactions between the different variables.

RESULTS

Population Characteristics

As presented in Table 1, there were no major differences in the initial demographic characteristics of the study population between the three earthquake zones. Spitak region was the area that included the epicentre of the earthquake, Gumri was the major urban agglomeration that had a high level of destruction, while the other areas were relatively less affected by the earthquake. Figure 1 is an isoseismal map of the earthquake zone

showing the different levels of earthquake intensity. This served as the basis for stratification of the study population.

Deaths

The current analysis involved all our study population of 32 743 inhabitants of the disaster area. Overall 831 deaths were reported in this particular population, giving an earthquake mortality rate of 2.5%. Of the deaths, 88% were reported as occurring during the first 24 hours after the earthquake. For 8.7% of the deaths no definite time of expiry was reported by the interviewee. A separate analysis of these deaths with undefined time did not identify any differences with the other deaths, and so all fatalities were combined during the multivariate analysis. As seen in Table 2, death rates were highest in the Spitak region (11.3%) which included the epicentre of the earthquake. For Gumri the death rate was 4.8% while for the rest of the disaster region rates were below 1%. These rates were relatively constant for the various age groups except for increases in those aged over 60 years.

As seen in Table 3 there were significant differences in death rates by a person's physical location at the moment of the earthquake. The age-adjusted relative odds for being inside a building versus outside was 9.8 (95% confidence interval [CI]: 6.3–15.3). The death rate for people in one-storey buildings was 0.6% and increased to 26.8% for those in buildings nine and more storeys high. Similarly, those located in the upper floors of the

TABLE 2 Rates of injuries and deaths by age, gender and geographic location

	Deaths		Injuries		Total
	N	%	N	%	N
Age					
0–10	153	2.6	136	2.3	5926
11–20	138	2.6	313	5.9	5338
21–30	141	2.3	241	4.0	6061
31–40	123	2.2	262	4.7	5573
41–50	73	2.7	157	5.7	2754
51–60	88	2.2	217	5.3	4094
61–70	74	3.4	111	5.1	2183
>70	41	5.0	17	2.1	814
	831		1454		32 743
Gender					
Females	496	2.9	796	4.6	17 175
Males	335	2.2	658	4.2	15 568
Geography					
Gumri	561	4.8	682	5.9	11 581
Spitak	239	11.3	494	23.3	2121
Others	31	0.2	278	1.5	19 041

TABLE 3 Rates of deaths and injuries by location at the moment of the earthquake and building characteristics

	Deaths		Injuries		Total
	N	%	N	%	N
Inside building	808	3.1	1318	5.0	26 453
Outside building	22	0.4	134	2.2	6232
Building type					
Panel	337	10.7	290	9.2	3137
Other	478	1.6	1072	3.6	29 606
Building height					
1 Storey	41	0.6	283	4.2	6689
2–4 Storeys	315	2.1	785	5.1	15 338
5–8 Storeys	226	5.3	227	5.3	4260
9+ Storeys	233	26.8	59	6.8	871
Location within building					
1st floor	181	1.4	597	4.5	13 258
2nd floor	194	2.3	408	4.8	8533
3–4 floor	246	6.0	268	6.5	4103
5–6 floor	70	8.0	53	6.0	879
7–8 floor	64	31.1	13	6.3	206
9+ floor	29	29.9	14	14.4	97

building had a higher death rate compared to those on the first two floors. Of the different types of construction, people located in panel type buildings had the highest mortality rates (10.7%) compared to other types of construction (1.6%). Following adjustment by multivariate logistic regression, the relative risk estimate for death in buildings with panel construction decreased to 1.6. Using multivariate adjustment, the height of the building became a better predictor of mortality than the location of the individual on the various floors. Thus, people in buildings that were over nine storeys high had a relative odds of 56.3 for death compared to those in buildings that were only one storey in height. There was also a gradient of mortality with the height of the building. However, following a small increase in risk by location at floors 2–4, compared to first floor, there was no additional increase in risk by the location of the person within the upper floors of the building after adjustment for the other variables (Table 4). These findings were also reconfirmed when separate models were developed for buildings of various heights.

Injuries

In all 1454 people sustained various types of injuries in this study population (4.4%). They reported 2771 different sites of injuries ranging from 533 fractures and 397 crush injuries to 646 minor injuries presenting

as superficial scratches. Injury rates were higher in females compared to males and were also highest in the Spitak region (Table 2). Being inside a building increased the risk of injury 2.3 times. People within a panel construction type of building were at 2.6 times increased risk of injury compared to other types of construction (Table 3). Within taller buildings there was a maximum 60% increase in risk for injuries. Within the different types of buildings the risk of injuries increased with the location of the individual at the higher levels of the building. However, the multivariate analysis of the data for injuries, as presented in Table 5, revealed that location of the individual and height of the building were not very important predictors of injuries following adjustment for geographical location, age and construction type of the building. Following adjustment, those in panel type buildings had a 1.8 fold increase in injury risk compared to other types of construction.

To ascertain whether there were different factors that contributed to death compared to injuries, a separate analysis was done comparing the 831 people who died with those of the 1454 who were injured. Occupant location within the upper floors of the building and height of the building were important predictors of death. On the other hand, panel construction type of building did not separate injuries and deaths.

TABLE 4 *Relative odds and confidence intervals of earthquake deaths in a logistic regression analysis for the various variables within the study population of Armenia*

Variables in the model	β value	Relative odds	95% confidence interval
Age (as a continuous variable)	0.005	1.005	1.001–1.009
Gumri versus other regions ^a	3.26	26.1	17.8–38.1
Spitak vs. other regions ^a	5.07	159.6	106.5–239.1
Building height			
2–4 versus 1	1.05	2.8	2.0–4.1
5–8 versus 1	2.10	8.2	5.5–12.1
9+ versus 1	4.03	56.3	35.9–88.1
Floor location			
2–4 versus 1	0.66	1.9	1.6–2.4
5+ versus 1	0.53	1.7	1.3–2.3
Panel versus other building materials	0.32	1.6	1.1–1.7

^a Earthquake affected areas other than Gumri and Spitak.

TABLE 5 *Relative odds and confidence intervals of earthquake injuries in a logistic regression analysis for the various variables within the study population of the Armenia earthquake of 1988*

Variables in the model	β value	Relative odds	95% confidence interval
Age (as a continuous variable)	0.009	1.009	1.006–1.012
Gumri versus other regions ^a	1.42	4.1	3.6–4.8
Spitak versus other regions ^a	3.14	23.1	19.6–27.4
Building height			
2–4 versus 1	0.28	1.3	1.1–1.6
5–8 versus 1	0.16	1.2	0.9–1.5
9+ versus 1	0.06	1.1	0.7–1.5
Floor location			
2–4 versus 1	0.22	1.2	1.1–1.4
5–14 versus 1	0.32	1.4	1.0–1.9
Panel versus other building materials	0.58	1.8	1.5–2.1

^a Earthquake affected areas other than Gumri and Spitak.

DISCUSSION

Past studies have stressed the importance of careful examination of earthquakes in order to identify more effective prevention strategies and to develop methods of rapidly assessing health care needs and improving disaster relief.²⁴ This is the first analytical study of earthquake injuries and deaths that is population based and uses the cohort approach by defining a study population for the day before the earthquake and tracing the outcomes in that same group following the disaster. Most of the results of this cohort study are consistent with what has been observed in our case-control study in Gumri.²³ In addition to estimating risk of injury and

death in a baseline population, the cohort approach has other advantages compared to cross-sectional and case-control studies. The potential for selection bias is lessened in such a cohort approach particularly in a disaster situation where major shifts in the population have occurred. Although a cohort study may be more demanding on resources, the current study was part of a broader surveillance programme that monitored the long term health effects of the earthquake. Monitoring of this cohort has been continued over 4 years following the earthquake.

Trauma caused by partial or complete collapse of buildings and infrastructures is the overwhelming cause

of death and injury in most earthquakes.^{25,26} The findings of this study highlight the importance of initial location, and building and structural factors in causing deaths and injuries in earthquake disasters. People finding themselves in structures that were nine or more storeys high, as well as panel construction type buildings, were at particularly high risk of death. Engineering investigations following the Armenian earthquake showed that the degree of damage sustained by different buildings depended on individual structural design and construction characteristics of each building.^{27–29} In other words, the majority of damaged buildings had similar weaknesses that resulted in similar types of failures during the strong seismic activity. Interestingly, these studies have shown that nine-storey residential buildings were widespread in the epicentral area and the complete collapse of many of these buildings was a major contributor to the high death toll in this earthquake.^{27,30,31}

The large numbers that were available in this study allowed us to conduct multivariate adjustments that identified construction factors (e.g. building height and materials used) as contributing relatively more to the possibility of death than location of the individual within the building. In our study we tried to answer the question of whether occupant behaviour contributes to survival or injury, including death. Our observation—within our previously conducted case-control study in Gumri (Leninakan)—that people outside a building were at lower risk compared to people inside a building at the time of an earthquake, was reconfirmed in this population-based study. Unfortunately, stairways were particularly vulnerable in residential buildings in the earthquake affected area making escape to the outside difficult.²⁷

Previous reports have recommended different initial protective responses following an earthquake.^{23,32–35} This is due to the fact that the relative efficacy of protective occupant actions is very much dependent upon the engineering and structural characteristics of the building and these vary around the world as do patterns of building use.^{11,13} Therefore, the best safety action to take is likely to depend on the specific type of building and may be different for densely populated urban areas versus rural areas.

Implications of this Study for Prevention

Implications of our study for earthquake morbidity and mortality prevention can be described in terms of those interventions which can be made before, during and after the impact of an earthquake.³⁶ Thus, in the pre-earthquake phase, we can alter building design practices in earthquake-prone areas and avoid the type of

very heavy construction materials common in residential high-rises in the Armenia earthquake zone. These collapsed in compact piles with few void spaces and little chance for occupant survival.^{14,37}

The impact phase relies on preventing or reducing injuries during the earthquake, for example, appropriate occupant behaviours to maximize survivability. It appears that the best safety actions to take in types of buildings similar to those in Armenia is to escape to the outside at the first instant of an earthquake or to seek safety in the lower floors of the building.

The post-event phase deals with reducing the consequences of the injuries following building collapse through better search and rescue methods and more effective emergency medical care. This study has shown that knowledge of injury patterns can provide valuable information to direct search and rescue efforts for potential survivors. Rescue and field medical teams should be aware that tall buildings with panel-type construction will have more deaths and severely injured trapped victims due to the very tight packing of the rubble with no cavities or ‘void spaces’. This greatly complicates the search and rescue effort and reduces significantly the opportunity for occupant survival. Survivors, however, will more likely be found in the lower floors of a collapsed building. Such information on places where survivors could be located may help to better guide future rescue and medical operations.^{38–40}

Future Earthquake Epidemiology Research Priorities

Few past studies have looked at exactly what components of a building cause the injuries, particularly in those situations where some people are killed and others are only injured or escape without injury.¹³ We hope that future epidemiological studies of injury patterns during earthquakes incorporate more detailed data about building design, the dynamic characteristics of soil around each building, and the population at risk in individual buildings. Because of difficulties of obtaining such information, available estimates are based on superficial observations of limited technical and statistical validity.⁴¹ Therefore, casualty extrapolations to other earthquakes and other geophysical settings have generally low credibility.⁴²

This epidemiological study represents another step in the process of refining disaster research methodology for the investigation of the complex relationship among factors related to survival following earthquakes.⁴³ Based upon the results of our study, we have made recommendations that may be useful in planning effective prevention actions and to enhance medical planning, preparedness, and response to future earthquake disasters.

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