

# Disaster Events and the Risk of Sudden Cardiac Death: A Washington State Investigation

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None.

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#### Abstract

**Background:** Psychological distress following disaster events may increase the risk of sudden cardiac death. In 2001, the Nisqually earthquake and the 11 September terrorist attacks profoundly affected Washington state residents.

**Hypothesis:** This research investigated the theory that the incidence of sudden cardiac death would increase following these disaster events.

**Methods:** Death certificates were abstracted using a uniform case definition to determine the number of sudden cardiac deaths for the 48-hour and one-week periods following the two disaster events. Sudden cardiac deaths from the corresponding 48-hour and one-week periods in the three weeks before the events, and the analogous periods in 1999 and 2000 were designated as control times. Using *t*-tests, the number of sudden cardiac deaths for the periods following the disaster events was compared to those of the control periods.

**Results:** In total, 32 sudden cardiac deaths occurred in the four counties affected by the Nisqually earthquake during the 48 hours after the event, compared to an average of  $22 \pm 3.5$  (standard deviation) in the same counties during the control periods ( $p = 0.02$ ). No difference was observed for the one-week period (94 compared to  $79.2 \pm 12.4$ ,  $p = 0.28$ ). No difference was observed in the number of sudden cardiac deaths in the 48-hours or one-week following the terrorist attacks compared to control periods.

**Conclusions:** A local disaster caused by a naturally occurring hazard, but not a geographically remote human disaster, was associated with an increased risk of sudden cardiac death. A better understanding of the underlying mechanisms may have implications for prevention of sudden cardiac death.

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#### Introduction

Acute psychological distress may produce autonomic changes that can increase heart rate and blood pressure, enhance platelet aggregation and the production of clotting factors, and reduce myocardial oxygen supply. Taken together, these mechanisms may lead to ischemia and dysrhythmias, and possibly result in sudden cardiac death.<sup>1–6</sup> Mental stress has been shown to increase following disasters due to natural hazards such as earthquakes and hurricanes.<sup>7–11</sup> Similarly, measures of psychological distress increased both locally and nationally following the terrorist attacks that occurred in the United States on 11 September 2001.<sup>12–14</sup>

Some evidence suggests that disaster incidents may be associated with sudden cardiac death. Several studies of cardiac events following severe earthquakes found increased rates of cardiac-related hospital admissions and/or death,<sup>15–20</sup> but, in at least one study, the risk for acute myocardial infarction (AMI) following an earthquake was not increased.<sup>21</sup>

Other evidence indicates that cardiac events increase following disasters from human causes such as wars and terrorist attacks. Two studies observed an increase in the incidence of myocardial infarction and sudden cardiac death in Israel during the first days of the Iraqi missile strike in 1991.<sup>22,23</sup>

Additionally, increases were seen in the incidence and mortality from coronary artery disease following air raids in Zagreb, Croatia in 1991.<sup>24</sup> Evidence of escalation of cardiac events following terrorist attacks in the United States is mixed. An analysis of myocardial infarctions, unstable angina, and tachyarrhythmia in Brooklyn following the 11 September 2001 terrorist attacks revealed a significantly increased rate of cardiac diagnoses in the two months after the attacks compared to several control periods.<sup>25</sup> Allegra *et al* similarly concluded that New Jersey hospital admissions for AMIs increased in the two months following those attacks.<sup>26</sup> However, an analysis of cardiac mortality in New York City in the month following the attacks revealed no increase in the number of deaths compared to several control years.<sup>27</sup> One of the few studies that examined the effects of the terrorist attacks at remote locations showed a general decrease in the number of emergency department visits following the attacks, but did document an increase in the number of diagnoses related to cardiac ischemia.<sup>28</sup>

At 10:54 hours (h) on 28 February 2001, one of the largest recorded earthquakes in Washington state history struck in Nisqually, Washington. Later that year, in an unprecedented attack in the United States, terrorists hijacked four commercial airplanes, resulting in the deaths of >3,000 people. The hypothesis of this study was that the Nisqually earthquake and the 11 September 2001 terrorist attacks would be associated with an increase in sudden cardiac deaths in the areas of Washington state most affected by these events. Institutional research board approval was not needed, since death certificate data are available to the public.

## Methods

### *Data Collection and Definitions*

**Classification of Sudden Cardiac Death**—The Washington state Department of Health records the cause and location of death for all decedents in the state of Washington. For this study, sudden cardiac death was classified using the criteria of Zheng *et al*, which defined a *sudden cardiac death* as International Classification of Diseases-10 (ICD-10) codes I00-I002, I05-I09, I11-I28, or I33-I51, and the location was out-of-hospital or in the emergency department.<sup>29</sup> Deaths that occurred in-hospital were excluded from this investigation.

**Classification of Exposure Period**—The 48-hour and one-week periods after the disaster events were chosen as the exposure periods before the study began. The 48-hour time period was selected because evidence from the 1994 Northridge, California earthquake indicated that the increased risk of sudden cardiac death occurred during the first two days. Following that earthquake, the incidence of sudden cardiac deaths was below the average,<sup>19</sup> so the seven-day period after the Nisqually earthquake was examined in order to determine whether the death rate similarly decreased. The duration of psychological distress after the unprecedented 11 September terrorist attacks was uncertain, but it was hypothesized that the stress would be greatest immediately following the attacks, so 48-hour and one-week periods following these events also were exam-

ined. Unexposed (control) periods for comparison were the 48-hour and one-week periods for the one, two, and three weeks prior to the disaster events, as well as the corresponding 48-hour and one-week periods in 1999 and 2000, matched to the day of the week, since rates of cardiac events have been shown to vary by day of week.<sup>30</sup> When evaluating the earthquake event, time periods began at 10:54 h and extended 48 hours and seven days. For the analysis of the 11 September attacks, the time periods began when the first plane struck the World Trade Center at 05:46 h (Washington time), and similarly extended 48 hours and seven days.

**Classification of Exposure Area**—The Nisqually earthquake chiefly affected four counties in Washington: Thurston, Pierce, King, and Snohomish. The primary earthquake analyses included sudden cardiac deaths that occurred in these four counties. Secondarily, sudden cardiac deaths that occurred in Washington State outside the four affected counties also were evaluated.

For the 11 September terrorist attacks, the distress may have been especially high in urban centers, as these communities were perceived to be the most likely targets of terrorism. The analyses for 11 September included sudden cardiac deaths that occurred in King County, the most populous county (1.8 million people) in Washington. Secondarily, sudden cardiac deaths in the rest of Washington State also were evaluated, since the unique nature of the events may have had more widespread effects.

### *Statistical Analysis*

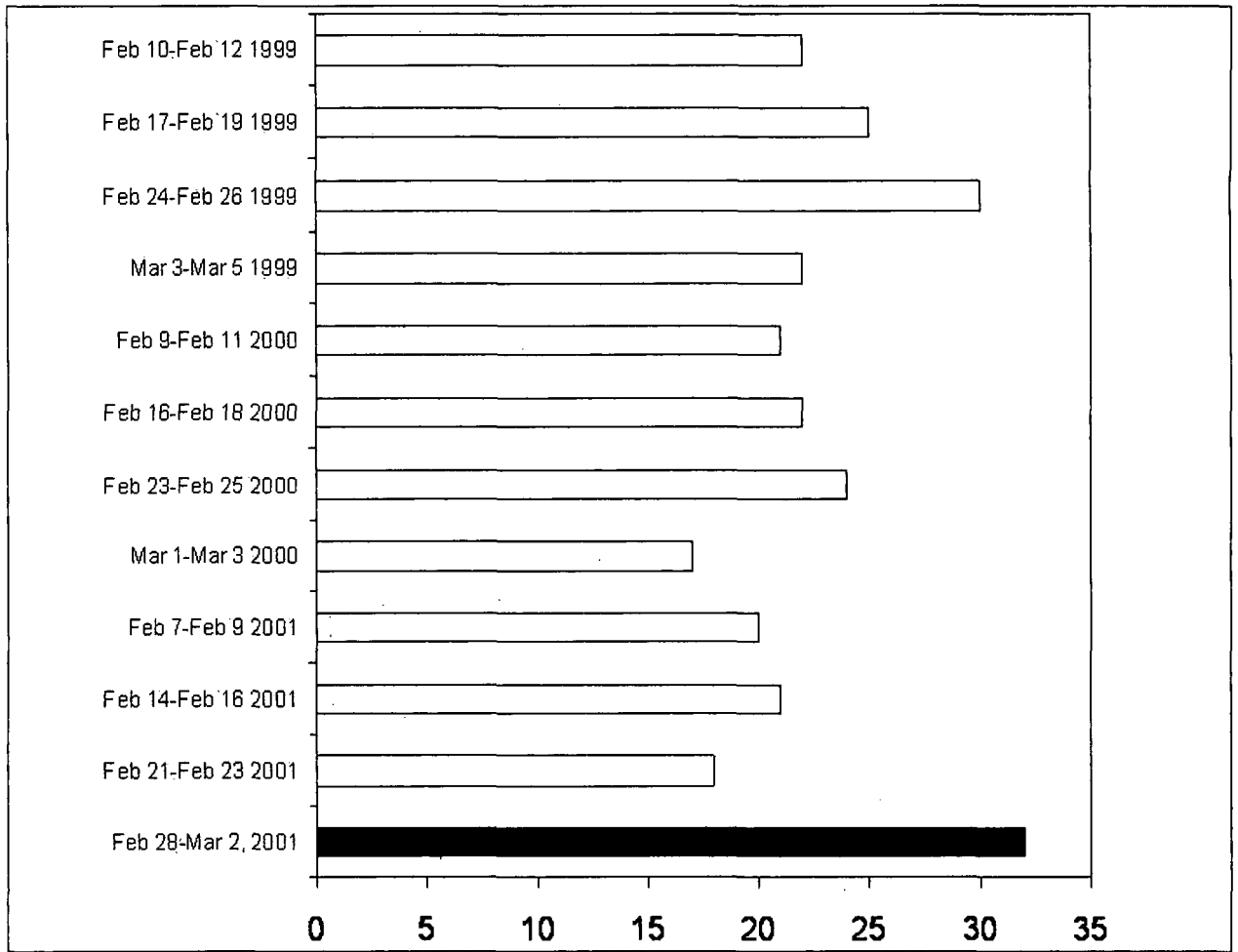
The count of sudden cardiac deaths for the time periods and counties of interest was determined. A comparison of counts was made between the “exposed” groups (those who died immediately following the Nisqually earthquake or the 11 September attacks) and the mean value for the counts in the “unexposed” groups (those who died during the corresponding control periods) using *t*-tests for independent samples. All *p*-values are two-tailed. Analyses were performed using the software package SPSS 11.0 (SPSS, Inc., Chicago, IL).

## Results

During the 48 hours following the Nisqually earthquake, 32 sudden cardiac deaths occurred in the affected four counties, compared to an average of 22.0 ±3.5 (standard deviation) in the same four counties during the control periods, constituting a 45% increase in incidence (*p* = 0.02) (Figure 1). Outside of the four affected counties of Washington state, 18 sudden cardiac deaths occurred during the 48-hour period following the earthquake, compared to an average of 19.1 ±4.8 during the control periods (*p* = 0.83).

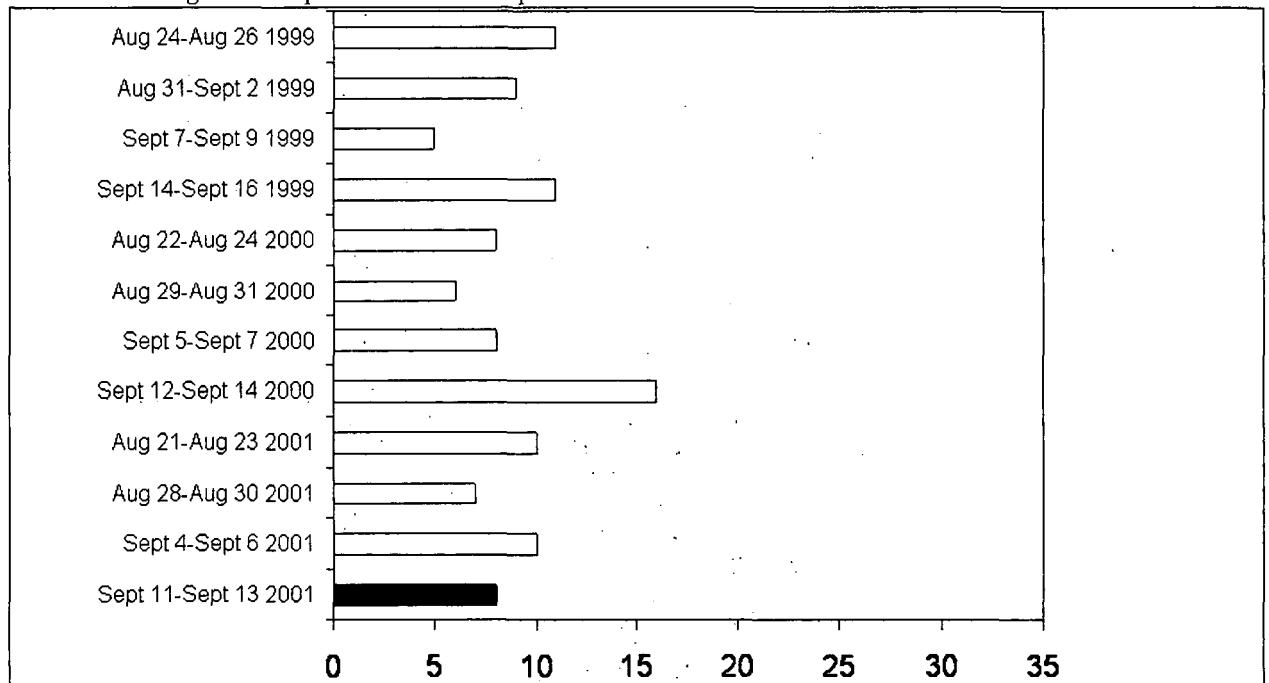
When the period of interest was extended to one week, 94 sudden cardiac deaths took place in the affected four counties, compared to an average of 79.2 ±12.4 during the control periods (*p* = 0.28). In all other counties in Washington, 82 sudden cardiac deaths occurred during the week following the earthquake, compared an average of 76.1 ±9.6 for the control weeks (*p* = 0.57).

During the 48 hours following the terrorist events of 11 September 2001, eight sudden cardiac deaths occurred in



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Figure 1—Counts of sudden cardiac deaths in four Washington State counties affected by the Nisqually Earthquake in the 48 hours following the earthquake and 11 control periods



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Figure 2—Counts of sudden cardiac arrest deaths in an urban Washington State county in the 48 hours following the 11 September 2001 terrorist attacks and 11 control periods

King County, Washington compared to an average of  $9.2 \pm 3.0$  in King County during the control periods ( $p = 0.71$ ) (Figure 2). In all other counties in Washington state, 24 sudden cardiac deaths occurred during the 48 hours following the event, compared to an average of  $24.6 \pm 5.6$  for control periods ( $p = 0.92$ ). During the week following the 11 September events, 35 cardiac death events occurred in King County, compared to an average of  $33.7 \pm 4.0$  for the corresponding control periods ( $p = 0.77$ ). In other Washington state counties, 105 sudden cardiac deaths took place during the week following the 11 September disaster, compared to an average of  $93.0 \pm 10.4$  for the control periods ( $p = 0.29$ ).

### Discussion

This investigation evaluated the relationship between disaster-producing events and the risk of sudden cardiac death. A local disaster due to natural causes, the Nisqually earthquake, was associated with a 45% increase in the number of sudden cardiac deaths during the first 48 hours after the earthquake in the affected counties. No increase in sudden cardiac deaths was observed among the Washington state counties that did not experience the earthquake. No increase in the incidence of sudden cardiac death following the 11 September attacks was observed for the subsequent 48-hour or one-week periods either on a state-wide basis or in the major metropolitan county in Washington.

Several studies have suggested potential pathological mechanisms by which disasters related to natural hazards could produce physiological effects that in turn would increase the risk for sudden cardiac death. Natural disasters such as earthquakes may increase heart rate, blood pressure, markers of inflammation, and blood viscosity.<sup>2,31,32</sup> An increase in the incidence of sudden cardiac death occurred in the affected counties, but not in the other Washington state counties for the 48 hours following the Nisqually earthquake. Over the course of a full week, however, no difference among the affected counties was evident. This finding suggests that the time window of elevated risk may be approximately two days, similar to that observed in the investigation of sudden cardiac death following the Northridge earthquake.<sup>19</sup> However, the magnitude of increased risk following the Nisqually earthquake was considerably less than the five-fold increase that was observed after the Northridge earthquake. This difference may be attributed to the locations of the epicenters (the Northridge earthquake occurred in the heart of the Los Angeles metropolitan area, whereas the Nisqually epicenter was almost 30 miles from the nearest heavily populated area), the times of day the earthquakes occurred (early morning in the Northridge earthquake versus late morning in the Nisqually earthquake), the depths of the earthquakes (the Northridge was centered 18 kilometers below ground, compared to 52 kilometers in the Nisqually), and/or the methods of identification of sudden cardiac deaths (medical examiner records for the Northridge study compared to death certificates for the Nisqually investigation).

While previous studies have shown increases in cardiac events following earthquakes in other cities,<sup>15,17-19</sup> these

earthquakes directly resulted in widespread structural damage, injuries, and deaths. The Nisqually earthquake, on the other hand, though large, caused relatively little physical damage or injuries, and no deaths from traumatic causes. The fact that an increase in sudden cardiac deaths was detected in the days immediately following the Nisqually earthquake contributes to the hypothesis that psychological, rather than physical, stress is a major contributor to deaths from cardiac causes following events related to natural hazards.

Symptoms of stress following the 11 September attacks were far reaching, with 90% of US adults reporting one or more symptoms of substantial stress as a result of the attacks.<sup>12</sup> However, no increases in sudden cardiac deaths following this event in the major urban center of King County or in Washington state overall were observed. These findings are consistent with reports that have shown no increase in cardiovascular mortality in New York City in the month following the 11 September attacks. This event was unprecedented in the United States, with presumably complex psychological consequences that may not increase sudden cardiac death risk.<sup>27</sup> Moreover, the level of psychological distress caused by the 11 September attacks was closely correlated to proximity to the events.<sup>12</sup> The fact that Washington state was geographically remote from the attacks may indicate that the level of stress was insufficient to substantially influence the risk for sudden cardiac death. Furthermore, the most appropriate time window for assessment of sudden cardiac deaths related to terrorist attacks may be a much longer period of observation than two or seven days.

This study had several limitations. The use of death certificates to assess sudden cardiac death has been shown to misclassify the cause of death.<sup>29,33</sup> However, there is no reason to believe that this classification would have differed between the exposed and unexposed time periods used in this study, and therefore, any misclassification that may have occurred probably would have resulted in bias toward the null. In addition to psychological stress, excessive physical exertion, missed medications or other therapeutics, and/or delays in accessing or delivering emergency care may have elevated risk of death following the earthquake.<sup>34,35</sup> Regarding this last factor, the earthquake could have limited or delayed emergency medical services or hospital access by increasing the number of patients (with or without cardiac events). Though outside the scope of this study, disaster events can increase patient volumes and affect triage decisions, and this, in turn, potentially could affect cardiac arrest treatment. Finally, these analyses involved the population of Washington state, where demographic or health characteristics may be distinct, and these findings may not be generalizable to other populations.<sup>36</sup>

### Conclusions

A local disaster caused by a naturally occurring hazard, but not a geographically remote human disaster, was associated with an increased risk of sudden cardiac death in four counties in Washington state. Future studies should focus on identifying mechanisms by which physiological responses to stress may lead to cardiac events.



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