Impact of a Major Disaster on the Mental Health of a Well-Studied Cohort

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IMPORTANCE There has been growing research into the mental health consequences of major disasters. Few studies have controlled for prospectively assessed mental health. This article describes a natural experiment in which 57% of a well-studied birth cohort was exposed to a major natural disaster (the Canterbury, New Zealand, earthquakes in 2010-2011), with the remainder living outside of the earthquake area.

OBJECTIVE To examine the relationships between the extent of earthquake exposure and mental health outcomes following the earthquakes—net of adjustment for potentially confounding factors related to personal circumstances, prior mental health, and childhood family background.

DESIGN, SETTING, AND PARTICIPANTS Data were gathered from the Christchurch Health and Development Study, a 35-year longitudinal study of a birth cohort of New Zealand children (635 males and 630 females). This general community sample included 952 participants with available data on earthquake exposure and mental health outcomes at age 35 years.

EXPOSURES A composite measure of exposure to the events during and subsequent to the 4 major (Richter Scale >6.0) Canterbury earthquakes during the years 2010-2011.

MAIN OUTCOMES AND MEASURES DSM-IV symptom criteria for major depression; posttraumatic stress disorder; anxiety disorder; suicidal ideation/attempt; nicotine dependence; alcohol abuse/dependence; and illicit drug abuse/dependence. Outcomes were measured approximately 20 to 24 months after the onset of exposure to the earthquakes and were assessed using DSM-IV diagnostic criteria and measures of subclinical symptoms.

RESULTS After covariate adjustment, cohort members with high levels of exposure to the earthquakes had rates of mental disorder that were 1.4 (95% CI, 1.1-1.7) times higher than those of cohort members not exposed. This increase was due to increases in the rates of major depression; posttraumatic stress disorder; other anxiety disorders; and nicotine dependence. Similar results were found using a measure of subclinical symptoms (incidence rate ratio, 1.4; 95% CI, 1.1-1.6). Estimates of attributable fraction suggested that exposure to the Canterbury earthquakes accounted for 10.8% to 13.3% of the overall rate of mental disorder in the cohort at age 35 years.

CONCLUSIONS AND RELEVANCE Following extensive control for prospectively measured confounding factors, exposure to the Canterbury earthquakes was associated with a small to moderate increase in the risk for common mental health problems.
n recent years, there has been growing research into the psychosocial consequences of major disasters including hurricanes, floods, and earthquakes. Much of this research has focused on assessing the social, personal, and emotional consequences of exposure to major disaster, and it has shown that exposure to a major disaster may lead to a series of adverse consequences including increased rates of mental health and substance use problems.1-5

From a theoretical standpoint, there are at least 2 reasons for suggesting that exposure to a natural disaster is a risk factor for mental health problems. The first concerns the immediate traumatic exposure to environmental conditions that may be both frightening and life-threatening. The second reason is that natural disasters may lead to consequential negative life events including death of family or friends; loss of employment/earnings; loss of housing; and related events. There is a substantial literature linking such life events to mental health problems.7

While existing literature has demonstrated linkages between disaster exposure and mental health, this literature is subject to a number of limitations. One limitation relates to the selection of a comparison group. In some studies, this has been achieved by comparing those exposed to disaster with similar population groups not exposed,8-10 whereas in other cases, time series comparisons have been made of outcomes assessed before and after the disaster.11-13 Both methods have limitations and, under ideal circumstances, it would be desirable to assess the outcomes of those exposed to the disaster with the outcomes of a comparison group, with both groups being assessed both before and after the disaster.

A second limitation is that studies have generally used a single means of measuring variability in exposure to a major disaster. While some studies have operationalized exposure as residence in the area subject to disaster,14 others have used different geographic locations as a proxy measure of disaster exposure variation.15,16 In addition, some studies have assessed exposure through use of measures reflecting the variability of exposure to the event itself (eg, being injured and witnessing death or injury)17,18 or the sequela of the event (eg, displacement and employment disruption).19,20 As just noted, there is reason to believe that natural disasters may lead to an increased risk for mental health problems due to both the immediate impacts of the disaster and consequential life events experienced following the disaster and that adequate assessment of disaster exposure must take all of these into consideration.

A third issue relates to the assessment of mental health problems. A number of studies have assessed mental health problems using either measures of symptoms8,11,16 or changes in substance consumption,15,17,18 whereas others have used categorical measures of meeting criteria for DSM disorders.10,12-14 There is a growing literature that suggests it is important to assess both categorical and dimensional aspects of mental disorders particularly as there may be individuals who display symptoms of disorder (including impairment) and experience significant distress but whose symptoms do not meet diagnostic criteria.25-28 These developments are reflected by the inclusion of dimensional aspects in the assessment of mental disorders in the DSM-5.29 One way of addressing this issue is to examine mental health using both categorical measures and subclinical symptom data.

In this article, we describe a study in which it was possible to address the issues of a comparison group, variation in exposure, and outcome measurement. These circumstances arose as a result of a series of more than 10,000 recorded earthquakes that struck the province of Canterbury (New Zealand) and the city of Christchurch, the population center of the province. The earthquake sequence took place during an approximately 18-month period from September 2010 to mid-2012 and involved 4 major earthquakes with values on the Richter scale exceeding 6.0. These earthquakes were September 4, 2010 (7.1); February 22, 2011 (6.3); June 13, 2011 (6.4); and December 23, 2011 (6.0). The February 22, 2011, earthquake proved to be the most devastating, resulting in 185 deaths and substantial damage to the central city. The extent of exposure to the 4 major earthquakes is the focus of the present study.

One of the features of this earthquake sequence was that Christchurch is home to an ongoing longitudinal study (the Christchurch Health and Development Study) of a birth cohort of 1265 children born in 1977. This cohort had been studied up to the age of 30 years and a check on the location of cohort members showed that 57% of the cohort was living in Canterbury at the time of the earthquakes. This combination of circumstances made it possible to report on the results of a natural experiment examining the mental health consequences of the Canterbury earthquakes by estimating the associations between exposure to the earthquakes and measures of mental health and substance use obtained in 2012 when cohort members were aged 35 years.

**Methods**

**Participants**

The data were collected at the age 35 years assessment of the Christchurch Health and Development Study, a longitudinal study of a cohort of 1265 children born in the Christchurch (New Zealand) urban region during a 4-month period from April to August 1977. This cohort has been studied on 23 occasions from birth to age 35 years.30,31 All aspects of data collection received ethical approval by the Canterbury regional Health and Disability Ethics Committee and all data were collected with the explicit written consent of study participants.

**Data Collection**

In 2012, at age 35 years, cohort members were assessed on a mental health interview lasting 1.5 to 2 hours, examining aspects of psychosocial adjustment since the previous assessment. In addition, participants who had been exposed to the Canterbury earthquakes were invited to take part in a further interview lasting approximately 1 hour, examining their earthquake experiences. These interviews took place approximately 20 to 24 months following the start of the Canterbury earthquakes sequence in September 2010. By the time the interviews began, cohort members could have been exposed to 4 major earthquakes, ranging in magnitude from 7.1 to 6.0.
The present analysis was based on a sample of 952 participants (78% of the surviving cohort at age 35 years) who completed the mental health interview and for whom information on earthquake exposure was available. Of this sample, 543 (57.0%) reported exposure to the Canterbury earthquakes.

**Extent of Earthquake Exposure**

The following measures were obtained from the 543 participants who reported some exposure to the 4 major Canterbury earthquakes:

1. The immediate impacts of the earthquakes. For each of the 4 major earthquakes, participants were asked a series of questions relating to the severity of the shaking they experienced and the immediate consequences of the shaking in terms of damage to furniture, equipment, and personal possessions; structural damage to their home and other buildings; loss of services and/or damage to infrastructure (power, phone, water, and sewage); the extent of liquefaction, flooding, or other land damage; and related issues. The questions were derived from the Modified Mercalli Earthquake Intensity Scale (eTable 1 in the Supplement).^{32}

2. The consequences of the earthquakes. Participants were also questioned about the level of stress and difficulties resulting from earthquake-related disruptions to their personal/family lives and daily activities. Questioning spanned the following domains: housing repairs, accommodation, and insurance issues; disruption of employment/loss of income; changes to daily routines; consequences for their wider family in terms of health, housing, employment, and related issues; and ongoing problems with infrastructure (eg, drainage, sewerage, and street access). The questions were modeled on the modified Holmes and Rahe Social Readjustment Rating Scale^{33} used to assess life-event exposure in the study (eTable 2 in the Supplement).

3. Overall impact of the earthquakes. The measures just described were included in a series of factor models. These analyses showed that when correlated specificity was taken into account, all items loaded on a common factor that represented the severity of the impact of the earthquakes. An account of the construction of this measure is given in the eAppendix in the Supplement (Assessment of Earthquake Exposure section). The resulting scale was of high internal consistency ($\alpha = .93$; eTable 3 in the Supplement).

For the purposes of data display and the present analyses, the overall measure of earthquake exposure was used to classify the cohort into 5 groups comprising (1) those who had no exposure to the earthquakes and (2) for those who were exposed, a further 4 groups representing quartiles on the distribution of the total earthquake impact/consequences score (the eAppendix in the Supplement provides details).

**Assessment of Mental Health at Age 35 Years**

Participants were questioned about the occurrence of suicidal thoughts, plans, or attempts and DSM-IV symptom and impairment criteria for a range of mental disorders in the previous 12 months. The disorders assessed included major depression; posttraumatic stress disorder (PTSD); other anxiety disorders (generalized anxiety disorder, panic disorder, agoraphobia, specific phobia, and social phobia); nicotine dependence; and alcohol and illicit drug abuse/dependence. Questioning was based on selected components of the Composite International Diagnostic Interview^{35} and the Diagnostic Interview Schedule^{36} supplemented by custom-written survey items. This information was used to classify participants on 2 measures of mental disorder for each outcome: (1) whether the participant met DSM-IV diagnostic criteria for disorder and (2) whether the participant reported any symptom of disorder. The measure of PTSD was not specific to the earthquakes. A detailed account of the assessment of mental disorders is given in the eAppendix in the Supplement (Mental Health Outcomes section).

**Covariates**

A range of covariates were selected from the database of the study to control for potential confounding and selection processes attributable to pre-earthquake factors associated with earthquake exposure. The selected covariates included factors known to be predictive of mental disorder outcomes in the Christchurch Health and Development Study cohort and/or potentially correlated with earthquake exposure, spanning the following domains: history of mental disorder 16 to 30 years; childhood family sociodemographic background and family functioning; exposure to child abuse and family violence; and personal characteristics and family circumstances at the onset of the earthquakes. In all, a total of 24 covariate factors were considered for inclusion in the analysis (the eAppendix in the Supplement provides an account of these variables; eTable 4 in the Supplement).

**Statistical Analysis**

The bivariate associations between the 5-group classification of the extent of earthquake exposure and rates of mental disorder (Table 1) were tested for linear trend using the Mantel-Haenszel $\chi^2$ test for dichotomous outcomes and Poisson regression for the count of the total number of disorders.

Significant bivariate associations between earthquake exposure and mental disorder outcomes were controlled for potential confounding and selection processes by fitting a series of regression models (logistic for dichotomous outcomes or Poisson for the number of mental disorders) in which each outcome was modeled as a linear function of the 5-level measure of earthquake exposure and the series of covariate factors previously described (Table 2; the eAppendix and eTable 4 in the Supplement provides details of the covariates considered and the covariate selection process). From the fitted models, estimates of effect size (odds ratios for dichotomous outcomes and incidence rate ratios for the number of disorders) and corresponding 95% CIs for a 1-step increase in earthquake exposure were obtained. Parallel analyses were carried out using the measures of disorder including subclinical symptoms/conditions in place of the measures representing DSM-IV diagnostic criteria (eTables 5 and 6 in the Supplement). Estimates of the fraction of mental disorders attributable to earthquake exposure after adjustment for confounding were calculated using the method described by Greenland and Drescher.^{37}
The fitted regression models were then extended to conduct supplementary analyses to examine (1) the extent to which the covariate-adjusted associations between earthquake exposure and number of mental disorders varied with the measure of exposure (ie, immediate impact, consequences of the earthquakes, and total impact/consequences) or with the use of continuous scale scores (eTable 7 in the Supplement) and (2) interactions between earthquake exposure and sex, parenthood, socioeconomic status, child abuse, and previous mental health.

Sample Size and Selection Bias
The 952 participants included in the analysis represented 78% of the surviving cohort at age 35 years. To address possible selection bias due to sample attrition, all analyses were repeated using techniques described by Carlin et al.38 A sample selection model was constructed using data gathered at birth to predict inclusion in the analysis sample. Comparison of the analysis sample with the remaining 323 participants showed statistically significant \(P < .05\) tendencies for the analysis sample to underrepresent respondents from socially disadvantaged backgrounds (ie, low parental education, low socioeconomic status, and single-parent family) and males. The fitted selection model was then used to poststratify the sample into a series of groups and the probability of inclusion in the analysis sample was estimated for each group. Then, the data were reanalyzed, with the observations weighted by the inverse of the probability of sample inclusion. The weighted analyses produced similar conclusions to the results reported here.

Results

Bivariate Associations Between Earthquake Exposure and Mental Health Outcomes
Table 1 shows the associations between the extent of exposure to the Canterbury earthquakes (classified into 5 groups) and measures of DSM-IV mental disorders assessed when cohort members were 35 years old. Table 1 shows that with increasing exposure to the earthquakes there were statistically significant linear increases in the rates of major depression \(P = .02\), PTSD \(P = .02\), other anxiety disorders \(P = .02\), and nicotine dependence \(P < .001\), and in the total number of disorders \(P < .001\).

Adjustment for Confounding
In the next step of the analyses, the significant associations in Table 1 were adjusted for a series of confounding variables (see the Methods section). Table 2 displays the adjusted results, which show that following adjustment for confounding, there were significant associations between the extent of

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**Table 1. Associations Between the Extent of Earthquake Exposure and Rates of Mental Disorder Outcomes (Past 12 Months)**

<table>
<thead>
<tr>
<th>Measure</th>
<th>%</th>
<th>Total Earthquake Impact/Consequences Score (Quartile)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not Exposed (n = 409)</td>
<td>1 (Low) (n = 137)</td>
<td>2 (n = 135)</td>
</tr>
<tr>
<td>Major depression</td>
<td>8.8</td>
<td>11.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Posttraumatic stress disorder</td>
<td>1.7</td>
<td>0.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Other anxiety disorder</td>
<td>11.5</td>
<td>11.7</td>
<td>11.9</td>
</tr>
<tr>
<td>Suicidal ideation/attempt</td>
<td>1.5</td>
<td>3.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Nicotine dependence</td>
<td>11.5</td>
<td>15.3</td>
<td>17.0</td>
</tr>
<tr>
<td>Alcohol abuse/dependence</td>
<td>8.3</td>
<td>9.5</td>
<td>6.7</td>
</tr>
<tr>
<td>Illicit drug abuse/dependence</td>
<td>4.7</td>
<td>6.6</td>
<td>3.0</td>
</tr>
<tr>
<td>No. of disorders, mean (SD)</td>
<td>0.51 (0.86)</td>
<td>0.66 (1.15)</td>
<td>0.53 (0.90)</td>
</tr>
</tbody>
</table>

* Mantel-Haenszel \(\chi^2\) test for linear trend for dichotomous outcomes and Poisson regression for number of disorders.

**Table 2. Adjusted Associations Between the Extent of Earthquake Exposure and Measures of Mental Disorder (Past 12 Months)**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>B (SE)*</th>
<th>P Value</th>
<th>OR/IRR (95% CI)(^b,c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major depression</td>
<td>0.10 (0.07)</td>
<td>.19</td>
<td>1.10 (0.95-1.27)</td>
</tr>
<tr>
<td>Posttraumatic stress disorder</td>
<td>0.23 (0.15)</td>
<td>.13</td>
<td>1.25 (0.93-1.68)</td>
</tr>
<tr>
<td>Other anxiety disorder</td>
<td>0.07 (0.07)</td>
<td>.26</td>
<td>1.08 (0.95-1.23)</td>
</tr>
<tr>
<td>Nicotine dependence</td>
<td>0.21 (0.08)</td>
<td>.01</td>
<td>1.23 (1.05-1.44)</td>
</tr>
<tr>
<td>No. of disorders</td>
<td>0.08 (0.03)</td>
<td>.004</td>
<td>1.08 (1.02-1.14)</td>
</tr>
</tbody>
</table>

Abbreviations: IRR, incidence rate ratio; OR, odds ratio.

* Estimated using multiple logistic regression for dichotomous outcomes and Poisson regression for number of disorders.

\(^b\) The adjusted OR/IRR represents the increase in the odds of disorder (dichotomous outcomes) or rate of disorder (number of disorders) for a 1-step increase in the 5-level measure of the extent of earthquake exposure.

\(^c\) All models included the following covariate factors: participant education, IQ, childhood family socioeconomic status, maternal age, maternal education, childhood sexual abuse, sex, race/ethnicity, parenthood, and time from first earthquake to assessment. In addition, each analysis included a lagged measure of mental disorder reflecting the rate of disorder for each outcome during the period 16 to 30 years of age.
earthquake exposure and nicotine dependence ($P = .01$). While other associations were not statistically significant, in all cases, the adjusted relative risk estimates were greater than 1. These trends were reflected in the association between the extent of exposure to the Canterbury earthquakes and the total number of disorders ($P = .004$), with those in the highest quartile of earthquake exposure having overall rates of disorder that were 1.4 (95% CI, 1.1-1.7) times higher than the rate for those not exposed to the earthquakes.

A parallel analysis was conducted using a classification of mental disorder that included those with subclinical symptoms/conditions (eTable 6 in the Supplement). This analysis showed a similar but more marked pattern of results in which increasing exposure to the Christchurch earthquakes was associated with increases in the rates of symptoms of depression ($P = .002$); PTSD ($P < .001$); anxiety ($P < .001$); nicotine dependence ($P < .001$); and the measure of overall number of disorders for which symptoms were present ($P < .001$). After adjustment for measures of prior mental health and covariate factors, the associations between earthquake exposure and measures of disorder, including subclinical symptoms, again showed a similar but more marked pattern of results with significant or marginally significant associations between the extent of earthquake exposure and major depression ($P = .04$), PTSD ($P < .001$), other anxiety disorders ($P = .09$), nicotine dependence ($P = .002$), and the overall number of disorders ($P < .001$) (eTable 7 in the Supplement).

Finally, to assess the overall impact of the earthquakes on the rates of mental disorder in the cohort, estimates of the attributable fraction were computed. These estimates suggested that exposure to the Canterbury earthquakes accounted for 13.3% (95% CI, 11.8%-14.9%) of the overall rate of DSM-IV disorders in the cohort and 10.8% (95% CI, 6.5%-14.8%) of the overall rate of disorder including subclinical conditions.

**Supplementary Analyses**

To further examine the associations reported in Tables 1 and 2, a number of supplementary analyses were conducted. These analyses included:

1. Examination of the linkages between mental disorders and alternative measures of earthquake exposure (impact, consequences of the earthquakes; or total impact/ consequences of the earthquakes) or with the use of continuous scale scores of earthquake severity (eTable 5 in the Supplement). These analyses produced results that were consistent with the findings in Tables 1 and 2.

2. Tests of interactions between measures of the extent of exposure to the Christchurch earthquakes and a number of factors: sex; parenthood; socioeconomic status; history of mental disorder; and exposure to childhood sexual abuse. No significant interactions were found, suggesting that the adverse effects of the earthquake exposure were general.

**Discussion**

This study examined the results of a natural experiment in which 57% of a well-studied birth cohort was living in an area subject to a major disaster and 43% were living outside of this area. The study had 3 key aspects that contributed to the understanding of mental health effects of disaster exposure. First, the study design permitted rigorous control of confounding using both predisaster and postdisaster data and contemporary data from a control series not resident in the disaster area. Second, the study used a comprehensive measure of earthquake exposure that took into account both exposure to the earthquakes and to the adverse personal, social, and economic circumstances that resulted from the earthquakes. Third, the study used multiple measures of mental health that took into account both categorical and dimensional aspects of mental health disorders, accounting for those individuals who experienced symptoms but who may not have met diagnostic criteria.

The major findings were that, after control for sources of confounding, increasing exposure to the Canterbury earthquakes was associated with significant increases in the number of disorders reported, with those who had high exposure having rates of disorder that were approximately 1.4 times greater than those resident outside of Canterbury. These conclusions hold for both DSM-IV-diagnosed disorders and for a more liberal definition that included subclinical symptoms. These overall increases in the rates of disorder were due to increases in the risks for 4 conditions: major depression; PTSD; other anxiety disorders; and nicotine dependence. These findings are consistent with the results of previous research that reported that among the mental health consequences of exposure to a major disaster are increased risks for major depression, anxiety disorders, and PTSD. The findings are also consistent with studies that have not shown increases in alcohol and illicit drug use disorders following exposure to disasters.

Estimates of the attributable fraction suggested that earthquake exposure accounted for 10.8% to 13.3% of the overall rate of mental disorder in the cohort, representing a modest increase in the risk for mental health disorders.

The study findings highlighted the critical role of the extent of exposure to the adverse consequences as a factor in postdisaster responses. Specifically, cohort members who lived in Canterbury at the time of the earthquakes who reported few, if any, adverse consequences of the earthquakes and their aftermath had mental health outcomes that were similar to those living outside of Canterbury, whereas those having high exposure to earthquake-related adversity showed clear increases in risk. These findings demonstrate the importance of services targeting attention to those individuals and areas where the impacts of disaster are greatest.

Simply living in an area in which a major disaster has occurred is not, by itself, a risk factor for increased mental disorder unless this exposure is accompanied by traumatic events and adverse consequences.

There have been suggestions that certain population groups, particularly women; those with dependent children; and socially disadvantaged groups are more susceptible to the consequences of major disaster. We were unable to confirm these hypotheses and tests of interaction showed that exposure to the earthquakes did not vary with sex; parenthood; socioeconomic status; history of mental disorder; and exposure to childhood sexual abuse.
A key consideration in understanding the present study was the well-organized and responsive way in which the Canterbury community responded to these disasters, with widespread reports of community action and support for those families affected by the disasters. This strong community-based action likely acted as a protective factor in mitigating the consequences of the earthquakes for those with high levels of exposure to earthquake-related adversity. One implication of availability of this support was that individuals exposed to natural disasters but who live in areas in which such support is not available are likely to experience greater levels of mental health difficulties than observed in the present cohort.

While the present study had a number of advantages because of the availability of a well-studied cohort, this feature was also a limitation of the study because the findings were limited to populations in their mid-30s. It is possible that the impacts of the Canterbury earthquakes varied with age, with the result that effects on younger and older populations may be different from those found for this cohort. Also, the time frame for assessment, which was 20 to 24 months after the onset of the earthquake sequence, limited the conclusions to longer-term effects of earthquake exposure. Notwithstanding these limitations, the present study suggested that increasing exposure to the adverse effects of the Canterbury earthquakes was associated with a modest but detectable increase in the rates of mental disorders assessed by both DSM-IV diagnostic categories and subclinical symptoms.

Conclusions
The present analysis represented the first stage of a larger analysis examining the impacts of the Canterbury earthquakes on the present cohort. Future studies will examine longer-term impacts of earthquake exposure on psychosocial outcomes and the effects of long-term exposure to economic, social, and personal hardship that resulted from the earthquake sequence. More generally, however, future research on the effects of disaster exposure would benefit from using comprehensive measures of exposure such as the one used in the present study. Such an approach may be particularly useful in the context of examining short-term reactions to disaster exposure to identify individuals who would benefit from acute psychiatric interventions.