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Geographic variation of clinically diagnosed mood and anxiety disorders in Christchurch after the 2010/11 earthquakes

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ABSTRACT

The 22nd February 2011 Christchurch earthquake killed 185 people, injured over 8000, damaged over 100,000 buildings and on-going aftershocks maintained high anxiety levels. This paper examines the dose of exposure effect of earthquake damage assessments, earthquake intensity measures, liquefaction and lateral spreading on mood and anxiety disorders in Christchurch after this event. We hypothesise that such disorders are more likely to develop in people who have experienced greater exposure to these impacts within their neighborhood than others who have been less exposed, but also live in the city. For this purpose, almost all clinically diagnosed incident and relapsed cases in Christchurch in a 12 months period after the 2011 earthquake were analysed. Spatio-temporal cluster analysis shows that people living in the widely affected central and eastern parts after the 2010/11 earthquakes have a 23% higher risk of developing a mood or anxiety disorder than people living in other parts of the city. Generally, mood and anxiety-related disorders increase with closer proximity to damage from liquefaction and moderate to major lateral spreading, as well as areas that are more likely to suffer from damage in future earthquakes.

1. Introduction

On the 22nd February 2011, the city of Christchurch (New Zealand) was hit by a shallow magnitude (Mw) 6.2 earthquake occurring just 9 km south of the Central Business District (CBD). This 'Christchurch' earthquake produced a Peak Ground Acceleration (PGA) among the highest ever recorded and strong ground shaking affected much of the Christchurch urban environment (Giovinazzi et al., 2011). As a consequence, two multi-story buildings collapsed in the CBD, a number of unreinforced masonry buildings partially collapsed, and rockfall, landslides, and cliff collapses occurred on the Port Hills near the epicentre. Much of the eastern suburbs of Christchurch experienced substantial liquefaction,[1] which caused extensive damage to buildings and buried services like freshwater, sewerage, and stormwater systems. In total, 185 people died in the event, over 8000 were injured, and over 100,000 buildings were damaged, destroyed or demolished (Canterbury Earthquake Recovery Authority, n. d.).

The Christchurch earthquake is part of an earthquake sequence initiated following the 4th September 2010 Mw 7.1 'Darfield' earthquake, which was located ~35 km to the west of Christchurch. Over the next 18 months, over 10,000 aftershocks occurred, including three large earthquakes which migrated eastward across the city area: the 'Christchurch' earthquake, the Mw 6.2 'Christchurch II' earthquake on the 13th June 2011 and the Mw 5.9 'Christchurch III' earthquake on the 23rd December 2011.

Following such events, in addition to deaths, injuries and damage to properties and infrastructure, high prevalence rates of adverse stress-related mental health outcomes have also been observed. These included Post-Traumatic Stress Disorder (PTSD), depression, anxiety, Acute Stress Disorder (ASD) or sleep disturbances (Chadda et al., 2007; Dorahy and Kannis-Dymand, 2012; Eksi and Braun, 2009; Kadak et al., 2013; Liu et al., 2011; Shinfuku, 2002; Suzuki et al., 1997; Varela et al., 2008; Wang et al., 2011; Zhang et al., 2011, 2012; Zhou et al., 2013). Out of this list, PTSD, anxiety, and depression haven been most often examined in the literature and are commonly found together after natural disasters (Madianos and Evi, 2010). For example, Zhang et al. (2012) found high prevalence rates of PTSD, anxiety, and depression after the

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[1] Liquefaction is a process where saturated soil turns into silt and loses its carrying capacity when shaken (Kalkan, 2012).

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2010 Yushu earthquake (China). Dell'Osso et al. (2014) identified higher PTSD and depression symptom scores, as well as a strong interrelationship between these disorders in young adults after the 2009 L'Aquila earthquake (Italy).

For the 2011 Christchurch earthquake, Duncan et al. (2013) found high levels of hyperarousal, re-experiencing, anxiety, and depression in 101 treatment-seeking individuals two to eight weeks after the event. Reed (2013) analysed the temporal variation of 524 arrival complaints for anxiety and stress to the Christchurch Public Hospital's Emergency Department between May 2010 and April 2012 and found a significant increase in anxiety cases one month after each major earthquake in the 2010/11 Christchurch series. These two examples confirm the same effect for Christchurch in the short-term, but it was unclear if these high levels were still present a year or more after the event. A newspaper article from April 2013 indicated this by reporting an increased demand for mental health care services since the earthquakes and a very high number of prescriptions for depression, anxiety, insomnia, and pain compared to the rest of New Zealand (Carville, 2013). Also, reports about the high levels of stress caused by the frustration of living in broken homes, dealing with insurance issues and often long-lasting claims, as well as coping with ongoing aftershocks, led to the assumption that there may be a significant long-term change in mood and anxiety disorders since the earthquakes (Atkinson, 2013; Canterbury Earthquake Recovery Authority, 2013).

While many studies have been carried out in the initial weeks or months after an earthquake event (Kadak et al., 2013; Liu et al., 2011; Wang et al., 2011; Zhang et al., 2012; Zhou et al., 2013), a number of studies have found PTSD and other mental health outcomes to be still highly prevalent even several years after a traumatic event: Zhang et al. (2011) and Xu and Song (2011) (one year after the 2008 Wenchuan earthquake (China)), Başoğlu et al. (2004) (more than one year after the 1999 Marmara earthquake (Turkey)), and Chen et al. (2007) (two years after the 1999 Chi-chi earthquake (Taiwan)). High levels of traumatic stress symptoms were even found four years after such an event in exposed subjects (Goenjian et al., 2000; Kılıç et al., 2006; Livanou et al., 2005; van den Berg et al., 2012).

Identified risk factors triggering the development of such mental disorders after natural disasters include socio-demographic factors such as being female or middle-aged, having low social support or low socio-economic status (Chen et al., 2007; Galea et al., 2005; Kadak et al., 2013; Norris and Elrod, 2006; Wang et al., 2011; Xu and He, 2012; Xu and Song, 2011; Zhang et al., 2011; Zhang et al., 2012; Zhou et al., 2013), medical factors such as co-morbidity with other mental disorders or history of psychiatric conditions (Galea et al., 2005; Kadak et al., 2013), and disaster-related experiences such as being seriously injured, seeing dead people, living in a prefabricated house after the event or feelings of fear and threat to life (Chen et al., 2007; Galea et al., 2005; Kadak et al., 2013; Wang et al., 2011; Xu and He, 2012; Xu and Song, 2011; Zhang et al., 2011; Zhang et al., 2012; Zhou et al., 2013). Disaster-related experiences can be categorised into objective (e.g. being injured) and subjective features (e.g. feelings of fear), which together determine the extent of exposure to the disaster. This measure has been stated to be the most important risk factor for developing PTSD after a disaster (Galea et al., 2005) and can be used to evaluate the dose of exposure effect, which assumes that living in an area with higher levels of exposure is closely linked to higher levels of stress and psychological symptoms that may finally result in a mental disorder.

Strategies to assess the dose of exposure effect include measuring the level of exposure in differently affected groups (severe vs. less severe or affected vs. unaffected) (Bödvarsdóttir and Elklit, 2004; Dell'Osso et al., 2013; Dorahy and Kannis-Dymand, 2012; Goenjian et al., 2000; Maruyama et al., 2001; Rowlands, 2012; Şahin et al., 2007), measuring different levels of exposure to individual exposure variables like the extent of damage to the property/home or loss of possessions (Başoğlu et al., 2004; Bergiannaki et al., 2003; Sattler et al., 2006; Sharan et al., 1996; Wang et al., 2011; Xu and He, 2012), or using a distance based approach (Groome and Soureti 2004; DiMaggio et al., 2010).

The last two strategies have been used within this paper to assess the effects of different earthquake impact variables on incident and relapsed cases of mood and anxiety in Christchurch residents up to one year after the three largest earthquakes: 'Darfield', 'Christchurch' and 'Christchurch II'. The inclusion of almost all clinically diagnosed mood and anxiety cases gives the study a unique quality.

The main aim of this study is to examine the spatio-temporal change of mood and anxiety disorders in Christchurch between 2009 and 2012, and to identify earthquake exposure variables that may cause such disorders.

It is important to know what causes mood and anxiety disorders, and when, as well as where they may occur, to initiate early intervention since they are a great burden on society (Madianos and Evi, 2010). The New Zealand Burden of Diseases, Injuries and Risk Factors Study (NZBD) states that anxiety and depressive disorders were the second leading causes of health loss[2] in New Zealand in 2006, and are risk factors for suicide, self-harm, and coronary heart diseases (Ministry of Health, 2013a).

In Christchurch not everyone was exposed to the same level of impact and stress due to the earthquakes.

It is hypothesised that mood and anxiety disorders occurred predominantly in, or nearer to the highly affected eastern parts of the city where people have been exposed to liquefaction and lateral spreading in their community, or experienced higher levels of earthquake shaking intensity. Furthermore, in the context of ongoing aftershocks, it is hypothesised that people living in, or nearer to neighborhoods at greater risk of further damage in any future earthquake due to poor soil conditions were more likely to develop a mood or anxiety disorder than people living in less prone parts of the city.

Although there have been studies in the past that assessed the relationship between the level of exposure to an earthquake expressed by the affectedness of the community or the proximity to the epicentre and mental health outcomes (Dorahy and Kannis-Dymand, 2012; Groome and Soureti, 2004; Reed, 2013; Rowlands, 2012), the role of the exposure to the level of impact to the neighborhood, as well as the known risk of damage to the home in future earthquakes is still not fully understood. This paper contributes by filling this gap with the intention to derive recommendations to better target mental health care services for those in most need in future seismic events.

2. Methods

2.1. Data

Earthquake impact variables included Canterbury Earthquake Recovery Authority (CERA)[3] land zones, hazards intensity measures consisting of Peak Ground Acceleration (PGA) and Modified Mercalli Intensity (MMI), liquefaction and lateral spreading.

After the 2011 Christchurch earthquake, CERA undertook land classification based on area-wide damage assessments to

[2] Health loss measures the gap between a population's current state of health and an ideal state of health.

[3] The Canterbury Earthquake Recovery Authority (CERA) is the agency established by the Government to lead and coordinate the ongoing recovery effort following the September 2010 and February 2011 earthquakes.

Table 1
CERA landzones (Department of Building and Housing, 2011).

CERA landzone	Description
Red	• Areas with widespread land and infrastructure damage in flat residential land or cliff collapse and rock roll affected areas in the Port Hills with risk to life. Land should be bought by the Crown, cleared and turned into green space
Green	• Suitable areas for residential rebuild and repairs divided into three technical categories (TCs)
TC1	• Future land damage from liquefaction is unlikely
TC2	• Minor to moderate land damage from liquefaction is expected in future significant earthquakes
TC3	• Moderate to significant land damage from liquefaction is expected in future earthquakes
Orange	• 'Hold zone' where further assessment, because of complex geotechnical issues was required
White	• 'Un-zoned' areas on the Port Hills and in the CBD that still had to be mapped

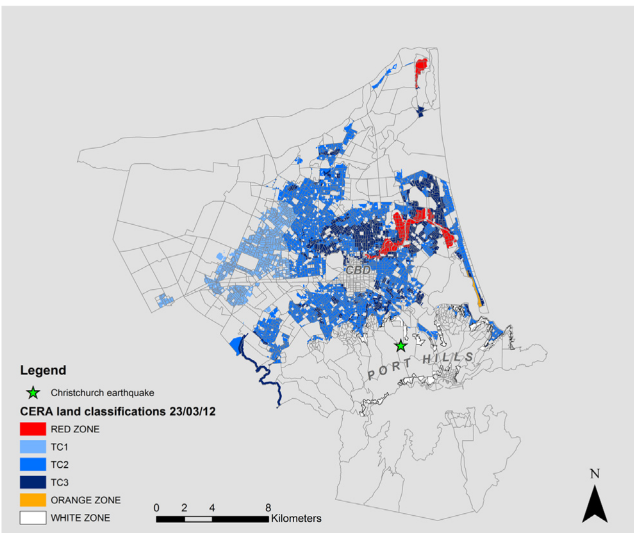

Fig. 1. CERA 'Red Zone', 'TC3', 'TC2' and 'TC1' classification on the 23rd March 2012 (*Source*: author)

residential properties and geotechnical characterisation of the land of the greater Christchurch area to provide a land use planning basis for rebuild and inform likely performance in future earthquake events (specifically considering liquefaction and slope stability hazards). The classification system was first published on the 22nd June 2011. Initially, there were four coloured land zones: 'Red', 'Green', 'White' and 'Orange'. The 'Green Zone' was further categorized into three technical categories: 'TC1', 'TC2' and 'TC3' (see Table 1). As a consequence of on-going geotechnical investigations, the zoning changed 15 times on an irregular basis until the 31st October 2012, with 'White' and 'Orange' zones gradually turning into 'Red' or 'Green'.

The post-earthquake analyses used the CERA zoning status on the 23rd of March 2012 (Fig. 1), because this was the last change that could have had an impact on mood and anxiety cases before the reporting year deadline on the 30th of June 2012. A distance based approach was used to examine the effect of living in or nearer to widely abandoned decrepit areas ('Red Zone') or areas with differently estimated future chance for residential damage ('TC1', 'TC2' and 'TC3') on mood and anxiety. 'Orange Zone' areas were excluded since there was only one left on the 23rd of March, which affected just a few meshblocks[4] in the east. 'White Zone' areas also weren't considered, because they didn't cover many residential areas and were dispersed in the Port Hills area.

To evaluate the hazard intensity of the Christchurch earthquake, PGA and MMI published by the U.S. Geological Survey (USGS) were used.[5] The datasets were only approximations since they were automatically computer generated maps for a wide area that don't reflect small distance changes, hence they may differ from other sources. For example, Giovinazzi et al. (2011) reported a maximum PGA of 2.2*g*, which doesn't correspond to the maximum PGA of 1.4*g* in the approximated USGS map. PGA ranged from 0.2 to 1.4*g* and MMI from category 6 to 9. At the time of analysis there weren't more accurate area-wide measurements available.

Lateral spreading and liquefaction were also included in the analysis since they represent direct physical earthquake impacts that caused considerable damage to structures and buildings, mainly in the central and eastern parts of the city. They have been mapped by the Earthquake Commission (EQC) and Tonkin & Taylor after the 2011 Christchurch earthquake and their spatial distribution largely corresponded to the CERA 'Red' and 'TC3' areas in Fig. 1. The level of affectedness was described by two categories ('moderate to major' and 'severe' lateral spreading, and 'minor to moderate' and 'severe' liquefaction).

Mental health data about mood and anxiety disorders were obtained from the Ministry of Health's New Zealand Health Tracker (NZHT), which links different administrative databases using the National Health Index (NHI)—a unique patient identifier. The data represents clinically diagnosed incident and relapsed cases within a years' period from those seeking help, throughout the Christchurch urban area boundary, which defines the study area and population. The study period ranged from 2009/10 to 2011/12 and included the number of newly and recurring diagnosed cases between July and June the following year. This measure is in contrast to many studies that look at prevalence rates, which describe the number of cases in a population at a specific point of time. The mood and anxiety indicator was built from more than 70 clinical codes based on the World Health Organization's Ninth and Tenth Revision of the International Classification of Diseases (ICD), including PTSD, depression, and anxiety among others.

Residential addresses, geocoded at a meshblock level, and further social indicators including age, gender and ethnicity were extracted from the Primary Health Organization (PHO) register and linked via the NHI to medical information including the mood and anxiety indicator and information about pre-existing mood, anxiety or other mental disorder(s), as well as co-morbidity with another mental disorder. Cases that couldn't be geocoded or were erroneously located in the Christchurch Urban Area were

[4] The meshblock is the smallest geographic area unit defined by Statistics New Zealand. There are 2939 meshblocks in the study area.

[5] The PGA expresses the amount of acceleration the earth was moving horizontally and vertically during the event compared to earth's gravity acceleration, which is $g=9.81$ m/s^2 (Linkimer, 2008), whereas the MMI scale "grades the impact of an earthquake on people living on the earth's surface, and so can be more useful as an indicator of the earthquake's significance to the community" (GeoNet, n. d.).

Table 2
Gender and age group distribution in the study population compared to the 2013 Census.

	2009/10	2010/11	2011/12	2013 Census*
Total	286,138	294,244	299,121	341,472
Gender				
female	149,385 (52.2%)	153,302 (52.1%)	155,800 (52.1%)	173,640 (50.9%)
male	136,753 (47.8%)	140,942 (47.9%)	143,321 (47.9%)	167,832 (49.1%)
Age group				
0–14	53,446 (18.7%)	54,512 (18.5%)	54,727 (18.3%)	60,861 (17.8%)
15–39	94,099 (32.9%)	96,870 (32.9%)	97,786 (32.7%)	116,355 (34.1%)
40–64	96,348 (33.7%)	99,491 (33.8%)	101,529 (33.9%)	113,193 (33.1%)
65+	42,245 (14.8%)	43,371 (14.7%)	45,079 (15.1%)	51,063 (15.0%)
Ethnicity**				
European	237,467 (83.0%)	242,694 (82.5%)	245,964 (82.2%)	273,306 (74.4%)
Maori	16,029 (5.6%)	16,739 (5.7%)	17,090 (5.7%)	27,765 (7.6%)
Pacific peoples	7,136 (2.5%)	7,370 (2.5%)	7,618 (2.5%)	10,101 (2.8%)
Asian	19,360 (6.8%)	20,992 (7.1%)	21,939 (7.3%)	30,717 (8.4%)
*MELAA****	2,818 (1.0%)	2,990 (1.0%)	3,012 (1.0)	3,384 (0.9%)
Other ethnicity	1,325 (0.5%)	1,389 (0.5%)	1,334 (0.4%)	6,276 (1.7%)
Not elsewhere included	2,003 (0.7%)	2,070 (0.7%)	2,164 (0.7%)	15,750 (4.2%)

* Refers to the Christchurch City territorial authority boundary including the whole more rural Banks Peninsula, which includes approx. 3000 more people than the Christchurch urban area.

** The sum of ethnicity counts in the 2013 Census exceed the total population since total responses from the census with multiple responses are stated.

**** Middle Eastern/Latin American/African.

excluded. Also, cases without a distinct gender or age entry were excluded from the analyses. The most often mentioned ethnicity was chosen in case of multiple entries, which may occur when individuals use multiple health care services in the year.

2.2. Analysis

The SaTScan™ v9.1.1 software, which implements spatio-temporal scan statistics, was used to analyse the spatio-temporal variation of mood and anxiety disorders in the study region. For this type of cluster analysis, a retrospective space-time discrete poisson model with a study period from 2010 to 2012 based on a yearly time aggregation and the recommended settings with a maximum temporal cluster size of 50%, a circular scanning window with a maximum spatial cluster size equal to 50% and a maximum of 999 Monte Carlo replications, was applied. Furthermore, secondary clusters could not geographically overlap with previously reported clusters and spatial clusters were determined to be statistically significant at a 5% level. Counts of mood and anxiety disorders for each meshblock unit provided the basis of the analysis. If any significant hotspots could be found after the earthquakes, they could be related to specific overlapping physical earthquake impacts to test if there were any relationships.

Distance to the CERA land classifications ('Red Zone', 'TC3', 'TC2' and 'TC1'), area-wide PGA and MMI, as well as distance to lateral spreading and liquefaction of the Christchurch earthquake were used as exposure variables. As a distance measure the Euclidean distance in kilometres between the population-weighted centroid of each residential meshblock and the boundary of the specific earthquake impact was used. The maximum Euclidean distances to CERA land classifications were 15.4 ('Red Zone'), 8.4 ('TC3'), 7.3 ('TC2') and 16.6 km ('TC1'), with mean distances of 4.3 ('Red Zone'), 0.7 ('TC3'), 0.4 ('TC2') and 4.4 km ('TC1'). Maximum Euclidean distances to lateral spreading and liquefaction categories didn't differ significantly ranging between 10.2 ('minor to moderate liquefaction') and 11.5 km ('severe lateral spreading'), whereas the mean distances ranged between 0.8 ('minor to moderate liquefaction') and 2.5 km ('severe lateral spreading').

Multivariate logistic regression was used to assess the relationship between mood and anxiety disorders and the varying degrees of exposure to the presented earthquake impacts, simultaneously controlling for possible confounders. The first model was a mixed effect model including a person-specific random effect for the whole study period of three years to identify general socio-demographic and mental health-related confounders. It tested the relationships between gender, age, ethnicity, NZ deprivation from 2013, mental health co-morbidity, pre-existing mood or anxiety, as well as other mental health disorders and mood and anxiety disorders. Next, these relationships were also tested in a fixed model for the year after the major earthquakes (2011/12), before the influence of each earthquake impact was tested. Because of multicollinearity, the earthquake impact variables were tested separately. For example CERA land classifications were not independent from liquefaction, because the classifications were mainly based on liquefaction assessments.

3. Results

The study population, defined by the Christchurch urban area boundary and limited to PHO enrolments, consisted 52% females and 48% males in each year between 2009/10 and 2011/12, which was similar to the proportions in the Christchurch City population identified by the 2013 Census (Table 2). The proportions of age groups were also similar to the 2013 Census figures. The mean age in each year was approx. 39, with a standard deviation of 23.

Comparing the gender and age group proportions between the three years showed little variation.

For the number of people diagnosed with a mood or anxiety disorder between 2009/10 and 2011/12, a trend towards a higher incidence with relapsed cases of mood and anxiety disorders can be seen. In 2009/10 18,264 people were diagnosed with a mood or anxiety disorder, which is 6.4% of that years' study population. In 2010/11, it was 20,361 (6.9%), and 21,644 (7.2%) in 2011/12.

Conspicuous about this result is the fact that the proportions increased from year to year with the highest of 0.5% between 2009/10 and 2010/11—the year of the Darfield, Christchurch and Christchurch II earthquakes. Looking at the conditional risk, expressing the proportion of people having been diagnosed with a mood or anxiety disorder given a previous mood or anxiety diagnosis at any time of their life before, there were 18,226 (6.3%) people in 2009/10, 20,351 (6.9%) in 2010/11 and 21,635 (7.2%) in 2011/12 showing the high numbers and proportions of recurring cases.

Table 3
Model 1—Multivariate mixed effects logistic regression model to identify socio-demographic, socio-economic and medical risk factors for mood and anxiety disorders in Christchurch urban area for the whole study period.

Independent variables	Odds ratio	*p*-Value	CI (95%)
Gender			
Female	1.00		
Male	0.732	< 0.001	0.697–0.769
Age (years)			
0–14	1.00		
15–39	3.583	< 0.001	2.906–4.419
40–64	4.601	< 0.001	3.725–5.682
≥ 65	6.095	< 0.001	4.916–7.556
Ethnicity			
European	1.00		
Maori	0.695	< 0.001	0.627–0.772
Pacific people	0.388	< 0.001	0.300–0.502
Asian	0.568	< 0.001	0.483–0.669
MELAA	0.605	< 0.001	0.455–0.804
Other ethnicity	0.790	0.249	0.529–1.118
Residual categories	1.033	0.819	0.783–1.363
NZ Deprivation Index 2013	1.001	0.798	0.993–1.009
Mental health co-morbidity			
No	1.00		
Yes	3.501	< 0.001	3.306–3.709
Pre-existing other mental health disorder(s)			
No	1.00		
Yes	1.165	< 0.001	1.104–1.230
Pre-existing mood/anxiety disorder(s)			
No	1.00		
Yes	3195.313	< 0.001	2845.173–3588.542
Study year			
2009/10	1.00		
2010/11	1.279	< 0.001	1.235–1.325
2011/12	1.554	< 0.001	1.500–1.611

The proportion of females diagnosed with a mood or anxiety disorder (~65%) in each year was much higher than the proportion of females in the whole study population in each year (~52%). Also the average age group distribution of people diagnosed with a mood or anxiety disorder with approx. 1% of 0 to 14 year olds, 32–35% of 15 to 39 year olds, 43–44% of 40 to 64 year olds and 21–23% of 65 and older showed a great difference in comparison to the average age group distribution in the study population (0–14: ~19%; 15–39: ~33%; 40–64: ~34%; 65+: ~15%). This already indicated that women and people over 39 were more frequently diagnosed with a mood or anxiety disorder than males and children. This was further investigated by a multivariate mixed effects logistic regression model in Table 3.

The first and second model identified being female, of older age, European, having mental health co-morbidity, pre-existing mood or anxiety disorder(s), as well as pre-existing other mental health disorder(s) as risk factors for being clinically diagnosed with a mood or anxiety disorder in the past 12 months period after the 2011 Christchurch earthquake (see Table 3). These factors were all highly statistically significant ($p < 0.001$) with the strongest risk factor of having a history of mood and/or anxiety disorders. Looking at the difference between children (0–14 years) and adults the odds of having a mood or anxiety disorder were increasing with age and approx. 3.6 to 6.1 times higher for adults in the whole study period. Ethnicity also played an important role with Pacific people, followed by Asians, MELAA and Maori to be less likely to have a mood or anxiety disorder compared to Europeans. Other ethnicities, as well as neighborhood deprivation showed no significant effect in the first model, whereas neighborhood deprivation was statistically significant in the second one showing a slightly negative association to mood or anxiety disorders, which means that the likelihood of having a mood or anxiety disorder slightly decreases in more deprived areas (see Table 4).

Table 4
Model 2—Multivariate fixed effects logistic regression model to identify socio-demographic, socio-economic and medical risk factors for mood and anxiety disorders in Christchurch urban area in 2011/12.

Independent variables	Odds ratio	*p*-Value	CI (95%)
Gender			
Female	1.00		
Male	0.812	< 0.001	0.782–0.844
Age (years)			
0–14	1.00		
15–39	1.223	< 0.001	1.004–1.489
40–64	1.454	< 0.001	1.194–1.771
≥ 65	1.763	< 0.001	1.444–2.153
Ethnicity			
European	1.00		
Maori	0.751	< 0.001	0.692–0.814
Pacific people	0.483	< 0.001	0.389–0.599
Asian	0.786	< 0.001	0.691–0.895
MELAA	0.745	< 0.05	0.594–0.934
Other ethnicity	0.941	0.706	0.684–1.293
Residual categories	1.097	0.395	0.887–1.356
NZ Deprivation Index 2013	0.988	< 0.001	0.981–0.994
Mental health co-morbidity			
No	1.00		
Yes	1.855	< 0.001	1.749–1.967
Pre-existing other mental disorder(s)			
No	1.00		
Yes	1.081	< 0.001	1.034–1.130
Pre-existing mood/anxiety disorder(s)			
No	1.00		
Yes	3863.872	< 0.001	2887.896–5169.681

Finally, the first model showed that the difference in years was highly statistically significant and the risk increased during, as well as after, the 2010/11 earthquakes compared to before (see Table 3). The spatio-temporal cluster analysis confirmed this result showing a statistically significant ($p < 0.001$) cluster covering the most affected central and eastern parts of the city, as well as the Port

Hills areas around the 2011 Christchurch earthquake epicentre in the year 2011/12. The relative risk (RR) was 1.23, so people living in the hotspot area had generally a 23% increased risk of having a mood or anxiety disorder compared to people living outside the cluster in the western and northern parts of the city. This hotspot overlapped to a large extent with the spatial distribution of 'Red Zone', 'TC3', lateral spreading, liquefaction, as well as high intensity PGA and MMI areas, which may have been a consequence of the exposure to these impacts and all the stress related to it.

First of all, the distance to 'Red Zone' areas was assessed as an independent risk factor adjusting for known risk factors including gender, age, ethnicity, mental health co-morbidity, history of mood or anxiety or other mental disorders, as well as neighborhood deprivation. However, the model showed no statistically significant effect for distance to Red Zone areas (Model 3 in Table 5).

On the other hand, exchanging this variable with distance to 'TC3' or 'TC2' areas (Model 4 and 5 in Table 5) resulted in a statistically significant association ($p<0.01$) with the odds decreasing by approx. 2.3% and 2.6% per kilometre distance. Thus, living farther away from these zones reduced the risk for having a mood or anxiety disorder in the study population, showing that conversely, close proximity to these areas was identified as a risk factor.

Looking at the hazard intensity measures PGA and MMI, MMI showed a statistically significant association ($p<0.05$) with a positive relationship. Thus, the odds of having a mood or anxiety disorder increased by 4% per MMI value increase.

For lateral spreading and liquefaction a statistically significant result ($p<0.05$) was found for distance to moderate to major lateral spreading, minor to moderate and severe liquefaction. A negative relationship between distance to these areas and having a mood or anxiety disorder was identified with a decrease in odds of approx. 1% per kilometre. As a result, living in a greater distance from these areas served as a protective factor. Severe lateral spreading nearly showed a statistically significant association to having a mood or anxiety disorder and indicated the same direction of the relationship.

4. Discussion

This paper is an original contribution to the literature, because it is one of few studies examining almost the whole population living in the study area before, during, and after an earthquake. Moreover, the mood and anxiety indicator also included the vast majority of clinical mood and anxiety diagnoses made within the study area and period. These circumstances shaped the unique character of this study, allowed us to get a very good indication of the mood and anxiety distribution as a consequence of the 2010/11 Christchurch earthquakes and resulted in a lot of interesting findings.

The study has identified socio-demographic, psychological and several earthquake impacts as risk factors for having a clinically diagnosed mood or anxiety disorder in 12 months periods before, during and after the 2011 Christchurch earthquake.

The socio-demographic and psychological risk factors include female gender, higher age, mental health co-morbidity and pre-existing mental health disorder(s), which is congruent with numerous studies (Başoğlu et al., 2004; Frans et al., 2005; Galea et al., 2005; Kadak et al., 2013; Lai et al., 2004; Norris and Elrod, 2006). Furthermore, Pacific people were least likely to having been diagnosed with a mood or anxiety disorder, followed by Asians, MELAA and Maori in the whole study period. This is in line with the 2011/12 New Zealand Health Survey for adults and children, where Pacific and Asian people were less likely to be diagnosed with a mental health problem compared to non-Pacific and non-Asian people (Ministry of Health, 2012a, 2012b). The reason may be that Maori, Pacific and probably Asian people are much less likely to seek and receive treatment for mental disorders than other ethnic groups. Looking at prevalence of mental disorders in the general population, the 2006 New Zealand Mental Health Survey revealed that unadjusted 12-months prevalences were highest for Maori, intermediate for Pacific people and lowest for other ethnic groups (Oakley Browne et al., 2006).

Neighborhood deprivation didn't show a significant effect for the whole study period, but living in a more deprived neighborhood was a protective factor for having a mood or anxiety disorder after the earthquakes. This finding is in contrast to the results of Ivory et al. (2011), who conclude from a nationally representative 2002/03 New Zealand Health Survey dataset that living in a more fragmented and deprived neighborhood was a risk factor for poor mental health. This was also supported by a survey from 2012/13 that found a 1.6 times higher risk of having a mental disorder for adults living in the most deprived areas compared to those living in the least deprived ones (Ministry of Health, 2013b). Our results may be due to population mobility, as the NZ deprivation index from 2013 was a fixed score for the neighborhood, whereas the underlying population in our study changed from year to year.

We also found that adults were more likely to be diagnosed with a mood or anxiety disorder than children with increasing odds per age group. The first result was in line with the New Zealand Health Survey of 2011/12 stating higher diagnosed rates of depression, bipolar disorder and/or anxiety disorder in adults compared to children in the general population (Ministry of Health, 2012a, 2012b). Nevertheless, older age as a risk factor for mood/anxiety disorders is discussed controversially in the literature. Several studies found an inverse effect between age and adverse mental health outcomes in adults after natural disasters (Norris et al., 2002; Xu and Song, 2011), and Norris et al. (2002) and Zhang et al. (2011) have reported that middle-aged adults show the highest risk for distress and resulting mental health prevalence. This was explained by greater responsibilities, burdens and resulting stress for people in this age after natural disasters (Chen et al., 2007; Norris et al., 2002). On the other hand, several studies on the 2008 Wenchuan earthquake (China), also for prevalence, confirm our findings by showing that older age is a risk factor for PTSD (Kun et al., 2013; Zhou et al., 2013), depression (Zhou et al., 2013), as well as anxiety (Zhou et al., 2013) in adults from heavily affected areas. Chen et al. (2007) also found this effect for psychiatric morbidity in severely hit survivors after the 1999 Taiwan earthquake. An explanation for our finding may be the fact that adults (≥ 15 years) showed higher clinically diagnosed rates of chronic mood and anxiety disorder(s) than children (<15 years) in our study. As a result older people may be more prone to the impacts of an unexpected traumatic event leading to a relapse of the disorder (Kun et al., 2013; Norris and Elrod, 2006).

Our finding that the strongest predictor for having a mood or anxiety disorder was a history of these disorders confirms this assumption and is a commonly found result in studies of prevalence after natural disasters (Bergiannaki et al., 2003; Galea et al., 2005; Kadak et al., 2013).

Looking at different earthquake exposure variables, an interesting finding was that living farther away from areas damaged by moderate to major lateral spreading and also minor to moderate and severe liquefaction as a consequence of the Christchurch earthquake was a protective factor for getting a mood or anxiety disorder. Additionally, closer proximity was a risk factor. Several qualitative studies indicated such a result by showing a stronger association between specific mood or anxiety disorders like PTSD or depression and living in a highly affected rather than a less affected or unaffected area (Bödvarsdóttir and Elklit, 2004; Dell'Osso et al., 2013; Dorahy and Kannis-Dymand, 2012;

Table 5
Model 3 to 12—Multivariate fixed effect logistic regression models to identify exposure to earthquake impacts as risk factors for mood and anxiety disorders in Christchurch urban area after the Christchurch earthquake adjusted for gender, age, ethnicity, deprivation, mental health co-morbidity, pre-existing mood/anxiety and other mental disorder(s).

Model	Independent variables	Odds ratio	*p*-Value	CI (95%)
	Distance (km) to CERA land classification			
3	Red Zone	0.995	0.108	0.988–1.001
4	TC3	0.977	< 0.01	0.962–0.992
5	TC2	0.974	< 0.01	0.957–0.992
6	TC1	1.003	0.311	0.998–1.007
	Hazard intensity measures of the Christchurch earthquake			
7	PGA	1.052	0.229	0.968–1.143
8	MMI	1.043	< 0.05	1.008–1.079
	Distance (km) to areas with lateral spreading from the Christchurch earthquake			
9	severe	0.993	0.091	0.984–1.001
10	moderate to major	0.988	< 0.05	0.977–0.999
	Distance (km) to areas with liquefaction from the Christchurch earthquake			
11	severe	0.985	< 0.05	0.973–0.997
12	minor to moderate	0.987	< 0.05	0.975–0.999

Goenjian et al., 2000; Rowlands, 2012; Şahin et al., 2007). For example Dorahy and Kannis-Dymand (2012) referring to the 2010 Darfield earthquake and Rowlands (2012) studying the 2011 Christchurch earthquake, found that highly affected communities showed higher depression scores than the less affected ones. Other studies used possession loss and/or extent of damage to the home as exposure variables showing that PTSD and depression was more common in exposed than less or unexposed people (Başoğlu et al., 2004; Bergiannaki et al., 2003; Sattler et al., 2006; Sharan et al., 1996; Wang et al., 2011). Groome and Soureti (2004), as well as DiMaggio et al. (2010), used a similar distance based approach as our study to confirm a dose of exposure effect. Groome and Soureti (2004) found a relationship between closer proximity to the 1999 Greek earthquake epicentre and increasing PTSD Symptoms, and DiMaggio et al. (2010) showed an association between closer proximity to the World Trade Centre and increasing anxiety-related diagnoses after the 11th September 2001 terrorist attacks.

Such a distance based dose of exposure effect was also found for the CERA land classifications TC3 and TC2, showing that living farther away from areas that are likely to suffer damage from liquefaction in future seismic events reduced the risk of having a mood or anxiety disorder. The fear of future damage due to the thousands of aftershocks of the 2010 Darfield earthquake, and especially the 2011 Christchurch catastrophe, may have contributed to this outcome. Numerous studies assume that there is an association between stress-related health outcomes and ongoing aftershocks (Başoğlu et al., 2004; Bödvarsdóttir and Elklit, 2004; Dorahy and Kannis-Dymand, 2012; Suzuki et al., 1997; Varela et al., 2008; Xu and He, 2012) and there are indications that reminders of past traumatic events leave people in constant fear of recurrence and result in symptoms of depression-like feelings of helplessness, as well as stress (Başoğlu et al., 2004; Bödvarsdóttir and Elklit, 2004; Duncan et al., 2013). Başoğlu et al. (2004) showed that damage to the home, in association with fear during the event and possibly the pervasive fear and helplessness concerning future aftershocks, was a predictor for getting traumatic stress symptoms. According to Dorahy and Kannis-Dymand (2012), uncontrollability of response to ongoing aftershocks is associated with acute stress symptoms in affected communities irrespective of the level of affectedness. Unfortunately, the direct effect of aftershocks couldn't be included in our regression analyses since the date of diagnosis was not known and only annual summaries were available.

We further identified that people living in areas affected by higher earthquake shaking intensity, measured by MMI of the Christchurch earthquake, were more likely to have a mood or anxiety disorder than people living in areas with lower shaking intensity. This result is in line with the study of Maruyama et al. (2001), who compared the severity of depressive symptoms and mental health status between three differently exposed groups to seismic intensity, and found an association between more depressive symptoms, as well as lower mental health status with greater intensity.

A factor that played an important part after the 2011 Christchurch earthquake, and may be a reason that exposure to 'Red Zone' areas wasn't significant in the regression model, is migration. When a property was classified as 'Red Zone' the Crown made an offer to buy it. Our exposure analyses only looked at residence on the 30th of June 2012, so many people with a mood or anxiety disorder may have already moved away from 'Red Zone' areas by then. Newell et al. (2012) found that approximately 20,000 residents redirected their mail to an alternative address within the city, and a further 5000 to addresses outside Christchurch after the earthquake, which shows the scale of residential movement. Furthermore, when people move away from their earthquake affected community, their social networks may change or get disrupted, which have been associated with lower quality of life (Chou et al., 2013), as well as higher risk for psychological distress (Oyama et al., 2012).

Also, life in Christchurch after the 22nd February 2011 earthquake involved dealing with a changing environment resulting in disruption of communities and services, uncertainty due to CERA land assessments, the ongoing threat of further severe earthquakes, long-lasting insurance processes, as well as insurance troubles and less frequent socialisation, which have been associated with symptoms of generalized anxiety and depression (Renouf, 2012). Therefore, high levels of stress are often found after such events (Carr et al., 1995; Duncan et al., 2013; Yuan et al., 2013) and may have contributed to the increased risk of having a mood or anxiety disorder in the year 2011/12, especially in the most affected central and eastern parts of Christchurch identified by the spatio-temporal cluster analysis. Further, Reed (2013) identified a similar high rates cluster of anxiety disorders, but for an earlier period between August 2010 and April 2011 and using a different geographical unit. On the other hand, higher rates of mood and anxiety recognized after an earthquake may also be due to the higher awareness of clinicians by more proactive case-finding when examining patients and increased service provision after such traumatic events.

In conclusion, the effects of ongoing exposure to physical earthquake impacts on adverse mental health outcomes is still a contested area and, to date, not fully understood. The results of this study showed that people living in regions more affected by liquefaction, lateral spreading, MMI, or areas at risk for further damage are more likely to having been diagnosed with a mood and anxiety disorder after the Christchurch earthquake and are the ones in greatest need for mental health care support. It is therefore important to employ early intervention as highlighted by Giannopoulou et al. (2006), who showed that PTSD symptoms were higher in non-treated children compared to those who attended an eight session group treatment, and that 93% of those likely to be diagnosed with PTSD didn't receive such a service. Reducing fear may also be helpful in preventing the development of PTSD by doing home visits and deploying mobile clinics to provide sustained psychosocial support for the high-risk population and to avoid the chronicity of symptoms (Xu and Song, 2011). Kun et al. (2013) also mention the importance of providing accessible and respectful services with an awareness of the vulnerability of survivors. They further emphasise the influence of social, economic and political environment on the well-being of the population, which are important factors in light of community disruption and resource losses after natural disasters. Mental health care services should provide support to survivors living in or in close proximity to communities affected by liquefaction, lateral spreading or MMI, to help them better cope with their situation until a stable social network and a high level of resilience has been rebuilt. However, the mobility of people may also play an important role since those who have been highly affected by the earthquake may not live in the same neighborhood anymore, something that merits further research.

5. Limitations

Our study has a number of limitations that should be considered, when interpreting and discussing the results.

The first limitation is the use of different exposure variables at a meshblock level. They don't represent individual experienced exposure, but are contextual variables with different levels of accuracy. The CERA land classification is based on area-wide geotechnical assessments of the structural damage to develop area-wide guidelines for future building design to better perform in future seismic events. Their spatial distributions can be viewed as good estimations for performance in future earthquake events. Lateral spreading and liquefaction maps were produced to assist in assessing insurance claims under the Earthquake Commission Act 1993 and can therefore also be considered as a good representation of the real spatial distribution. On the other hand, MMI and PGA were automatically generated maps and therefore only rough approximations.

Furthermore, the exposure variables were highly intercorrelated since high shaking intensity can cause lateral spreading and liquefaction in areas with poor soil conditions. Additionally, these impacts influenced the outcomes of the geotechnical assessments for CERA land classifications.

Another limitation was that diagnosed cases were used, which greatly underrepresent actual cases and especially some sectors of the population including Maori and Pacific people. Moreover, lots of diagnoses with over 70 clinical codes were included into the mood and anxiety indicator, so that inferences to individual disorders, like PTSD, anxiety or depression, couldn't be made. So the indicator was aggregated to annual summaries. This also didn't allow inclusion of the mobility of people to look at the length of exposure to an impact, or to examine how long a person has been exposed until he or she got diagnosed. Having these data would have given a more accurate measure of the relationship between exposure and getting a mood or anxiety disorder. This will be investigated in future research.

6. Conclusions

The findings of this study suggest that up to over one year after a major earthquake people are more likely to have a mood or anxiety disorder if they live in close proximity to areas with moderate to major lateral spreading or liquefaction, or in a highly affected area measured by MMI. Furthermore, after showing a weak, but statistically significant effect, living in closer proximity to areas that are likely to perform poorly in future earthquakes may increase the risk of getting a mood or anxiety disorder in the population.

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