GEOGRAPHIC VARIATION

IN EXPOSURE TO THE

2010/11 CANTERBURY EARTHQUAKE SERIES

AND ITS IMPLICATIONS ON

ADVERSE MENTAL HEALTH OUTCOMES

A thesis submitted in partial fulfilment

of the requirements for the

Degree of Doctor of Philosophy in Geography

at the

University of Canterbury

by

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2016

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Acknowledgments

Abstract

Natural hazard disasters often have large area-wide impacts, which can cause adverse stress-related mental health outcomes in exposed populations. As a result, increased treatment-seeking may be observed, which puts a strain on the limited public health care resources particularly in the aftermath of a disaster. It is therefore important for public health care planners to know whom to target, but also where and when to initiate intervention programs that promote emotional wellbeing and prevent the development of mental disorders after catastrophic events. A large body of literature assesses factors that predict and mitigate disaster-related mental disorders at various time periods, but the spatial component has rarely been investigated in disaster mental health research.

This thesis uses spatial and spatio-temporal analysis techniques to examine when and where higher and lower than expected mood and anxiety symptom treatments occurred in the severely affected Christchurch urban area (New Zealand) after the 2010/11 Canterbury earthquakes. High-risk groups are identified and a possible relationship between exposure to the earthquakes and their physical impacts and mood and anxiety symptom treatments is assessed. The main research aim is to test the hypothesis that more severely affected Christchurch residents were more likely to show mood and anxiety symptoms when seeking treatment than less affected ones, in essence, testing for a dose-response relationship.

The data consisted of mood and anxiety symptom treatment information from the New Zealand Ministry of Health's administrative databases and demographic information from the National Health Index (NHI) register, when combined built a unique and rich source for identifying publically funded stress-related treatments for mood and anxiety symptoms in almost the whole population of the study area. The Christchurch urban area within the Christchurch City Council (CCC) boundary was the area of interest in which spatial variations in these treatments were assessed. Spatial and spatio-temporal analyses were done by applying retrospective space-time and spatial variation in temporal trends analysis using SaTScan^{TM} software, and Bayesian hierarchical modelling techniques for disease mapping using WinBUGS software.

The thesis identified an overall earthquake-exposure effect on mood and anxiety symptom treatments among Christchurch residents in the context of the earthquakes as

they experienced stronger increases in the risk of being treated especially shortly after the catastrophic 2011 Christchurch earthquake compared to the rest of New Zealand. High-risk groups included females, elderly, children and those with a pre-existing mental illness with elderly and children especially at-risk in the context of the earthquakes. Looking at the spatio-temporal distribution of mood and anxiety symptom treatments in the Christchurch urban area, a high rates cluster ranging from the severely affected central city to the southeast was found post-disaster. Analysing residential exposure to various earthquake impacts found that living in closer proximity to more affected areas was identified as a risk factor for mood and anxiety symptom treatments, which largely confirms a dose-response relationship between level of affectedness and mood and anxiety symptom treatments. However, little changes in the spatial distribution of mood and anxiety symptom treatments occurred in the Christchurch urban area over time indicating that these results may have been biased by pre-existing spatial disparities. Additionally, the post-disaster mobility activity from severely affected eastern to the generally less affected western and northern parts of the city seemed to have played an important role as the strongest increases in treatment rates occurred in less affected northern areas of the city, whereas the severely affected eastern areas tended to show the lowest increases. An investigation into the different effects of mobility confirmed that within-city movers and temporary relocatees were generally more likely to receive care or treatment for mood or anxiety symptoms, but moving within the city was identified as a protective factor over time. In contrast, moving out of the city from minor, moderately or severely damaged plain areas of the city, which are generally less affluent than Port Hills areas, was identified as a risk factor in the second year post-disaster. Moreover, residents from less damaged plain areas of the city showed a decrease in the likelihood of receiving care or treatment for mood or anxiety symptoms compared to those from undamaged plain areas over time, which also contradicts a possible dose-response relationship. Finally, the effects of the social and physical environment, as well as community resilience on mood and anxiety symptom treatments among long-term stayers from Christchurch communities indicate an exacerbation of pre-existing mood and anxiety symptom treatment disparities in the city, whereas exposure to 'felt' earthquake intensities did not show a statistically significant effect.

The findings of this thesis highlight the complex relationship between different levels of exposure to a severe natural disaster and adverse mental health outcomes in a severely affected region. It is one of the few studies that have access to area-wide health and impact information, are able to do a pre-disaster / post-disaster comparison and track their sample population to apply spatial and spatio-temporal analysis techniques for exposure assessment. Thus, this thesis enhances knowledge about the spatio-temporal distribution of adverse mental health outcomes in the context of a severe natural disaster and informs public health care planners, not only about high-risk groups, but also where and when to target health interventions. The results indicate that such programs should broadly target residents living in more affected areas as they are likely to face daily hardship by living in a disrupted environment and may have already been the most vulnerable ones before the disaster. Special attention should be focussed on women, elderly, children and people with pre-existing mental illnesses as they are most likely to receive care or treatment for stress-related mental health symptoms. Moreover, permanent relocatees from affected areas and temporarily relocatees shortly after the disaster may need special attention as they face additional stressors due to the relocation that may lead to the development of adverse mental health outcomes needing treatment.

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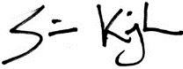
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The original idea for the paper was conceived through discussion between the candidate and the senior supervisor along subsequent contributions from the co-authors. Edward Griffin extracted the health and sample information from the Ministry of Health's administrative databases. The candidate gathered exposure information, performed the statistical analysis, produced figures and tables and wrote a complete (100%) first draft of the manuscript. Comments resulting in minor edits were the result of advice by the co-authors and a major revision was requested by the peer-reviewers. The paper was accepted for publication after the peer-reviewers concerns have been addressed by the candidate. The candidate contributed no less than 90% of the total work required for this chapter.

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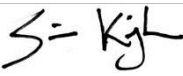
The original idea for the paper was the candidate's and included subsequent contributions from the co-authors. The candidate gathered health information from the Ministry of Health, performed the statistical analyses, produced figures and tables and wrote a complete (100%) first draft of the manuscript. Comments resulting in minor edits were the result of advice by the co-authors. The candidate contributed no less than 95% of the total work required for this chapter.

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Hogg, D., Kingham, S., Wilson, T. M., & Ardagh, M. (2016). The effects of relocation and level of affectedness on mood and anxiety symptom treatments after the 2011 Christchurch earthquake. *Social Science & Medicine*, *152*, 18-26. doi:10.1016/j.socscimed.2016.01.025

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Hogg, D., Kingham, S., Wilson, T. M., & Ardagh, M. (2016). The effects of spatially varying earthquake impacts on mood and anxiety symptom treatments among long-term Christchurch residents following the 2010/11 Canterbury earthquakes, New Zealand. Under peer-review in *Health & Place*

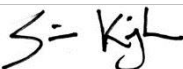Please detail the nature and extent (%) of contribution by the candidate:

The original idea for the paper was conceived through discussion between the candidate and the senior supervisor. The candidate gathered exposure information, performed the statistical analyses, produced figures and tables and wrote a complete (100%) first draft of the manuscript. In the context of gathering earthquake felt reports, the candidate spent time at GNS Science to help developing a method to summarise felt reports to produce Modified Mercalli Intensity (MMI) measures for different geographical units. Comments resulting in minor edits were the result of advice by the co-authors. The candidate contributed no less than 95% of the total work required for this chapter.

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Note: The figures have been produced by the author; however, Figure 1.1 has been adapted from GeoNet (2015)

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Chapter One: Introduction

Natural hazard disasters and mental health

The burden of natural hazard disasters

Worldwide geophysical and climatic activities pose a threat to millions of people and their living environment since they can trigger natural hazards like earthquakes, tsunamis, volcanic eruptions, hurricanes, tornadoes and floods. The United Nations define a natural hazard as a "natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR, 2009, p. 20). Unfortunately, due to worldwide population growth and urbanisation, environmental degradation and changes caused by human activity, more and more people live in natural hazard prone areas (Huppert & Sparks, 2006; UNISDR, 2013) increasing the risk of structural damage and adverse human health consequences including detrimental physical and mental health outcomes.

Physical health outcomes include death and injury, which may be direct or indirect consequences of disasters, e.g. illnesses from water contamination as a result of damage to the infrastructure. They can vary substantially according to the type of natural hazard and the location where the disaster occurs, with higher casualty rates in low-income countries (Lindell & Prater, 2003). Earthquakes for example show great variability in their magnitude and reported casualties, but are largely concentrated at the edges of tectonic plates like the Pacific Rim (Ramirez & Peek-Asa, 2005). At-risk countries like Japan, the United States of America (USA) or New Zealand have managed to achieve very low fatality rates among exposed populations of severe seismic events mainly attributable to good building code standards (Crowley & Elliott, 2012). Nonetheless, the health and economic impacts of large seismic events still remain large burdens even for relatively well-prepared countries since earthquakes are unpredictable and have large scale impacts, where nearly everyone in close

proximity to the epicentre is, to some extent, likely to be affected (Nolen-Hoeksema & Morrow, 1991). There are distinctive elements of vulnerability for countries like New Zealand, which "has some of the most detailed and advanced seismic hazard models in the world" (Crowley & Elliott, 2012, p. 212).

Research Context - The 2010/11 Canterbury earthquake sequence

On the 4th September, 2010 the Darfield earthquake with a moment magnitude (M_W) of 7.1 occurred on previously unknown faults beneath the Canterbury Plains around 40 km west of Christchurch, the biggest city on New Zealand's South Island with approximately 390,000 inhabitants in June 2010 (Statistics New Zealand, 2010), causing severe damage to the city's built environment. Before this event, Christchurch was deemed one of the safest cities in New Zealand for earthquake risk due to the absence of large tremors in the Canterbury region for decades (Wilson, 2013) as the last earthquake producing a strong shaking intensity in Christchurch - VI on the Modified Mercalli Intensity (MMI) scale - was the 9th March, 1929 Arthur's Pass earthquake (M_W 7.0) (Environment Canterbury, 2015). Moreover, the Darfield event just marked the beginning of the 2010/11 Canterbury earthquake series as it triggered thousands of aftershocks, which predominantly migrated eastwards towards the city along a newly identified east-west fault trace subsequently named as the Greendale Fault (Bannister & Gledhill, 2012) (Figure 1.1).
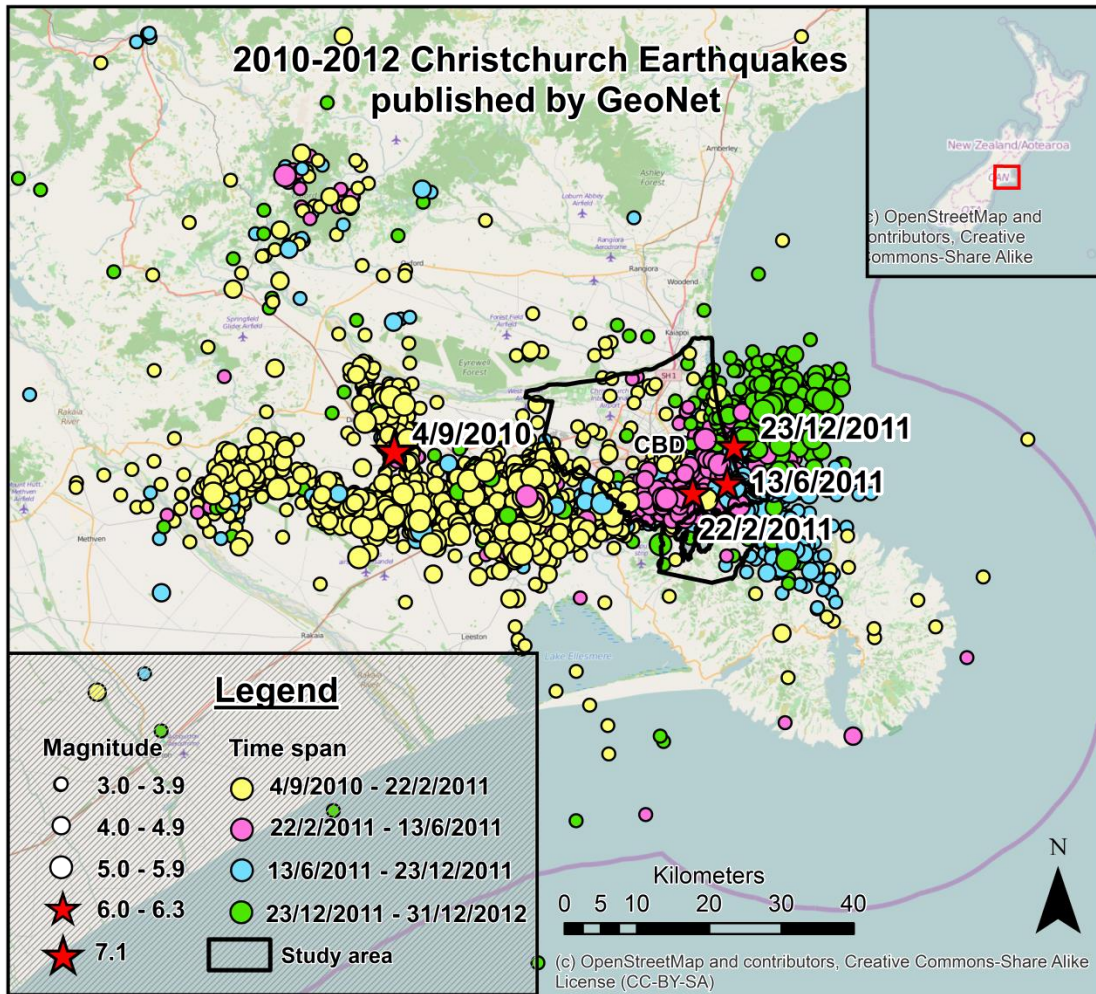
Figure 1.1: Map showing the 4th Sept 2010 Darfield mainshock, the significant 22nd Feb 2011, 13th June 2011 and 23rd Dec 2011 earthquakes and all other aftershocks above M_W 3.0 till 31/12/2012 in Christchurch and its hinterland (source: author adapted from GeoNet, 2015)

The most devastating earthquake event of this long-lasting series of tremors happened on the 22nd February 2011 at 12:51pm local time, when a M_W 6.2 earthquake occurred at a shallow depth of 5-6 km with the epicentre on the Port Hills approximately 6 km southeast of the Christchurch city centre.

Peak Ground Accelerations (PGA) of 1.7g in the horizontal and 2.2g in the vertical direction were recorded in Christchurch, which were significantly higher than the maximum peak ground accelerations experienced in the city as a consequence of the Darfield event (~0.3g) (Giovinazzi et al., 2011). Moreover, these were the highest ever recorded in New Zealand (Kalkan, 2012) and amongst the highest ever recorded in the world (McColl & Burkle, 2012). As a result, much more severe damage occurred to the urban build environment, with the earthquake killing 185 people and leaving the whole city in a state of shock (Bannister & Gledhill, 2012).

But not every part of the city has been affected to the same extent by the earthquakes making it an interesting place to study the effects of different levels of affectedness on adverse health outcomes at a fine geographic scale. Hence, the Christchurch urban area, which is a part of the 'Christchurch City' territorial authority in 2006, was used as the area of interest (Figure 1.1).

Common adverse stress-related health outcomes after natural hazard disasters

The acute emotional stress caused by sudden traumatic events may trigger increased stress-induced physical health outcomes especially on the cardiovascular system including acute myocardial infarctions (Suzuki et al., 1997; Tsai, Lung, & Wang, 2004), stress cardiomyopathy (Chan et al., 2013; Hata, 2009; Watanabe et al., 2005), pulmonary embolism (Hata, 2009), cardiac arrhythmia or cerebrovascular accidents (Bartels & VanRooyen, 2012), but may also lead to the depletion of mental health resources as a consequence of disaster-related changes in living conditions, object/personal resource loss or energy loss among the exposed population. This phenomenon is well-known as the Conservation Of Resources (COR) theory, where individuals strive to hold onto and/or expand their resources, but get stressed if they lose them or fail to gain new ones after an investment (Norris & Wind, 2009). This can result in symptoms of acute stress including emotional numbness, anxiety, fear of aftershocks and sleeping difficulties in the first days and weeks after the traumatic event (Bartels & VanRooyen, 2012), although such

symptoms can still be elevated in exposed populations several years after the disaster happened (Tempesta, Curcio, De Gennaro, & Ferrara, 2013). A few weeks after disaster exposure, symptoms of re-experiencing, avoidance and increased arousal may occur and if they persist for more than one month, the criteria for a Posttraumatic Stress Disorder (PTSD) are satisfied according to the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorder (DSM)-IV (Bartels & VanRooyen, 2012; March, 1993; Mohay & Forbes, 2009). Increased symptom levels can be detected in the long-term up to several years after disaster-exposure (Chen et al., 2007; Goenjian et al., 2000). For example, Chen et al. (2007) found PTSD prevalence of 20.9% among 6,419 hard-hit survivors of the 1999 Chi-Chi earthquake (Taiwan) about 2 years after the event, while Goenjian et al. (2000) found that high PTSD scores among severely affected survivors of the 1988 Spitak earthquake (Armenia) did not diminish up to 4.5 years after the event. PTSD is the most often examined mental disorder after a natural hazard disaster (Galea, Nandi, & Vlahov, 2005; Norris et al., 2002a) and is commonly observed in combination with other psychiatric disorders including generalized anxiety disorder (GAD), major depression disorder (MDD) and/or panic disorder (PD) (Galea et al., 2005; Goenjian et al., 1995; Norris et al., 2002a; Perkonigg, Kessler, Storz, & Wittchen, 2000; Ursano, Fullerton, & Benedek, 2009). Also increased substance use is a common reaction after traumatic events (DiMaggio, Galea, & Vlahov, 2009; Ursano et al., 2009).

Exposure assessment in disaster mental health research

The importance of adverse stress-related mental health outcomes in the aftermath of disasters is widely recognised, since they have been the focus of numerous studies in recent years (Norris, Friedman, & Watson, 2002b). Disaster exposure assessment has also become an essential part in examining mental health effects after a traumatic event as it is believed to be "the most important risk factor for the development of disaster-related PTSD" (Galea et al., 2005, p. 84), as well as a common identified risk factor for other disaster-related mental disorders like depression (Armenian et al., 2002; Giannopoulou et al., 2006;

Goenjian et al., 2001; Sezgin & Punamäki, 2012; Tracy, Morgenstern, Zivin, Aiello, & Galea, 2014; Ying, Wu, Lin, & Chen, 2013) or anxiety (Lonigan, Shannon, Finch, Daugherty, & Taylor, 1991; Sezgin & Punamäki, 2012; Shore, Tatum, & Vollmer, 1986; Xu, Xie, Li, Li, & Yang, 2012). To measure an individual's nature and extent of disaster exposure a number of individual experiences have been associated with mental disorders in the aftermath of natural hazards disasters including the death of a family member or friend (Heir & Weisaeth, 2008; Wang et al., 2009), economic loss, job loss, loss of home, the disruption of social networks (Kılıç et al., 2006) or disruption of everyday activities/life (La Greca, Silverman, & Wasserstein, 1998) to name but a few. These factors can be categorized as objective like injury, loss of loved ones, economic loss or property damage, and subjective like perceived threat to life, feelings of fear or personal helplessness (Goenjian et al., 2001). It also needs to be kept in mind that factors can influence others, for example the complete destruction of the house or property can also act as economic loss and may lead to relocation, which in turn can result in a loss of social networks (Chen et al., 2007). On the other hand, they can also be categorized into primary and secondary stressors. Primary stressors are direct experiences from people's involvement in a disaster like injury, witnessing someone being killed or fear during the event, whereas secondary stressors are indirectly related to the event like disruption of everyday life, loss of home, insurance problems or lack of social support (Lock et al., 2012). Likert-type scales are often used to measure the intensity of such experiences (Bödvarsdóttir & Elklit, 2004; Dorahy & Kannis-Dymand, 2012; Fan, Zhang, Yang, Mo, & Liu, 2011; Huang & Wong, 2014; Zhang, Wang, Shi, Wang, & Zhang, 2012b) and another common approach is to aggregate stressors to an exposure index (Bal, 2008; Chen, Lin, Tseng, & Wu, 2002; Lai, Chang, Connor, Lee, & Davidson, 2004; van den Berg, Wong, van der Velden, Boshuizen, & Grievink, 2012; Verger et al., 2003). Several studies also utilized the geographic location of an individual when the event happened (Giannopoulou et al., 2006; Maruyama, Kwon, & Morimoto, 2001) or the individual's residential location (Goenjian et al., 1994a, 1994b, 1995, 1996, 2000; Greaves et al., 2015; Pynoos et al., 1993; Şahin, Batıgün, & Yılmaz,

2007) to assign contextual information and measure disaster exposure and stressors in a wider context, for example across different communities. More advanced spatial analysis techniques like distance-based approaches were applied in the context of the 9/11 terrorist attacks to assess the effects of spatial proximity to the World Trade Center on psychopathology and substance abuse (DiMaggio, Galea, & Emch, 2010; DiMaggio et al., 2009). Such techniques have been mainly utilised in the field of spatial epidemiology, where inference about the cause of diseases is drawn from space-time information (Jacquez, 2000). As an example, space-time exposure patterns have been modelled to assess a possible environmental disease causation pathway of Amyotrophic Lateral Sclerosis (ALS) (Sabel, Boyle, Raab, Löytönen, & Maasilta, 2009) and space-time information used to identify the effects of deprivation mobility on cardiovascular disease (CVD) hospitalizations (Exeter, Sabel, Hanham, Lee, & Wells, 2015), but such combinations of residential histories, contextual information and spatial analysis techniques to assess individual space-time exposure trajectories can rarely be found in disaster mental health research.

Gaps in disaster mental health research

Despite the large body of literature on adverse mental health outcomes after natural hazard disasters, there is still a need for long-term studies on the general population, utilizing hard data on physical destruction, environmental disruptions, mobility of exposed populations, as well as economic damage, in order "to better assess the nature, duration, and scope of the effects on mental and physical health" (Neria, Galea, & Norris, 2009, p. 604). This enables a better understanding and more reliable prediction of the mental health needs of exposed populations.

Knowledge about geographic differences in mental health outcomes can additionally help target mental health services more efficiently in the aftermath of natural hazard disasters. For this purpose, spatial analysis techniques are an obvious tool of choice, but have rarely been applied. One reason for this may be the domination of psychology, psychiatry and

public health in the disaster mental health research field. Another reason may be the limited availability of area-wide health and physical impact information in the aftermath of natural hazard disasters. In this respect, the 2010/11 Canterbury earthquakes provide an exception since the National Health Index (NHI), which is a registration system to provide unique patient identifiers for healthcare users in New Zealand covering approximately 98% of the population (Ministry of Health, 2009), offers a large health and demographic source of data to assess geographic variations in adverse health outcomes and relate them to various physical and social disaster impacts. The physical impacts of the most severe Canterbury earthquakes have been mapped and published by governmental authorities including information about the geographic distribution of liquefaction or lateral spreading, as well as land classifications based on current and expected future earthquake damage.

Hence, this thesis used these rich data sources to address the discussed limitations of some previous disaster mental health research by examining the dose-response relationship between different levels of exposure to community-wide impacts of the 2010/11 Canterbury earthquake sequence (measured by joining residential histories and environmental factors via spatial analysis techniques) and mental health symptom treatments up to nearly two and a half years after the devastating February 22, 2011 Christchurch earthquake.

Study aim

Thesis hypothesis

The overarching aim of the thesis was to investigate if Christchurch residents who have been more severely affected by the Canterbury earthquakes and their impacts were more likely to show mood or anxiety symptoms when seeking care or treatment than residents who were less affected, but live in the same city.

Research objectives

To achieve this aim, specific research objectives were to identify:

1. what role geographic location plays in assessing the relationship between exposure to natural hazard disasters and adverse mental health outcomes and what research opportunities arise from this

2. if there has been an increased need for mood and anxiety symptom treatments in Christchurch as a consequence of the earthquakes

3. where and when increased, but also decreased, levels of mood and anxiety symptom treatments occurred within Christchurch in the context of the earthquakes

4. who was at increased risk of being treated for mood and anxiety symptoms in the context of the earthquakes

5. which role different types of relocation play on mood and anxiety symptom treatments in the aftermath of severe earthquakes

6. which factors may have increased or mitigated the need for mood and anxiety symptom treatments with a specific focus on earthquake-related impacts like different levels of damage to the built environment, felt earthquake intensities and disruptions to the social, economic and natural community environment

Data sources and research challenges

To achieve the research goals, demographic, health and residential history information from the New Zealand Ministry of Health's administrative databases was combined with community-wide impact information allowing us to examine individual space-time exposure trajectories and associate these with adverse mental health outcomes measured by publically funded mood and anxiety symptom treatments. In New Zealand the health system consists of fully publically funded hospital care, subsidised primary (General Practitioners) and other community healthcare, and subsidised pharmaceuticals. A parallel private health care system is available. The public and subsidised care is overseen centrally by the New Zealand Government's Ministry of Health, with funding devolved to a number of District Health Boards (DHBs) responsible for the provision of services in their regions. General Practitioner services are arranged in Primary Healthcare Organisations (PHOs), consisting of a number of General Practitioners in a geographical area. All people who access any of these services have a unique, National Health Identifier (NHI) number which the individual normally keeps for life and which identifies every episode of care within the system. As a result, the Ministry of Health's administrative health data – the so called "Health Tracker" – enables identifying a large proportion of help-seekers being treated for moderate or severe symptomatology and drawing large area-wide samples based on the National Health Index (NHI) register information[1]. This register contains demographic information such as date of birth, sex and ethnicity, and quarterly residential information at a meshblock level[2] allowing the assessment of exposure pathways.

A key role in answering the main research hypothesis is exposure assessment as there are many different approaches to measure the extent of disaster exposure and along with the uniqueness of every catastrophe and its impacts it is difficult to choose the most appropriate one. The need for longitudinal studies, as well as assessment of community-level processes

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[1] Primary health organisations (PHOs) (2 in Christchurch and 32 in New Zealand) are health care providers to support the provision of essential primary health care services through general practices.

[2] The smallest geographic unit defined by Statistics New Zealand with on average 110 people

in disaster mental health research (Neria et al., 2009; Norris et al., 2002b) led to the utilization of neighbourhood- and community-level impact information for assessing disaster-exposure in this study. Additionally, a special focus was given to mobility, because a relatively large population shift occurred from the severely to less affected areas after the 22nd February 2011 Christchurch earthquake (Howden-Chapman et al., 2014) and relocatees face quite different challenges than stayers after a disaster (Uscher-Pines, 2009). This gives a unique insight into the spatio-temporal effects of different extents of exposure to community-wide impacts on adverse mental health outcomes in a severely affected city whilst taking into account the mobility of the exposed population.

Significance of research

The thesis contributes to create awareness and inform public health providers and political decision makers about the spatio-temporal variation of adverse mental health outcomes and associated risk and protective factors after severe earthquakes enabling a better planning and targeting of the limited mental health services after severe seismic events. The studies in this thesis help show that adverse mental health outcomes are not evenly distributed and can vary substantially on a fine geographic scale. The important role of geographic location and tracking affected populations to assess different levels of exposure to disaster impacts is highlighted as a strong mobility activity is commonly observed after natural hazard disasters. Consequently, the thesis substantially expands the international and interdisciplinary natural disaster mental health literature by using spatial analysis techniques to assess the geographic variation of adverse mental health outcomes, track sample populations and measure their exposure to various earthquake impacts. Finally, investigating different levels of exposure on a fine geographic scale in the most severely affected city including almost all of the city's population constitutes a novel approach.

Thesis structure

The thesis answers the research objectives in the form of a series of studies presented as chapters to meet the main research hypothesis. Initially, a literature review examines different exposure assessment techniques applied to test the dose-response relationship between exposure to natural hazard disasters and adverse mental health outcomes, identifying shortcomings and research opportunities in disaster mental health research (Chapter 2). The next four chapters are empirical research studies examining

- the geographic variation of mood and anxiety symptom treatments in Christchurch over time and post-disaster associations with different physical earthquake impacts (Chapter 3),

- a possible earthquake exposure effect compared to less exposed populations from other parts of the country, high-risk groups and the spatio-temporal variation and changes of mood and anxiety symptom treatments (Chapter 4),

- the effects of different types of relocation, as well as level of affectedness on mood and anxiety symptom treatments (Chapter 5),

- the effects of community disruptions, resilience and ongoing aftershocks on mood and anxiety symptom treatments among long-term stayers (Chapter 6).

The final chapter (Chapter 7) summarises and contextualises the linked research chapters by putting the results into the context of the current state of disaster mental health research and highlighting the implications on mental health planning policy. An overview of the linkages between chapters and objectives is presented in Figure 1.2.
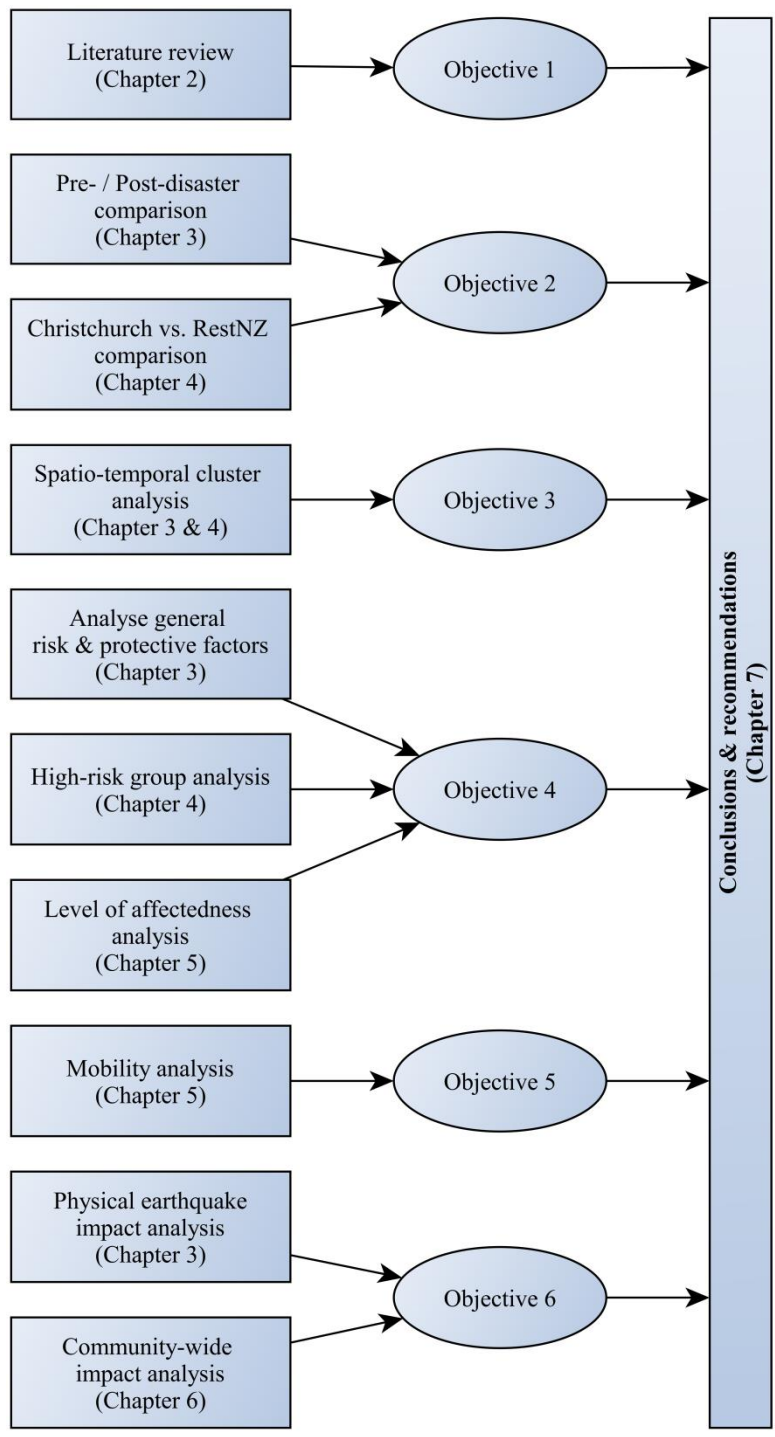
Figure 1.2: Thesis structure overview showing the chapter and objective connections

Academic publications

The contents of chapters 2 to 6 have been collated from papers submitted to different peer-reviewed journals for publication. As a result, some parts of the chapters are repetitive. Each publication aims to meet the research objectives in a clear and logical order, but simultaneously emerges from previous findings leading to a multiple targeting of objectives by different chapters. The nature of the papers and publication status can be seen in Table 1.1.

Table 1.1: Academic publications in the context of the thesis

Chapter	Publication Title	Objective	Authors	Journal	Status
2	Spatial Variation in Individual/Community Exposure to Natural Hazard Disasters and Implications for Mental Health Outcomes: A Review	1	Hogg D., Kingham S., Wilson T. M., Ardagh M.	Natural Hazards	Under peer-review. Submitted 01/12/2014
3	Geographic variation of clinically diagnosed mood and anxiety disorders in Christchurch after the 2010/11 earthquakes	2, 3, 4, 6	Hogg D., Kingham S., Wilson T. M., Griffin E., Ardagh M.	Health & Place	Published in Volume 30, pp. 270-278. http://dx.doi.org/10.1016/j.healthplace.2014.10.003

Chapter	Publication Title	Objective	Authors	Journal	Status
4	Spatio-temporal variation of mood and anxiety symptom treatments in Christchurch in the context of the 2010/11 Canterbury earthquake sequence	2, 3, 4	Hogg D., Kingham S., Wilson T. M., Ardagh M.	Spatial and Spatio-temporal Epidemio-logy	Under peer-review. Submitted 10/08/2015
5	The effects of relocation and level of affectedness on mood and anxiety symptom treatments after the 2011 Christchurch earthquake	4, 5	Hogg D., Kingham S., Wilson T. M., Ardagh M.	Social Science & Medicine	Published in Volume 152, pp. 18-26. http://dx.doi.org/10.1016/j.socscimed.2016.01.025
6	The effects of spatially varying earthquake impacts on mood and anxiety symptom treatments among long-term Christchurch residents following the 2010/11 Canterbury earthquakes, New Zealand	6	Hogg D., Kingham S., Wilson T. M., Ardagh M.	Health & Place	Under peer-review. Submitted 30/12/2015

Chapter Two: Natural hazards disaster exposure and mental health: A literature review

Preface

This chapter reviews different techniques used to assess exposure to natural hazard disasters and its relationship to adverse mental health outcomes highlighting the role of location and geographic analysis techniques. Shortcomings and research opportunities in disaster mental health research are identified.

Abstract

Exposure of individuals and/or communities to natural hazard disasters and the relationship to adverse mental health outcomes have been assessed in a number of studies in recent years. Many different exposure assessment techniques have been developed and a range of different exposure variables identified which may have an impact on mental health outcomes. In this chapter the key literature relating to the methods used to assess exposure to natural hazards disasters and associated mental health outcomes is reviewed. Since there are few standardised tools to assess exposure to a disaster, the different assessment techniques were classified according to strategies employed. The identified exposure assessment techniques were then evaluated to assess their suitability to test the dose of exposure effect theory. Based on this, the value of geographical location in examining exposure to a natural hazard disaster is highlighted, and how effectively this has been addressed by previous studies is assessed.

Introduction

Exposure to a natural hazard disaster is deemed to be the most important risk factor for PTSD (Galea et al., 2005), which is comorbid with other psychiatric disorders (Başoğlu, Kılıç, Salcioğlu, & Livanou, 2004; Goenjian et al., 1995; Perkonigg et al., 2000). Consequently, exposure assessment has become a key element in disaster mental health research and numerous studies found that people experiencing more disaster-related adversities show more severe mental health symptoms and more frequently develop mental disorders after natural hazard disasters (Carr et al., 1997; Galea et al., 2007; Goenjian et al., 1994a, 1994b, 1995, 2000; McDermott, Lee, Judd, & Gibbon, 2005; McFarlane, 1987; Shore et al., 1986; Sprang & LaJoie, 2009; Verger et al., 2003; Weems et al., 2007; Wu, Yin, Xu, & Zhao, 2011). This phenomenon is commonly referred to as the dose-response relationship (Shore et al., 1986) or dose of exposure effect (Bulut, Bulut, & Tayli, 2005). Despite the knowledge about this effect and the importance of disaster exposure, there is no golden rule how to assess exposure as every natural hazard disaster is different, but various approaches have been developed in the last decades. Therefore, this literature review will present these approaches, as well as comment on their usability to assess disaster exposure and implications on adverse mental health outcomes. It also identifies some of the key links between exposure to natural hazard disasters and mental health by reviewing the published literature in this field. Specifically it will develop an insight into the role that geographical/spatial location plays in measuring the nature and extent of disaster exposure, and the impacts this has on the links identified. This is done in light of the growth and development of geospatial analysis tools that could potentially enable better exposure assessment to be undertaken.

Method

Selection criteria

Papers were included in the review if they fulfilled the following criteria:

- stress-related adverse mental health outcome(s) after a natural hazard disaster were assessed

- exposure to the natural hazard disaster was measured and included in the analysis as an independent variable

- at least one group of study participants was resident in a disaster affected area

- the paper was available in English and was peer-reviewed

Only papers from the last three decades were reviewed to capture the more recent developments in the field of research. In addition, papers about less catastrophic events with no fatalities and limited damage to the built environment, like the ones about the Mount Ruapehu (New Zealand) volcanic eruptions in 1995 (Huzziff & Ronan, 1999; Ronan, 1997), were not considered in the evaluation due to limited exposure assessment to disaster impacts and limited analyses on their health effects.

Search strategy

The selection process was based on a multi-step procedure. First of all, the academic databases 'Web of Science', 'ScienceDirect' and 'PubMed/Medline', as well as 'Google Scholar' were used to do a systematic search of peer-reviewed articles addressing the relationship between exposure to natural hazard disasters and mental health outcomes. Therefore the search was based on keywords addressing natural hazard disasters (e.g. 'earthquake', 'tornado', 'tsunami', 'hurricane', 'volcanic eruption', 'flood', 'avalanche', 'landslide', 'snowstorm', 'sandstorm', 'wildfire', 'bushfire', 'natural disaster'), their mental health outcomes (e.g. 'mental health', 'psychopathology', 'traumatic', 'anxiety', 'depression', 'stress', 'PTSD') and known methodology or observed phenomena ('dose of exposure', 'dose of response', 'distance', 'proximity', 'spatial').

These keywords were then combined with 'OR' and 'AND' to search the databases based on long search strings like the following, which led to 332 results in the Web of Science, 512 in the Science Direct and 176 in the PubMed database (25th March 2014):

(earthquake OR tornado OR hurricane OR volcanic eruption OR flood OR avalanche OR landslide OR wildfire OR bushfire OR drought OR snowstorm OR sandstorm OR natural hazard disaster) AND (mental health OR psychopathology OR anxiety OR depression OR mood OR traumatic stress OR PTSD) AND (dose of exposure OR distance OR proximity OR spatial)

The title and abstract of each paper were then analysed based on the selection criteria. After this selection step, a full-text analysis was done for the remaining papers. Finally, the reference lists of suitable publications were used to find any previously unidentified papers about the topic (Jalali & Wohlin, 2012).

Classification criteria

The papers were classified by the type of exposure assessment used, which "estimate the intensity and duration of exposure" to natural hazard impacts (Nurminen, Nurminen, & Corvalan, 1999, p. 586). Estimating exposure to natural hazard disasters has traditionally been done by examining the level of affectedness to disaster impacts based on individual experiences. These experiences can be classified as objective and/or subjective. Objective features include quantitative measures like being trapped, personal injury, injury or death of close ones (e. g. family members, relatives or friends), property loss or damage to the home/property, living conditions (e. g. relocation, living in shelter or own home), separation from family, financial or even job loss and received support. Subjective features include qualitative measures like perceived fear, panic, threat or helplessness during the event, perceived risk of being harmed or loved ones getting harmed or also the feeling of being unable to escape. Such exposure factors can be used to assess the individual exposure effect of each variable, create an exposure index or categorise the sample into different exposure groups based on the severity and/or affirmation of selected objective and

subjective features. Normally a mixture of both features has been used, but with a dominance of the objective ones. The classification was based on the disaster exposure variables described in the methods section and used in the analyses of each paper. Consistent characteristics were identified, resulting in different exposure assessment strategies (Table 2.1). Identified strategies include the utilisation of several individual exposure variables like damage to the home/property or loss of home/property, creation of an exposure index or comparison between affected and unaffected, severely and less severely and also directly and indirectly exposed groups based on different degrees of disaster exposure measured by subjective and/or objective exposure elements, as well as distance to the disaster.

Finally the papers were assessed based on the dose of exposure effect theory, also known as the dose-response relationship, which assesses the "relation between exposure to an identified hazard at different dose levels and the disease risk it induces" (Nurminen et al., 1999, p. 586). If a study found an association between the severity of measured exposure variables and mental disorders, the theory was confirmed, but otherwise rejected. There were a few papers where the theory could only be confirmed for a partial set of exposure variables or only in specific model scenarios, so no clear overall statement could be made in such cases.

Table 2.1: Type of exposure measures used in the reviewed studies

Exposure assessment	Studies
Individual exposure variables	Ahmad et al., 2010[†]; Başoğlu et al., 2002, 2004; Bland et al., 1996, 2005; Bödvarsdóttir & Elklit, 2004; Bradburn, 1991; Chen et al., 2001; Chen et al., 2002; Chen et al., 2007; Chou et al., 2005; Fan et al., 2011; Galea et al., 2007; Heir & Weisæth, 2008; Kolaitis et al., 2003; Kun et al., 2009, 2013; Küçükoğlu et al., 2014; Liu et al., 2010[††]; Livanou et al., 2002; Lonigan et al., 1994; Ma et al., 2011; Maruyama et al., 2001; McDermott et al., 2005; McFarlane, 1987; Naeem et al., 2011; Nolen-

Exposure assessment	Studies
	Hoeksema & Morrow, 1991; Norris et al., 1999; Russoniello et al., 2002; Sattler et al., 2006; Sezgin & Punamäki, 2012; Sharan et al., 1996; Soldatos et al., 2006; Tempesta et al., 2013[†]; Wang et al., 2009; Wang et al., 2011; Wu et al., 2011; Xu et al., 2012; Yang et al., 2003; Ying et al., 2013; Zhang et al., 2011, 2012a, 2012b; Zhou et al., 2013
Exposure Index	Bal, 2008; Carr et al., 1995, 1997; Catani et al., 2008; Chang et al., 2005; Chen & Wu, 2006; Goenjian et al., 1994b, 2001; La Greca et al., 1996, 1998; Lai et al., 2004; McFarlane, 1987; Neuner et al., 2006; Roussos et al., 2005; Shaw et al., 1995; Sprang & LaJoie, 2009; Verger et al., 2003; Vernberg et al., 1996
Affected vs. unaffected group	Bulut, 2006[†††]; Dell'Osso et al., 2012[†††], 2013[†††]; Dorahy & Kannis-Dymand, 2012; Kolaitis et al., 2003[†††]; Maj et al., 1989; Scott et al., 2003[†††]; Zahran et al., 2011
Severely vs. less severely affected groups	Armenian et al., 2000[†††], 2002[†††]; Bulut et al., 2005[†††]; Cao et al., 2003[†††]; Chan et al., 2011[†††]; Chen & Wu, 2006; Dogan, 2011[†††]; Fu et al., 2013; Goenjian et al., 1994a[†††], 1994b, 1995[†††], 1996[†††], 2000[†††]; Groome & Soureti, 2004[†††]; Jin et al., 2014; Kun et al., 2009, 2013; Lonigan et al., 1991; Maruyama et al., 2001; Najarian et al., 2001; Pynoos et al., 1993[†††]; Roussos et al., 2005[†††]; Şahin et al., 2007; Shaw et al., 1995; Shore et al., 1986; Tempesta et al., 2013[†††]; Wang et al., 2009[†††]; Wang et al., 2000a[†††], 2000b[†††]; Weems et al., 2007; Zhang et al., 2010[†††]
Direct vs. indirect exposure	Giannopoulou et al., 2006

[†] distance to epicentre used as an individual exposure variable

[††] school locations in different distances from epicentre used as an individual exposure variable

[†††] distance to epicentre used to separate exposure groups into affected/unaffected or severely/less severely affected groups

Results

Ninety-one papers assessing the relationship between the exposure to a natural hazard disaster and mental health outcomes were found. The earliest paper in this review was published in 1986 (Shore et al., 1986) and the most recent in 2014 (Küçükoğlu, Yıldırım, & Dursun, 2014). Over half of the papers were published within the last ten years (48 of 91), which may be in part due to the increasing digitalisation of articles, but also might indicate that the topic has become of increased interest. Earthquakes have been by far the most often examined natural hazard disasters with 70 papers, followed by hurricanes (13), especially those hitting the USA. Only a handful of papers looked at other natural hazard disasters including tsunamis (3), wildfires (2), floods (1), volcanic eruptions (1) and snowstorms (1). The most often examined event was the 2008 Wenchuan earthquake (China) with 16 publications, followed by the 1988 Spitak earthquake (Armenia) with 9, and the 1999 Chi-Chi earthquake (Taiwan) and the 1999 Marmara earthquake (Turkey) with 8 publications each. A categorization by country showed that 21 papers have been published about events in China, followed by the USA (16), Turkey (10), Armenia (9), Taiwan (8), Italy (6), Greece (5), Australia (4), Pakistan (2), Sri Lanka (2) and a number of countries with 1 selected paper including Colombia, El Salvador, France, Iceland, India, Japan, New Zealand, Nicaragua and Thailand.

The most often examined mental health disorders after natural hazard disasters were PTSD, depression and anxiety, which have been assessed 75, 33 and 23 times respectively. Less frequently assessed mental health outcomes were Acute Stress Reactions (ASR), general psychopathology, psychological distress or morbidity. In addition, predictors for mental disorders after traumatic events, like Disruptive Nocturnal Behaviour (DNB) and sleep disruption have been examined (Tempesta et al., 2013).

Sample sizes ranged from 22 (Bradburn, 1991) to 528,389 (Zahran, Peek, Snodgrass, Weiler, & Hempel, 2011) respondents with a median size of 555. As far as it was possible to categorise publications based on demographic groups or age distribution, 42 papers

solely included adults, 17 just assessed the impacts on children and 9 focused solely on adolescents, but exhibit different age ranges (see Limitations). Children and adolescents were examined in 11 papers and 2 included adolescents and adults. Others remained undefined, because they didn't mention any age limitations (e.g. Zahran et al., 2011) or focussed on a specific demographic group like males (Bland, O'Leary, Farinaro, Jossa, & Trevisan, 1996; Bland et al., 2005; Maruyama et al., 2001).

Separating the papers based on the study period after the event into short- (≤ 6 months) and mid- to long-term (> 6 months), the majority (54) assessed the mid- to long-term consequences of natural hazards disaster exposure on mental health outcomes.

Finally, a clear dose of exposure effect characterized by the relationship between degree of disaster exposure and the severity of a disorder or its symptoms could be confirmed by 72 publications. Only 4 papers didn't show such a dose of exposure effect. The 15 remaining publications couldn't be clearly categorized since the relationship had only been shown for a limited set of exposure variables.

Exposure assessment strategies

Individual exposure variables

To assess the effects of individual exposure variables on mental health outcomes after natural hazard disasters, study populations were usually chosen from highly affected areas. Besides physical injury to self or close ones, damage to the home, loss of home and/or property were very popular exposure variables to measure exposure to natural hazard disasters in terms of their effects on mental health, since these factors represent severe stressors and have been related to PTSD (Bödvarsdóttir & Elklit, 2004; Chen et al., 2007; Küçükoğlu et al., 2014; Kun, Tong, Liu, Pei, & Luo, 2013; Lonigan, Shannon, Taylor, Finch, & Sallee, 1994; McDermott et al., 2005; Naeem et al., 2011; Ying et al., 2013), depression (Chou et al., 2005; Ying et al., 2013), anxiety (Xu et al., 2012), distress (Bland et al., 1996) and general psychiatric morbidity (Chen et al., 2001; Sharan, Chaudhary, Kavathekar, & Saxena, 1996; Yang et al., 2003).

Assessment of degree of home damage has also been used either by categorization of level of damage e.g. 'no', 'minimal', 'moderate', 'severe' damage, 'collapse' (Başoğlu et al., 2004; Başoğlu, Salcioğlu, & Livanou, 2002; Chen et al., 2001; Chen et al., 2002; Chou et al., 2005; Fan et al., 2011; Küçükoğlu et al., 2014; Livanou, Başoğlu, Salcioğlu, & Kalendar, 2002; Lonigan et al., 1994; Nolen-Hoeksema & Morrow, 1991; Norris, Perilla, Riad, Kaniasty, & Lavizzo, 1999; Soldatos, Paparrigopoulos, Pappa, & Christodoulou, 2006; Ying et al., 2013; Zhang et al., 2012a) or using a dichotomous measure, e.g. yes or no, which indicated, if there was any damage (Bland et al., 1996, 2005; Kun et al., 2009, 2013; McDermott et al., 2005; Naeem et al., 2011; Russoniello et al., 2002; Sattler et al., 2006; Wang et al., 2011; Zhou et al., 2013) or if the house had been destroyed (Chen et al., 2007; Ma et al., 2011; Maruyama et al., 2001; Sezgin & Punamäki, 2012; Sharan et al., 1996; Yang et al., 2003; Zhang et al., 2012b). Property loss and other property damage (besides damage to the house) were mainly assessed by dichotomous variables (Başoğlu et al., 2004, 2002; Galea et al., 2007; Kolaitis et al., 2003; Küçükoğlu et al., 2014; Livanou et al., 2002; McFarlane, 1987; Sezgin & Punamäki, 2012; Sharan et al., 1996; Xu et al., 2012; Zhang, Shi, Wang, & Liu, 2011; Zhang et al., 2012b), but in few cases also measured by categories (Fan et al., 2011; Wang et al., 2011; Zhang et al., 2012a). Heir and Weisaeth (2008), as well as Wang et al., (2009), used several individual exposure variables, but not damage to home/property or loss of property. Bödvarsdóttir and Elklit (2004) mentioned that damage to one's property was positively related to PTSD symptoms severity, but didn't explain if they used a dichotomous or categorical measure. Other damage variables were used in some studies. Bradburn (1991) used distances from a collapsed highway after the 1989 Loma Prieta earthquake (USA) as an individual exposure variable to test the association with PTSD symptoms, while Ahmad et al. (2010) and Tempesta et al. (2013) used residential distance from the epicentre in their models. Finally, Wu et al. (2011) tested the association between different school-to-home distances, implying longer exposure with longer walking distances, and post-traumatic stress reactions of Chinese children in a heavy snowstorm.

Exposure indices

Instead of using exposure variables independently, another approach is to build an exposure index/score from various self-reported disaster experiences (Ali, Farooq, Bhatti, & Kuroiwa, 2012; Bal, 2008; Carr et al., 1995; Catani, Jacob, Schauer, Kohila, & Neuner, 2008; Chen et al., 2002; La Greca, Silverman, Vernberg, & Prinstein, 1996; La Greca et al., 1998; Sprang & LaJoie, 2009; Verger et al., 2003). To measure hurricane exposure Vernberg, Silverman, La Greca and Prinstein (1996) developed the Hurricane Related Traumatic Experience (HURTE) inventory which was also used by other studies (La Greca et al., 1996, 1998; Shaw et al., 1995). It is a 17-item dichotomous self-reporting questionnaire assessing three exposure factors consisting of life-threatening experiences (6-items), perceived life threat (1-item) and experiences reflecting disruption and loss (10-items) (Vernberg et al., 1996).

Another index measuring tsunami exposure was developed by Neuner, Schauer, Catani, Ruf and Elbert (2006) after the 2004 Asian tsunami. They calculated an objective and subjective exposure score using dichotomous questions to assess the objective initial exposure to the tsunami (e.g. fled from wave, saw wave, saw people struggling for life, caught by wave or lost father) and subjective event experiences in three severely affected regions in Sri Lanka (e.g. felt very confused or felt disgusted or grossed by what has been seen). Catani et al. (2008) adopted 5 questions from the objective exposure score of this index to calculate the severity of exposure to the same tsunami among 296 Tamil school children in Sri Lanka's North-Eastern provinces.

One tool developed to assess the severity of exposure to an earthquake is the Earthquake Exposure Index (Chen et al., 2002). It has been modified to the Earthquake Exposure Index for Youths (EEIY) by Chen et al. (2002) after the 1999 Taiwan Chi-Chi earthquake and consists of 10-items including an index for death and injury (e.g. injury or death to self or a family member), property loss (e.g. damage to home) and life destruction (e.g. current dwelling or separation from parents). Chen and Wu (2006) also used it to assess PTSD symptoms in children and adolescents after the 1999 Chi-Chi earthquake.

On the other hand, Lai et al. (2004), as well as Chang, Connor, Lai, Lee and Davidson (2005) used the Taiwan Earthquake Experiences Questionnaire (TEEQ) to assess earthquake exposure after the same event. The TEEQ is a 21-item questionnaire containing several subscales assessing the subjects' experiences during and after the earthquake(s) resulting in an exposure score between 0 (no exposure) and 55 (highly exposed). The first subscale consists of 6-items measuring personal loss due to injury (3-items; max. score=13) and exposure to death (3-items; max. score=7), whereas further subscales assess property loss (2-items; max. score=8), dislocation and job loss (3-items; max. score=19), agency support (1-item; max. score=4) and perceived threat (1-item; max. score=4) (Lai et al., 2004). Another index to assess exposure to an earthquake is the Level of Exposure (LoE) scale, which is based on Nolen-Hoeksema and Morrow's (1991) 4-item stress score, and used by Bal (2008) to assess the severity of exposure to the 1999 Marmara earthquake (Turkey). It is a 6-item inventory asking about the damage to the area, as well as home at the time of the earthquake, perceived stress due to injury and/or loss of loved ones, perceived stress due to being injured and daily life disruption using a 4-point Likert-Type self-reported scale (1=none to 4=great deal), which results in a maximum score of 24 (Bal, 2008).

Finally, there is the Cumulative Exposure Indicator (CEI), which is broader and contains 30-items in total. For example, Verger et al. (2003) applied it to measure the exposure to a flood disaster in southeast France in 1992 including damage to the property, physical presence during the event and threat to life as possible stressors, among others.

Exposure group comparisons and the role of spatial location

The earliest study by Shore et al. (1986) categorized their population into different exposure groups to assess the effect of different exposures to the Mount St. Helens (USA) volcanic eruption in 1980 on symptoms of PTSD, depression and anxiety. They recruited 2,152 adults from two severely affected rural areas and one unaffected community splitting them into three differently exposed groups (high-impact, low-impact and control group)

based on residential damage and death of a family member due to the eruption and resultant floods. So, different locations were chosen to retrieve affected and unaffected subjects and then individual-level disaster experiences utilized to create two different impact groups.

In general, the intensity of a disaster can be derived from the disaster impact at a specific location (Ramirez & Peek-Asa, 2005). For example, Zahran et al. (2011) estimated the intensity of the 2005 Hurricane Katrina (USA) based on different degrees of property damage and crop loss suffered by counties, while Maruyama et al. (2001) used the Japan Meteorological Agency (JMA) seismic intensity scale, which follows the likelihood of earthquake damage, to relate the experienced intensity at each subject's location during the great 1995 Hanshin-Awaji earthquake (Japan) to depressive symptoms and mental health status. The first study linked objective contextual information on disaster impacts (property damage and crop loss by county) with residential location information, whereas the second study used a self-reported measure of intensity at the place and time of the event to assess different levels of exposure.

Giannopoulou et al. (2006) used each subject's location during the 1999 Athens earthquake (Greece) to separate its sample into a directly exposed group of children experiencing the earthquake in Athens and an indirectly exposed group, which was away from Athens when it struck.

Furthermore, residential location has been used to assign different levels of exposure based on distances to the disaster, but this can misrepresent localised disaster impacts when small distances are chosen (Ramirez & Peek-Asa, 2005). With greater distances the level of affectedness is likely to decrease in many cases. A lot of studies take advantage of this phenomenon by comparing affected with unaffected or severely with less severely affected communities based on different distances from the epicentre of an earthquake up to hundreds of kilometres (Ahmad et al., 2010; Armenian et al., 2000, 2002; Bulut et al., 2005; Bulut, 2006; Cao, McFarlane, & Klimidis, 2003; Chan et al., 2011; Dogan, 2011; Goenjian et al., 1994a, 1994b, 1995, 1996, 2000; Liu et al., 2010; Najarian, Goenjian, Pelcovitz, Mandel, & Najarian, 2001; Pynoos et al., 1993; Şahin et al., 2007;

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Tempesta et al., 2013; Wang et al., 2000a, 2000b; Zhang et al., 2010). Zhang et al. (2010) compared a highly exposed group from an area 35 km away from the Wenchuan earthquake epicentre with a lowly exposed group from an area 125 km away, while Cao et al. (2003) compared three different exposed groups and a control group 20, 37, 62 and 520 kilometres from the 1988 Yun Nan earthquake (China) epicentre. Several studies in the aftermath of the 1988 Spitak earthquake (Armenia) drew their subjects from three cities with increasing distances from the epicentre (Spitak a few kilometres from the epicentre, Gumri 35 km away and Yerevan 75 km away) to measure and compare different degrees of earthquake exposure with PTSD, depression and anxiety (Goenjian et al., 1994a, 1994b, 1995, 1996, 2000; Pynoos et al., 1993). Roussos et al. (2005) used a similar approach by comparing a group of children and adolescents from a highly affected community near the epicentre of the 1999 Athens earthquake (Greece) and a group from a less affected community just 10 km away and also Wang et al. (2000a) assessed two groups from two villages in 0.5 and 10 km distance from the 1998 Hebei earthquake (China) epicentre. These examples illustrate how various distance measures have been used to assess exposure to a disaster and that differences in the degree of exposure occur even at relatively small distances.

Groome and Soureti (2004) chose a larger spatial aggregation by comparing three groups from different districts with increasing distances from the 1999 Athens earthquake (Greece) epicentre. Dorahy and Kannis-Dymand (2012) didn't consider distance from the epicentre, but chose subjects from two differently affected suburbs in the severely affected city of Christchurch after the 2010 Darfield earthquake and examined individual disaster experiences. So, the geographic unit may also be used to draw samples with different degrees of exposure. Relatively large geographic areas like cities or regions with increasing distances from an earthquake epicentre were more often used (Ahmad et al., 2010; Armenian et al., 2000; Cao et al., 2003; Chan et al., 2011; Dogan, 2011; Goenjian et al., 1996; Groome & Soureti, 2004; Tempesta et al., 2013; Wang et al., 2000a, 2000b) than smaller areas such as suburbs within a community (Bulut et al., 2005; Carr et al., 1995;

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Dorahy & Kannis-Dymand, 2012), where the severity of physical impacts may vary little over space and is not necessarily linked to the distance to the epicentre as it can change abruptly.

Summary of exposure assessment strategies

In conclusion, many different approaches have been used to measure different levels of exposure to a natural hazard disaster and its physical impacts with location playing a key role in this process. It has been shown that distance from an epicentre is a good approach to measure area-wide exposure differences and is also useful, if limited information on individual exposure is available. Nevertheless, spatial analysis techniques to measure area-wide exposure differences more accurately have not been employed yet in natural disaster mental health research. On the other hand, individual exposure variables captured via surveys most accurately reflect individual experiences to disaster impacts and enable testing of the independent relationship of several experiences. Additionally, they can be summarised to exposure indices to get fine scale exposure levels, which can't be retrieved as easily by area-wide measures. A very important exposure variable that has been used by many studies as a measure of disruption, and was often accompanied by further secondary stressors like financial loss, displacement or dealing with insurance claims, is damage to the home or property (Carr et al., 1995, 1997; Lonigan et al., 1994). It is a good measure of exposure in the short-term aftermath of a disaster, but its effect has been found to decrease over time (Norris & Wind, 2009).

Dose of exposure effect

As stated above, the dose of exposure effect also known as the dose-response relationship describes the phenomenon where the severity of mental health symptoms increases with increasing exposure to a disaster (Bulut et al., 2005; Bulut, 2006). Shore et al. (1986) found this effect by identifying increasing onset rates of generalized anxiety, depression and PTSD in differently affected groups of adults 3 ½ years after the Mount St. Helens volcanic

eruption. Similar results have been repeatedly reported for these three mental disorders, as well as psychological morbidity for different kinds of natural hazard disasters, different population types and in the short- and long-term aftermath. Increasing severity of PTSD, depression and anxiety symptoms have been found in children by Goenjian et al. (1995), as well as Pynoos et al. (1993), in closer proximity to the epicentre of the 1988 Spitak earthquake (Armenia) 1 ½ years after the event. The same result was confirmed for adults for symptoms of PTSD (Goenjian et al., 1994a, 1994b, 2000), depression (Armenian et al., 2002; Goenjian et al., 2000) and anxiety (Goenjian et al., 2000). Carr et al. (1997) showed a dose-response relationship between the degree of exposure and level of psychological morbidity in adults up until 2 years after the 1989 Newcastle earthquake (Australia) after they previously already identified the same effect 6 months after the event (Carr et al., 1995). According to Weems et al. (2007), those who experienced more immediate traumatic events after Hurricane Katrina (USA) had more PTSD symptoms 2 to 5 months after the event and Galea et al. (2007) and Sprang and LaJoie (2009) found similar results with higher exposure intensity being a stronger predictor for PTSD or other mental disorders referring to the same event. Further examples could be found in terms of the 2004 Asian Tsunami in Thailand (Heir & Weisæth, 2008) and Sri Lanka (Neuner et al., 2006), the 1992 flood in France (Verger et al., 2003), Hurricane Andrew in the USA (La Greca et al., 1996, 1998; Norris et al., 1999; Shaw et al., 1995; Vernberg et al., 1996), Hurricane Floyd in the USA (Russoniello et al., 2002), Hurricane Hugo in the USA (Lonigan et al., 1991, 1994), Hurricane Mitch in Nicaragua (Goenjian et al., 2001), a snowstorm in China (Wu et al., 2011), wildfires in Australia (McDermott et al., 2005; McFarlane, 1987) and numerous earthquakes (Armenian et al., 2000; Bal, 2008; Başoğlu et al., 2002; Bland et al., 1996, 2005; Bödvarsdóttir & Elklit, 2004; Bradburn, 1991; Bulut, 2006; Cao et al., 2003; Chan et al., 2011; Chen et al., 2001; Chen et al., 2007; Chen et al., 2002; Chen & Wu, 2006; Chou et al., 2005; Dell'Osso et al., 2012, 2013; Dorahy & Kannis-Dymand, 2012; Fu et al., 2013; Goenjian et al., 1996; Groome & Soureti, 2004; Jin, Xu, Liu, & Liu, 2014; Kolaitis et al., 2003; Kun et al., 2009, 2013; Lai et al., 2004; Liu et al., 2010; Maj et al.,

1989; Maruyama et al., 2001; Naeem et al., 2011; Najarian et al., 2001; Nolen-Hoeksema & Morrow, 1991; Şahin et al., 2007; Sattler et al., 2006; Scott, Knoth, Beltran-Quiones, & Gomez, 2003; Sezgin & Punamäki, 2012; Tempesta et al., 2013; Wang et al., 2011; Wang et al., 2009; Xu et al., 2012; Yang et al., 2003; Ying et al., 2013; Zhang et al., 2010). On the other hand, there are also studies which did not show a clear dose of exposure effect. Fan et al. (2011) reported that earthquake disaster exposure in adolescents 6 months after the 2008 Wenchuan earthquake (China) was a predictor for PTSD, depression and additionally anxiety, but not for every exposure variable and disorder since house damage and property loss were not associated with depression and anxiety. In Zhang et al.'s (2012a) study only damage to the home was a predictor for PTSD 12 months, but not 6 or 18 months, after the same event. In addition, there were non-significant results for other factors like injury to self or a family member, as well as property damage at each time period. Changing effects due to the statistical model type have also been observed with exposure variables showing a significant effect in a bivariate model, but not multivariate models accounting for possible confounders (Chang et al., 2005; Ma et al., 2011; Zhang et al., 2012b). Furthermore, there are studies that didn't show a dose of exposure effect at all (Ali et al., 2012; Bulut et al., 2005; Soldatos et al., 2006; Wang et al. 2000a, 2000b). Bulut et al. (2005) didn't find a dose of exposure effect between the high and low impact group in their study about the prevalence rates of PTSD in Turkish children 11 months after the Marmara earthquakes (Turkey), while Soldatos et al. (2006) tested for early predictors of PTSD in the immediate aftermath of the 1999 Athens earthquake and only found Acute Stress Reaction (ASR) to be associated with the development of PTSD. Similarly, they did not find a significant association with experienced degree of exposure or extent of damage (Soldatos et al., 2006). Wang et al. (2000a, 2000b) even reported an inversed effect with lower psychological well-being and poorer Quality of Life (QOL) in the lower impact group of earthquake-affected subjects from two villages at different distances from the epicentre, which may be due to differently received social and physical post-disaster support.

Discussion and research opportunities

In this section we discuss the applicability of identified exposure assessment techniques considering spatial location to draw inferences on adverse mental health outcomes. Furthermore, we briefly comment on identified protective factors and intervention techniques and lastly discuss future research opportunities.

It has been shown that different variables such as feelings of fear during the event, being injured, having been trapped, witnessing people dying, injury and death of close/loved ones, loss of property or proximity to the disaster, among others, have been identified as exposure assessment features and represent risk factors for PTSD, depression, anxiety and psychiatric morbidity in general. Damage to the home and property loss were frequently used as measures of exposure, which may be due to disaster damage as a severe stressor that varies over space depending on the intensity of a disaster and therefore represents a good measure of exposure (Bland et al., 1996; Chen et al., 2001; Chou et al., 2005; Kolaitis et al., 2003; Nolen-Hoeksema & Morrow, 1991; Sattler et al., 2006).

A number of studies also showed that the degree of individual exposure varied due to the intensity of the natural hazard disaster and/or its impacts over space (Bulut et al., 2005; Bulut, 2006; Cao et al., 2003; Chan et al., 2011; Dogan, 2011; Giannopoulou et al., 2006; Goenjian et al., 1994a, 1994b, 1995, 1996, 2000; Liu et al., 2010; Maruyama et al., 2001; Najarian et al., 2001; Pynoos et al., 1993; Wang et al., 2000a, 2000b, Zhang et al., 2010). After Hurricane Katrina and Rita hit the USA in 2005, Zahran et al. (2011) estimated the intensity of the destructive path based on damage and crop loss data among counties, while for an earthquake the likelihood of damage has been linked to perceived shaking intensity (Maruyama et al., 2001), which is linked to factors like ground composition, liquefaction or landslide susceptibility (Ramirez & Peek-Asa, 2005). As a consequence the impacts can vary significantly at fine geographic scales, whereas in general the shaking intensity attenuates with increasing distance from the epicentre (Naghii, 2005). This is why individual or residential distance from the epicentre of an earthquake isn't necessarily a

good predictor of the degree of damage in a relatively small study area, but can be appropriate for large study areas with more varying impact levels over space. As a result, a number of studies have selected groups with large differences in distances from the epicentre of an earthquake up to and over a hundred kilometres (Armenian et al., 2000; Başoğlu et al., 2004; Chan et al., 2011; Goenjian et al., 1994a, 1995, 1996, 2000; Pynoos et al., 1993; Zhang et al., 2010) or compared groups from different districts or counties (Ali et al., 2012; Dogan, 2011; Groome & Soureti, 2004; Kun et al., 2009) to get highly-differentiated impact groups. Only a few studies have done an exposure assessment based on different exposures within a relatively small study area covering just neighbourhoods or communities within a city. For example, Bulut et al. (2005) compared children from two differently affected neighbourhoods in the worst affected city Sakarya after the 1999 Marmara earthquakes (Turkey) and Dorahy and Kannis-Dymand (2012) compared subjects from two differently impacted suburbs in Christchurch after the 2010 Darfield earthquake (New Zealand). These studies utilised prior knowledge of the spatial distribution of physical disaster impacts in a severely affected community to select their study samples without explicitly using spatial analysis techniques. Such techniques have rarely been used in disaster mental health research as this field of research is dominated by studies from the disciplines of psychology, psychiatry and public health. On the other hand, studies in the field of spatial epidemiology have shown that these analysis techniques allow us to get a detailed insight into the spatial distribution of mental disorders and identify contextual variables associated with this spatial variation to help better plan health intervention programs (Chaix et al., 2006; DiMaggio et al., 2009). Additionally, the use of space-time geography, which takes into account residential exposure histories, have been shown to be helpful for determining environmental influences on diseases (Sabel et al., 2009).

Another identified approach uses a random choice of participants from affected area(s) to assess the individual exposure based on the self-report basis ignoring the spatial component (Carr et al., 1997; Catani et al., 2008; Chang et al., 2005; Chen et al., 2001; Jin et al., 2014; Lai et al., 2004; Naeem et al., 2011; Nolen-Hoeksema & Morrow, 1991; Verger et al.,

2003; Wang et al., 2011; Xu et al., 2012; Yang et al., 2003; Ying et al., 2013; Zhou et al., 2013). Here, different individual objective exposure features like damage to the home/property were included for separate groups, but spatial information about the wider neighbourhood-level damage, for example if subjects with similar degrees of damage live in the same neighbourhood, hasn't been retained or included in the analyses. This information can be relevant, because the living and social environment can act as a reminder of trauma due to seeing destroyed buildings in daily life, and also indicate the disruption of community and services (Goenjian et al., 1994b). Giannopoulou et al. (2006) identified in their study that it made no difference for the development of depression symptoms, if children or adolescents were directly or indirectly exposed to the 1999 Athens earthquake and its impacts at the time it happened, whereas post-earthquake adversity including house damage, serious structural damage to the residence and living in an extensively damaged area, among others, played a significant role. Further studies also found a relationship between damage to the property and depressive, as well as posttraumatic stress symptoms after natural hazard disasters (Kolaitis et al., 2003; Xu et al., 2012; Ying et al., 2013), while Fan et al. (2011) concluded from their study that younger people are not as concerned about damage to the property as adults. Post-disaster loss of community, social network disruption and disruption of daily life are also often mentioned as exposure factors that may significantly contribute to the development of psychological morbidity, particularly PTSD and depression, after natural hazard disasters (Armenian et al., 2002; Goenjian et al., 1995; Nolen-Hoeksema & Morrow, 1991; Roussos et al., 2005). Nevertheless, they have been rarely included as exposure variables, but could be retrieved from public resources in contextual form and assigned to an individual's location via spatial analysis techniques.

The absence of such information may have contributed to the fact that some studies could not confirm a dose-response relationship for mental health outcomes. As an example Roussos et al. (2005) did not find a statistically significant difference in depression, as well as PTSD scores between highly and less exposed children and adolescents 3 months after

the 1999 Athens earthquake (Greece). They concluded that depression symptoms were "probably due to multiple losses, both personal losses and loss of community, and ongoing adverse living conditions" (Roussos et al., 2005, p. 536). They additionally suggested that the lack of statistically significant difference in mean PTSD Reaction Index scores was due to similar exposure severity caused by vicarious traumatisation. Media coverage of the event as an indirect exposure can contribute to such a vicarious traumatisation and simultaneously act as a trauma reminder that reinforces adverse psychological experiences (Bulut et al., 2005; Goenjian et al., 1995). Further examples of traumatic reminders include exposure to extensive damage (Chen & Wu, 2006; Dogan, 2011) and recurring events, which can lead to equally perceived threat to life due to potential risk rather than actual varying impacts (Huzziff & Ronan, 1999). Such traumatic reminders and post-disaster adversities can lead to severe and persisting PTSD, depression and anxiety symptoms prevalent even 4 ½ years after the traumatic event (Goenjian et al., 2000). Generally cumulative stress, multiple trauma experiences like living in temporary shelters, and an environment that leads to daily life disruptions, increase the risk of developing mental disorders (Catani et al., 2008; Dogan, 2011; Heir & Weisæth, 2008; Livanou et al., 2002; Verger et al., 2003). Ying et al. (2013) suggested that the limited exposure to potential reminders can lead to a decrease of PTSD and depressive symptoms. In contrast, living in an intact city doesn't necessarily help to reduce PTSD symptoms and high levels of distress can remain due to severe trauma and/or social network disruption (Kılıç et al., 2006; Najarian et al., 2001). On the other hand, social and emotional support by family members or friends or other groups like congregations help people to cope better with post-disaster adversities and show better resilience (Armenian et al., 2002; La Greca et al., 1996; Ma et al., 2011; Najarian et al., 2001; Weems et al., 2007; Xu et al., 2012; Zahran et al., 2011; Zhang et al., 2012b).

Fu et al. (2013) furthermore reported that students who received psychological tutorship were less prone to develop PTSD, so educating people about positive coping with adverse situations, as well as reducing distress and effective problem solving (Ronan & Johnston,

1999), might help prevent the development of mental disorders. Additionally, controlled natural hazard exposure and cognitive behavioural intervention have been shown to improve PTSD-related distress and coping ability in children (Ronan & Johnston, 1999).

In summary, a number of post-disaster adversities, as well as protective factors, play an important role when examining the relationship between exposure to a disaster and mental disorders. Many objective and subjective features have been identified to assess the dose of exposure and it is a popular approach to build different exposure groups by using distance to the highest point of disaster intensity. On the other hand, few studies have looked at the neighbourhood-level variation of exposure and mental health disorders, so it is still not fully known how mental health outcomes like PTSD, depression or anxiety, could vary within a highly affected city or community after a natural hazard disaster, and what contribution is made by factors like damage to the neighbourhood, community disruption or relocation. It is also worth noting that the mobility and migration of people hasn't been taken into account in many studies, but could play a significant role in the development and also prevention of such disorders. For example, Jacquez (2000, p. 91) stated that "meaningful inference about the causes of disease is impossible without both spatial *and* temporal information". A reason that it hasn't been done may be the difficulty of gaining the necessary information to track people, but it is a challenge that should be addressed by future research projects.

Limitations

Several limitations have to be taken into account, when interpreting the results of this review. Studies have been categorised according to various exposure assessment techniques (see Table 2.1) based on exposure variables described in the methods and used in the analyses. Papers have used different sample populations and as a result inferences from one group to another can't always be easily drawn. For example, Bland et al. (1996, 2005) only recruited male factory workers, Sezgin and Punamäki (2012), as well as

Najarian et al. (2001) only included women in their studies and Nolen-Hoeksema and Morrow (1991) just examined undergraduate students, who enrolled in a general psychology course at Stanford University. The mental health outcomes of such groups differ widely after a natural hazard disaster and especially children, frail elderly, people with pre-existing mental illness, racial and ethnic minorities, people who lost someone in the event and emergency workers are at greater risk for psychosocial impacts (Lindell & Prater, 2003). Moreover, when comparing groups of seemingly the same characteristic e.g. 'adults' or 'adolescents', it has to be kept in mind, that they can still differ in their age ranges and distributions. For example, Dell'Osso et al. (2013) had a relatively young sample with a mean age of 30.1, whereas Lai et al. (2004) and Chang et al. (2005) had an older sample with mean age of 55.5. Furthermore most of the studies looked at adults, which were often seen as persons over 18 years in western countries, but some also included subjects at the age of 15 (Kun et al., 2009, 2013; Sharan et al., 1996; Zhou et al., 2013), 16 (Bödvarsdóttir & Elklit, 2004; Armenian et al., 2000; Zhang et al., 2011, 2012b) or 17 (Cao et al., 2003). In addition, it isn't always clear what the threshold was separating adults from adolescents and/or children. Terms like "young adult", "youth" or "elderly" were used in some studies, which can differ based on cultural backgrounds, norms and laws. Cultural differences may also have an impact on coping strategies or beliefs concerning disasters, which may affect the outcome of a study. Another factor that may have an influence on disaster impacts, as well as mental health outcomes, is the differentiation into developed and undeveloped or rich and poor countries. People from poor undeveloped countries are generally more prone to large-scale destruction and often experience numerous traumatic events due to war and violence (Naeem et al., 2011; Neuner et al., 2006). So higher numbers of disaster-related trauma experiences in those countries could also have an influence on the study outcomes and should be considered when comparing them to others from developed countries.

Conclusions

The aims of this literature review were to summarise the different techniques used to measure exposure to a natural hazard disaster, highlight the role of spatial location, and examine and discuss its relationship with disaster-related mental health outcomes, which is closely linked to the dose response relationship, in order to identify future research opportunities.

Typically examined mental health outcomes after natural hazard disasters were PTSD, depression and anxiety. Disaster exposure has mainly been assessed by self-reported questionnaires asking about earthquake-related experiences based on objective and subjective exposure features. These experiences have been used to build exposure indices, compare groups from differently affected areas, e.g. in different distances to the disaster or in a case-control manner, or have just been used separately as independent variables measuring the degree of exposure based on a dichotomous or rating scale. All of these exposure assessment methods were suitable for testing relationships between exposures to a natural hazard disaster and mental health outcomes since the vast majority of studies that used these methods found a dose-response relationship. However, some studies did not show this effect for every mental health outcome, which shows how complex the nature of the relationship can be, as well as the uniqueness of every natural hazard disaster and the exposure to it, which is determined by a variety of factors often difficult to capture. It can therefore be concluded that there is not one optimal solution to accurate exposure assessment. Furthermore, the relationship between mental health outcomes and exposure to natural hazard disasters is still not fully understood, especially on a more local scale focussing on the spatial variation in the most affected area in close proximity to the disaster and on the exposure trajectory tracking exposure over a longer post-disaster period up to several years. Spatial analysis techniques would be suitable to undertake such assessments, but have rarely been used, which may be due to most of the studies having been undertaken

in the fields of psychology, psychiatry and public health. A more spatially and also temporally focussed approach on a local scale would help to understand where and when the greatest need for mental health care services arise after a natural hazard disaster. Finally, the mobility and migration of people is rarely included in such studies, probably due to the difficulty of gaining the necessary information to track people, yet may play a significant role in the development and/or prevention of adverse mental health outcomes.

Chapter Three: Geographic variation of mood and anxiety symptom treatments in Christchurch after the 2010/11 Canterbury earthquakes

Preface

The literature review in chapter two showed that the impacts of natural hazards disaster exposure on mental health are still not fully understood and have rarely been investigated on a local scale. This first analytical chapter uses annual mood and anxiety symptom treatment information for Christchurch residents in 2009/10, 2010/11 and 2011/12 to assess the dose-response relationship between exposure to different area-wide earthquake impacts from the 2010/11 Canterbury earthquake sequence and adverse mental health outcomes in the severely affected Christchurch urban area accounting for known risk factors. Spatio-temporal cluster analysis is used to identify areas in Christchurch exhibiting high or low treatment rates compared to the rest of the city and explore possible links to earthquake impacts. A distance-based approach in kilometres is then applied to examine residential exposure to different physical earthquake impacts from the catastrophic 22nd February 2011 Christchurch earthquake including different levels of damage based on Canterbury Earthquake Recovery Authority (CERA) land classifications, liquefaction and lateral spreading. Furthermore, residential exposure to the intensity of the 2011 Christchurch earthquake based on area-wide Peak Ground Acceleration (PGA), as well as Modified Mercalli Intensity (MMI) mappings is examined.

The aim is to identify areas within the city, where residents showed increased risks of receiving treatment for moderate or severe mental health symptoms after the catastrophic 2011 earthquake and if associations to various earthquake impacts exist, using contextual

area-wide impact information and spatial analysis techniques. This is important as it enhances our understanding of the dose-response relationship between disaster exposure and mental health on a local scale and helps to better plan and target mental health intervention programs in case of future seismic events.

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 symptom treatments in Christchurch after this event. We hypothesise that such disorders are more likely to occur in people, who have experienced greater exposure to these impacts within their neighbourhood than others, who have been less exposed, but also live in the city. For this purpose, almost all incident and relapsed cases of mood and anxiety symptoms having been treated 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 receiving care or treatment for mood or anxiety symptoms than people living in other parts of the city. Generally, mood and anxiety-related symptom treatments 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.

Introduction

On the 22nd February 2011, the city of Christchurch (New Zealand) was impacted by a shallow moment magnitude (Mw) 6.2 earthquake occurring just 6 kilometres southeast of the Central Business District (CBD) (Bannister & Gledhill, 2012). This 'Christchurch' earthquake produced a Peak Ground Acceleration (PGA) among the highest ever recorded (McColl & Burkle, 2012) 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, various 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,[3] which caused extensive damage to structures and buried services like freshwater, sewerage, and stormwater systems. In total, 185 people died in the event, over 8,000 were injured, and over 100,000 buildings 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.

After such sudden and unpredictable events, which cause a large number of deaths and injuries as well as substantial damage to properties and infrastructure, high prevalence rates of adverse stress-related mental health outcomes were observed. These included Post-Traumatic Stress Disorder (PTSD), depression, anxiety, Acute Stress Disorder (ASD) or sleep disturbances (Chadda, Malhotra, Kaw, Singh, & Sethi, 2007; Dorahy & Kannis-

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

Dymand, 2012; Eksi & Braun, 2009; Kadak, Nasıroğlu, Boysan, & Aydın, 2013; Liu et al., 2011; Shinfuku, 2002; Suzuki et al., 1997; Varela, Koustouki, Davos, & Eleni, 2008; Wang et al., 2011; Zhang et al., 2011, 2012; Zhou et al., 2013). Out of this list, PTSD, anxiety, and depression are the most often examined in the literature and are commonly found together after natural disasters (Madianos & Evi, 2010). For example, Zhang et al. (2012b) found high prevalence rates of PTSD, anxiety, and depression after the 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, Dorahy, Hanna, Bagshaw and Blampied (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 one or more years 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, lead 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., 2012b; 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 & Elrod, 2006; Wang et al., 2011; Xu & He, 2012; Xu & Song, 2011; Zhang et al., 2011, 2012b; 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 & He, 2012; Xu & Song, 2011; Zhang et al., 2011, 2012b; 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.

A strategy to assess the dose of exposure effect is measuring the level of exposure in differently affected groups (severe vs. less severe or affected vs. unaffected) (Bödvarsdóttir & Elklit, 2004; Dell'Osso et al., 2013; Dorahy & 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, Psarros, Varsou, Paparrigopoulos, & Soldatos, 2003; Sattler et al., 2006; Sharan et al., 1996; Wang et al., 2011; Xu & He, 2012), or using a distance based approach (Groome & 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 or anxiety symptom treatments 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, as well as subsidised prescriptions for mood or anxiety symptoms gives the study a unique quality.

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

It is important to know what causes mood and anxiety symptoms needing care or treatment, and when, as well as where they may occur, to initiate early intervention since they are a great burden of society (Madianos & 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[4] 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.

We have the hypothesis that mood and anxiety symptom treatments 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, we hypothesise that people living in, or nearer to neighbourhoods at greater

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

risk of further damage in any future earthquake due to poor soil conditions were more likely to develop mood or anxiety symptoms needing treatment 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 & Kannis-Dymand, 2012; Groome & Soureti, 2004; Reed, 2013; Rowlands, 2012), the role of the exposure to the level of impact to the neighbourhood, 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.

Methods

Data

Earthquake impact variables included Canterbury Earthquake Recovery Authority (CERA)[5] 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 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' (Table 3.1). As a consequence of on-going geotechnical

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[5] 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.

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'.

Table 3.1: CERA landzones according to 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	o Future land damage from liquefaction is unlikely
TC2	o Minor to moderate land damage from liquefaction is expected in future significant earthquakes
TC3	o 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 had to be mapped.

The post-earthquake analyses considered the zoning status on the 23rd of March 2012 (Figure 3.1), because this was the last change that could have had an impact on mood and anxiety treatment cases before the financial year deadline on the 30th of June 2012. A distance based approach in kilometres was used to examine the effect of living in or nearer to widely abandoned areas ('Red Zone') or areas with differently estimated future chance for residential damage ('TC1', 'TC2' and 'TC3') on mood and anxiety symptom treatments.[6]

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[6] 'Orange Zone' areas were excluded since there was only one left on the 23rd of March, which affected just a few meshblocks in the east. 'White Zone' areas also weren't considered, because they didn't cover many residential areas and occurred dispersed in the Port Hills area.
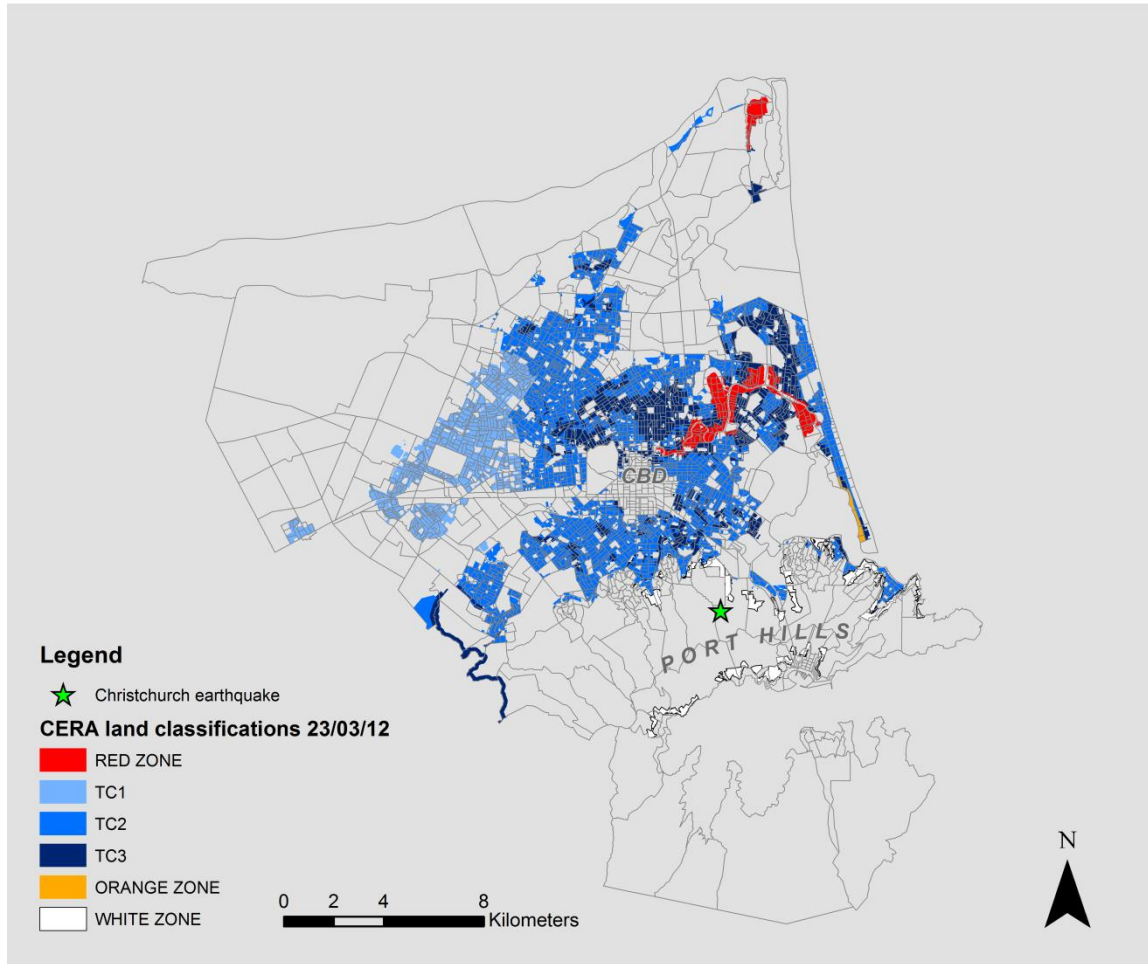
Figure 3.1: CERA 'Red Zone', 'TC3', 'TC2' and 'TC1' classification on the 23rd March 2012

To evaluate the hazard intensity of the Christchurch earthquake, PGA and MMI published by the U.S. Geological Survey (USGS) were used[7]. The datasets were only approximations

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[7] 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.).

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 Figure 3.1. 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 symptom treatments 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 mood and anxiety symptom treatments qualifying for a clinically diagnosis, but also incident and relapsed cases of less severe mood and anxiety symptoms based on publically funded secondary mental health (inpatient, outpatient or community), laboratory test information and subsidised pharmaceutical dispensing within a years' period from help-seekers covering 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 cases receiving care or treatment between July and June the following year. Each subject got a dichotomous measure (yes/no) identifying if the person received care or treatment for mood or anxiety symptoms within each annual study period. 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, but represents a rich source for identifying those showing moderate or severe mood or anxiety symptoms among help-seekers. 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) and chemical codes, including PTSD, depression, and anxiety among others (see Table A.1).

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 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.

Analysis

The SaTScan^{TM} v9.1.1 software, which implements spatio-temporal scan statistics, was used to analyse the spatio-temporal variation of mood and anxiety symptom treatments in the study region. For this type of cluster analysis, a retrospective space-time discrete Poisson model with a study period from 2009/10 to 2011/12 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 symptom treatments 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 symptom treatments and the varying degrees of exposure to the presented earthquake impacts, simultaneously controlling for possible confounders. The first model was a mixed effects 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 treatments for mood or anxiety, as well as other mental health symptoms and mood and anxiety symptom treatments. 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 examined. 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.

Results

Sample characteristics

The study population, defined by the Christchurch urban area boundary and limited to PHO enrolments, consisted of about 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 3.2). 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 (Table 3.2).

Table 3.2: Gender, age and ethnicity 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. 3,000 more people than the Christchurch urban area

[††] The sum of ethnicity counts in the 2013 Census exceeds the total population since total responses from the census with multiple responses are stated

[†††] Middle Eastern/Latin American/African

Exploratory analysis

Considering the number of people receiving care or treatment for mood or anxiety symptoms between 2009/10 and 2011/12, a trend towards higher incident and relapsed cases can be seen. In 2009/10, 18,264 people received care or treatment for mood or anxiety symptoms, which is 6.4% of this 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, but may also be explained by an increase in the set of subsidised medications at the end of 2010. Looking at the conditional risk, expressing the proportion of people having received care or treatment for mood or anxiety symptoms given a previous treatment 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.

The proportion of females receiving care or treatment for mood or anxiety symptoms (~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 receiving care or treatment for mood or anxiety symptoms 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 receiving care or treatment for mood or anxiety symptoms than males and children. This was further investigated by a multivariate mixed effects logistic regression model in Table 3.3.

Modelling results

The first and second model identified being female, of older age, European, having mental health co-morbidity, pre-existing mood or anxiety symptom treatment(s), as well as pre-existing other mental health symptom treatment(s) as risk factors for receiving care or treatment for mood or anxiety symptoms in the past 12 months period after the 2011 Christchurch earthquake (see Table 3.3). These factors were all highly statistically significant (p<.001) with the strongest risk factor of having a history of mood and/or anxiety symptom treatments. Looking at the difference between children (0-14 years) and adults the odds of receiving care or treatment for mood or anxiety symptoms 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 receive care or treatment for mood or anxiety symptoms compared to Europeans. Other ethnicities, as well as neighbourhood deprivation showed no significant effect in the first model, whereas neighbourhood deprivation was statistically significant in the second one showing a slightly negative association to mood and anxiety symptom treatments, which means that the likelihood of receiving care or treatment for mood or anxiety symptoms slightly decreased in more deprived areas (Table 3.3).

Finally, the first model showed that the difference in years was highly statistically significant and the likelihood increased during, as well as after, the 2010/11 earthquakes compared to before (Table 3.3). The spatio-temporal cluster analysis confirmed this result showing a statistically significant (p<.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.[8] The relative risk (RR) was 1.23, so people living in the hotspot area had generally a 23% increased risk of receiving care or treatment for mood or anxiety symptoms 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

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[8] For reasons of confidentiality, the cluster of mental health symptom treatments is not displayed at a meshblock level

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.

Table 3.3: Model 1 & 2 - Multivariate logistic regression models to identify socio-demographic, socio-economic and medical risk factors for mood and anxiety symptom treatments in Christchurch urban area for the whole study period (mixed-effects model) and 2011/12 (fixed-effects model)

Independent Variables	OR (95% CI) for the whole study period	OR (95% CI) for 2011/12
Gender		
Female	1	1
Male	0.73 (0.7-0.77); p<.001	0.81 (0.78-0.84); p<.001
Age (years)		
0 - 14	1	
15 - 39	3.58 (2.91-4.42); p<.001	1.22 (1-1.49); p<.001
40 - 64	4.6 (3.73-5.68); p<.001	1.45 (1.19-1.77); p<.001
$\geq$ 65	6.1 (4.92-7.56); p<.001	1.76 (1.44-2.15); p<.001
Ethnicity		
European	1	1
Maori	0.7 (0.63-0.77); p<.001	0.75 (0.69-0.81); p<.001
Pacific People	0.39 (0.3-0.5); p<.001	0.48 (0.39-0.6); p<.001
Asian	0.57 (0.48-0.67); p<.001	0.79 (0.69-0.9); p<.001
MELAA	0.61 (0.46-0.8); p<.001	0.75 (0.59-0.93); p<.05
Other Ethnicity	0.79 (0.53-1.12); p=.25	0.94 (0.68-1.29); p=.71
Residual Categories	1.03 (0.78-1.36); p=.82	1.1 (0.89-1.36); p=.40
NZ Deprivation Index 2013	1 (0.99-1.01); p=.80	0.99 (0.98-0.99); p<.001
Mental health co-morbidity		
No	1	1
Yes	3.5 (3.31-3.71); p<.001	1.86 (1.75-1.97); p<.001

Independent Variables	OR (95% CI) for the whole study period	OR (95% CI) for 2011/12
Pre-existing other mental health treatment(s)		
No	1	1
Yes	1.17 (1.1-1.23); p<.001	1.08 (1.03-1.13); p<.001
Pre-existing mood/anxiety treatment(s)		
No	1	1
Yes	3,195.31 (2,845.17-3,588.54); p<.001	3,863.87 (2,887.9-5,169.68); p<.001
Study year		
2009/10	1	-
2010/11	1.28 (1.24-1.33); p<.001	-
2011/12	1.55 (1.5-1.61); p<.001	-

First of all, the distance to 'Red Zone' areas in km 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 health symptom treatments, as well as neighbourhood deprivation. However, the model showed no statistically significant effect for distance to Red Zone areas (Model 3 in Table 3.4).

On the other hand, exchanging this variable with distance to 'TC3' or 'TC2' areas (Models 4 and 5 in Table 3.4) resulted in a statistically significant association (p<.01) with the odds decreasing by approx. 2% and 3% per kilometre distance. Thus, living farther away from these zones reduced the risk for being treated for mood or anxiety symptoms 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 (Models 7 and 8 in Table 3.4), MMI showed a statistically significant association (p<.05) with a positive relationship. Thus, the odds of receiving care or treatment for mood or anxiety symptoms increased by 4% per MMI value increase. For lateral spreading and liquefaction (Models 9 and 10

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and 11 and 12 in Table 3.4) a statistically significant result (p<.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 receiving care or treatment for mood or anxiety symptoms 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 being treated for mood or anxiety symptoms and indicated the same direction of the relationship.

Table 3.4: Model 3 to 12 - Multivariate fixed effect logistic regression models to identify exposure to earthquake impacts as risk factors for mood and anxiety symptom treatments in Christchurch urban area after the Christchurch earthquake

Model[†]	Independent Variables	OR (95% CI)
Distance (km) to CERA land classification		
3	Red Zone	1 (0.99-1); p=.11
4	TC3	0.98 (0.96-0.99); p<.01
5	TC2	0.97 (0.96-0.99); p<.01
6	TC1	1 (1-1.01); p=.31
Hazard intensity measures of the Christchurch earthquake		
7	PGA	1.05 (0.97-1.14); p=.23
8	MMI	1.04 (1.01-1.08); p<.05
Distance (km) to areas with lateral spreading from the Christchurch earthquake		
9	Severe	0.99 (0.98-1); p=.09
10	moderate to major	0.99 (0.98-1); p<.05
Distance (km) to areas with liquefaction from the Christchurch earthquake		
11	Severe	0.99 (0.97-1); p<.05
12	minor to moderate	0.99 (0.98-1); p<.05

† models were adjusted for gender, age, ethnicity, deprivation, mental health co-morbidity, pre-existing mood/anxiety and other mental health symptom treatment(s)

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 treatment indicator also included the vast majority of clinical mood and anxiety diagnoses, as well as pharmaceutical dispensing for mood or anxiety symptoms 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 symptom treatment 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 receiving mood or anxiety symptom treatment 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 symptom treatment(s), which is congruent with numerous studies assessing psychopathology in the population (Başoğlu et al., 2004; Frans, Rimmö, Åberg, & Fredrikson, 2005; Galea et al., 2005; Kadak et al., 2013; Lai et al., 2004; Norris & Elrod, 2006). Furthermore, Pacific People were least likely to be receiving care or treatment for mood or anxiety symptoms, 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 the unadjusted 12-months prevalence was highest for Maori, intermediate for Pacific people and lowest for other ethnic groups (Oakley Browne, Wells, & Scott, 2006).

Neighbourhood deprivation didn't show a significant effect for the whole study period, but living in a more deprived neighbourhood was a protective factor for receiving treatment for mood or anxiety symptoms after the earthquakes. This finding is in contrast to the results of Ivory, Collings, Blakely and Dew (2011), who conclude from a nationally representative 2002/03 New Zealand Health Survey dataset that living in a more fragmented and deprived neighbourhood 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 the nature of our outcome variable as we investigate treatments for mood or anxiety symptoms, which is influenced by treatment seeking behaviour, instead of mental disorder prevalence, but also population mobility may have an influence, as the NZ deprivation index from 2013 was a fixed score for the neighbourhood, whereas the underlying population in our study changed from year to year.

We also found that adults were more likely to receive treatment for mood or anxiety symptoms than children with increasing odds per age group. The first result was similar to 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., 2002a; Xu & Song, 2011), and Norris et al. (2002a) and Zhang et al. (2011) have reported that middle-aged adults show the highest risk for distress and resulting mental health problems in prevalent cases. 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., 2002a). On the other hand, several studies on the 2008 Wenchuan earthquake (China) confirm our findings also for prevalent cases by showing that older age is a risk factor for PTSD (Kun et al., 2013; Zhou et al., 2013), depression

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(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 ($\geq$ 15 years) showed higher rates of chronic mood and anxiety symptoms 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 mental health symptoms and disorders (Kun et al., 2013; Norris & Elrod, 2006). Our finding that the strongest predictor for receiving care or treatment for mood or anxiety symptoms was a history of those confirms this assumption and is a commonly found result in prevalent cases after natural disasters (Bergiannaki et al., 2003; Galea et al., 2005; Kadak et al., 2013).

Looking at different earthquake exposure variables, a very 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 being treated for mood or anxiety symptoms representing a dose of exposure effect. Additionally, closer proximity was a risk factor. Several quantitative 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 & Elklit, 2004; Dell'Osso et al., 2013; Dorahy & Kannis-Dymand, 2012; 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 were 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 likelihood of being treated for mood or anxiety symptoms. 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 & Elklit, 2004; Dorahy & Kannis-Dymand, 2012; Suzuki et al., 1997; Varela et al., 2008; Xu & He, 2012). 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 & 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 receive care or treatment for mood or anxiety symptoms 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 mood or anxiety symptoms seeking treatment may have already moved away from 'Red Zone' areas by then. Newell, Beaven and Johnston (2012) mentioned that approximately 20,000 residents redirected their mail to an alternative address within the city, and about 5,000 people 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., 2004), as well as higher risk for psychological distress (Oyama, Nakamura, Suda, & Someya, 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 increased incidence and relapse of mood or anxiety symptoms, as well as help-seeking activity in the year 2011/12. This especially applied to the most affected central and eastern parts of Christchurch, which have been identified as high risk areas for increased mood or anxiety symptom treatments 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 symptom treatments 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 are still discussed controversially and not fully understood so far. Our results showed that people living in regions more affected by liquefaction, lateral spreading, MMI, or areas at risk for further damage are more likely to be receiving care or treatment for mood or anxiety symptoms after the Christchurch earthquake, thus may also be 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 & 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 emphasize 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 neighbourhood anymore. This merits further research.

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 inter-correlated 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 treatment status was used as an outcome variable, which is biased by treatment-seeking behaviour greatly underrepresenting actual cases and especially some sectors of the population including Maori and Pacific people. Moreover, lots of diagnoses with over 70 clinical and chemical codes were included into the mood and anxiety indicator (see Table A.1), so that inferences to individual disorders, like PTSD, anxiety or depression, couldn't be made. The mental health indicator was retrieved on an aggregated level as annual summaries, which also didn't allow to include 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 received care or treatment. Having these data would have

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given a more accurate measure of the relationship between exposure and receiving care or treatment for mood or anxiety symptoms.

Conclusions

The findings of this study suggest that up to over one year after a major earthquake people living in close proximity to areas with moderate to major lateral spreading or liquefaction, or in a highly affected area measured by MMI are more likely to receive care or treatment for mood or anxiety symptoms. 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 likelihood of seeking help for moderate or severe mood or anxiety symptoms in the population.

Chapter Four: Spatio-temporal variation of mood and anxiety symptom treatments in Christchurch in the context of the 2010/11 Canterbury earthquake sequence

Preface

In chapter three, an increase of mood and anxiety symptom treatments over time and a post-disaster hotspot of these adverse mental health outcomes in the more severely affected areas of the city were found. In addition, various earthquake impacts could be related to mood and anxiety symptom treatments using a distance-based approach.

In this chapter, a more detailed investigation into a possible earthquake exposure effect is done as the temporal increase of mood and anxiety symptom treatments may have been biased by an extension of the set of subsidised medications at the end of 2010. Therefore, daily mood and anxiety symptom treatment information was retrieved for both Christchurch and non-Christchurch residents from other parts of New Zealand to compare the treatment rates between these differently earthquake-affected groups over time. In addition, the study identifies vulnerable groups in the context of the disaster and undertakes more detailed analyses on the spatio-temporal variation of mood and anxiety symptom treatments within the Christchurch urban area on the basis of the cluster analysis in the previous chapter. More advanced spatio-temporal cluster analyses techniques and Bayesian modelling approaches are applied and their results compared.

Abstract

This article explores the spatio-temporal variation of mood and anxiety symptom treatments in the context of the 2010/11 Canterbury earthquake sequence. The aim was to examine a possible earthquake exposure effect, identify populations at risk and areas with particularly large mood and anxiety symptom treatment rate increases or decreases in the affected Christchurch urban area.

Using negative binomial regression a significantly stronger increase of mood and anxiety symptom treatments has been found among residents in Christchurch compared to others in New Zealand, with children and elderly being identified as especially vulnerable. Spatio-temporal cluster analysis accounting for temporal trends and Bayesian spatio-temporal modelling revealed little change in mood and anxiety symptom treatment patterns for most parts of the city, although some of the most severely earthquake-affected areas in the east experienced decreases, and some areas in the less affected north and northwest the highest increases, in the risk of receiving care or treatment for moderate or severe mood or anxiety symptoms, which merits further research.

Introduction

High intensity earthquake shaking can cause traumatic experiences in directly exposed populations (Bonanno, Brewin, Kaniasty, & La Greca, 2010; Galea et al., 2005). As a result, high prevalence rates of affective disorders have been commonly reported among affected disaster survivors (Bartels & VanRooyen, 2012), whereas only a minority of exposed individuals show severe symptoms and there is a wide-ranging variability in mental health responses depending on the individual disaster (Bonanno et al., 2010). High-risk groups include women (Başoğlu et al., 2002, 2004; Bödvarsdóttir & Elklit, 2004; Dell'Osso et al., 2012; Galea et al., 2005; Giannopoulou et al., 2006; Kun et al., 2013; Maguen, Neria, Conoscenti, & Litz, 2009; Neria et al., 2009), middle-aged adults (Neria et al., 2009), as well as young children (Giannopoulou et al., 2006; Groome & Soureti, 2004), ethnic minorities (Kun et al., 2013; Neria et al., 2009), people with low income or socio-economic status (Armenian et al., 2000; Kun et al., 2013; Maguen et al., 2009; Norris et al., 2002a), people with low education (Başoğlu et al., 2002; Norris et al., 2002a) and those with a history of psychiatric illness (Başoğlu et al., 2004). The level of exposure also plays an important role with closer proximity to the epicentre having been found to be related to higher rates of psychopathology and more severe post-traumatic stress and depressive symptoms (Başoğlu et al., 2002, 2004; Dell'Osso et al., 2012; Goenjian et al., 1994a; Groome & Soureti, 2004; Pynoos et al., 1993; Roussos et al., 2005). But it needs to be mentioned that geographic location as a proxy for experienced trauma intensity is a measure of cumulative risk and resilience factors and therefore can be misleading (Bonanno et al., 2010).

Christchurch, the biggest city on New Zealand's South Island was significantly affected by the 4th September 2010 'Darfield earthquake' with a moment magnitude (M_w) of 7.1, which was centred approx. 35 km to the west of the city. Following this earthquake, a series of smaller but still shallow earthquakes migrated eastward directly under the city, which caused high intensity shaking and became known as the Canterbury Earthquake Sequence

(Bannister & Gledhill, 2012). This included the M_w 6.2 22nd February 2011 'Christchurch earthquake', which was centred almost directly under southern Christchurch, causing very high shaking intensities, killed 185 people and caused severe damage to the built environment (Bannister & Gledhill, 2012).

Qualitative studies have reported that adults in Christchurch expressed feelings of uncertainty and distress, fear, sleep disturbances and anxiety (Rowney, Farvid, & Sibley, 2014), while the elderly showed adjustment and psychological problems in the short-term (Annear, Wilkinson, & Keeling, 2013). Quantitative studies also found adverse mental health outcomes. Spittlehouse, Joyce, Vierck, Schluter and Pearson (2014) identified higher rates of major depressive disorder among 50-year-old earthquake survivors compared to historical, local and national surveys, although these were not statistically significant. Higher levels of distress were found among severely affected 35-year old Christchurch born subjects (Fergusson, Boden, Horwood, & Mulder, 2015). Additionally, Dorahy and Kannis-Dymand (2012) identified higher depression and anxiety scores among subjects from the severely affected 'Avonside' suburb in the east compared with the less affected 'Hornby North' suburb in the west of the city indicating a dose-response relationship, where greater earthquake exposure is associated with poorer mental health (Bonanno et al., 2010). Preliminary spatio-temporal cluster analysis as part of this study supported this conclusion by identifying a high-risk cluster (hotspot) of mood and anxiety symptom treatments in the central and eastern parts of the city in the first year after the Christchurch earthquake (see Chapter Three). On the other hand, this approach didn't adjust for a temporal trend that occurred due to an extension of the set of subsidised medication during the earthquakes and might have biased the result and partly explained the cluster (Kulldorff, Athas, Feuer, Miller, & Key, 1998). Furthermore, certain demographic groups, as well as areas with significant increases in mood and anxiety symptom treatments in the context of the earthquakes, are of special interest as they may exhibit exposure-related adverse mental health effects.

The aims of this study were therefore to compare the temporal trends of mood and anxiety symptom treatments between Christchurch and the rest of New Zealand in the context of the earthquakes and thereby identify a possible earthquake exposure effect, examine groups at high risk of receiving care or treatment for mood or anxiety symptoms to identify those in most need of mental health treatment after severe earthquakes, and finally to analyse spatio-temporal patterns of mood and anxiety symptom treatments in Christchurch as they could potentially play an important role in improving the targeting of post-disaster support services and prioritising of recovery efforts to reduce distress.

Methods

Measures

New Zealand Health Tracker (NZHT) data, sourced from New Zealand's Ministry of Health, was used to retrieve daily counts of mood and anxiety symptom treatments between 1st January, 2009 and 30th June, 2013 for people registered in the Primary Health Organisation (PHO) register in New Zealand. It should be noted that this outcome variable is likely to significantly underestimate the real prevalence of mood and anxiety symptoms and disorders in the population as it likely only identifies severe or moderate cases in treatment-seekers, while untreated illness and non-pharmaceutical treatments will not be detected (Pearson, Griffin, Davies, & Kingham, 2013). The health data is similar to that used by Pearson et al. (2013) including mood and anxiety symptom care or treatment information from publically funded secondary mental health (inpatient, outpatient or community) and hospital inpatient care, laboratory test information, and subsidised pharmaceutical dispensing, which is the most important source for detecting treatment. The majority of prescribed medications in New Zealand attract a government subsidy, including commonly used medications for depression and anxiety and, consequently, their prescription is monitored. An individual is deemed to be receiving care or treatment and counted if he or she interacts with the health system for mood or anxiety symptoms in any

of the ways above. Furthermore, care or treatment can be recognised if a subject is enrolled with a PHO. Primary health care providers receive government funding based on the population they have enrolled in their organisation and enrolled patients benefit from cheaper doctors' visits and prescribed medicine. Consequently, a high proportion of New Zealanders (over 95%) are registered as enrolled with PHOs. Therefore the PHO register is assumed to be largely representative of the New Zealand population. The mood and anxiety symptom treatment information had been linked to the PHO via an anonymised version of the National Health Index (NHI), which "is the cornerstone of health information in New Zealand" and covers approximately 98 percent of the population (Ministry of Health, 2009). The linkage allowed the assigning of demographic information including gender ('M' or 'F'), age (0-14, 14-39, 40-64, 65+) and ethnicity (European, Asian, Maori, Pacific peoples, Middle Eastern/Latin American/African, Other ethnicity). Additionally, residential information at a census area unit (CAU)[9] level and on a quarterly basis ranging from the first quarter in 2009 to the second quarter of 2013 was assigned to Christchurch residents, which allowed us to track these subjects over time to assess spatio-temporal occurrences of mood and anxiety symptom treatments in Christchurch. It also enabled a separation between Christchurch and non-Christchurch residents (Christchurch vs. rest of New Zealand) in each quarter, so that Christchurch and non-Christchurch residents could be compared in different earthquake phases (pre-, during- and post-disaster).

Moreover, distances of the CAUs population-weighted centroids from the 2011 Christchurch earthquake epicentre, as well as socio-economic deprivation at a CAU level based on the NZDep2006 (2009 Q1 – 2010 Q2) and the NZDep2013 (2010 Q3 – 2013 Q2) Index of Deprivation were calculated to examine their effects on mood and anxiety symptom treatments over time. Literature suggests that a dose-response relationship exists between proximity to the epicentre and adverse mental health outcomes after severe earthquakes (Başoğlu et al., 2002, 2004; Dell'Osso et al., 2012; Goenjian et al., 1994a;

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[9] Census area units (CAUs) are non-administrative areas that contain a population of 3,000–5,000 in urban areas.

Groome & Soureti, 2004; Pynoos et al., 1993; Roussos et al., 2005) and low socio-economic status is commonly reported as a risk factor for adverse mental health after natural hazard disasters (Armenian et al., 2000; Kun et al., 2013; Maguen et al., 2009; Norris et al., 2002a).

Annual subnational population estimates from Statistics New Zealand were linearly interpolated and used to account for changing population sizes in the Christchurch/non-Christchurch comparison and for the identification of high-risk groups since only treated cases were provided for non-Christchurch residents. In case of the Christchurch urban area, the whole set of PHO enrolments was available allowing us to create detailed residential histories and account for changing population sizes of CAUs in further spatio-temporal analyses.

Statistical models

Multiple regression analyses were applied to compare daily counts of incident and relapsed cases of mood and anxiety symptom treatments between Christchurch (severely exposed) and non-Christchurch residents (less or unexposed) over time and identify high risk groups. Negative binomial regression was used due to overdispersion in the outcome variable. The models were adjusted for gender, age and ethnicity. Furthermore, they were adjusted for a temporal variation (weekday=0, weekend/public holiday=1) as mood and anxiety symptom treatment rates were higher on weekdays than on weekends or public holidays. Linearly interpolated population estimates from Statistics New Zealand's annual subnational estimates were included as an offset. The Akaike's Information Criterion (AIC) indicated the best model fit (the lower, the better).

Bayesian hierarchical modelling using the WinBUGS software in version 1.4 and spatio-temporal cluster analysis techniques implemented in the SaTScan[TM] v9.1.1 software were utilised to analyse spatio-temporal patterns of mood and anxiety symptom treatments in Christchurch and compare the results.

Spatio-temporal hierarchical Bayesian modelling was applied to generate disease maps and calculate changes in relative risks over time to identify areas that experienced the highest increase or decrease in risk. The time-space model proposed by Rojas (2011) with non-informative vague priors and a large variance for the intercept, so that the model was predominated by the observations (DiMaggio et al., 2009), was used. It assumes that observed counts of mood and anxiety symptom treatments O follow a Poisson distribution and vary over space i and time t, so for each CAU and quarter a standardized treatment rate is calculated by dividing the observed O by expected E number of cases (Rojas, 2011). The model follows the approach of Besag, York and Mollié (1991) by including a spatially-correlated random effect s implemented as a conditionally autoregressive model (CAR) to improve local area estimates via spatial smoothing. In addition to Besag et al.'s (1991) approach, this effect can vary over time t. The model also features an uncorrelated random effect u varying over space i and time t (see Supplementary material for WinBUGS Code). We ran three chains with 20,000 iterations and a burn-in of 5000. Convergence was tested by examining trace histories and the Gelman diagnostics. Model fit was determined by the Deviance Information Criterion (DIC) (the lower, the better). Results were presented as mean values with 95% Credible Intervals (CI).

The SaTScan^{TM} v9.1.1 software was applied for spatio-temporal cluster analysis of mood and anxiety symptom treatments. To identify CAUs with significant decreases and increases of mood and anxiety symptom treatment rates, the spatial variation in temporal trends method was additionally used. Both methods included quarterly mood and anxiety symptom treatment counts, as well as population counts for each area unit from the Health Tracker. The most reliable cluster was selected via a reliability index R based on Chen, Roth, Naito, Lengerich and MacEachren's (2008) work, where multiple runs with stepwise increasing scaling parameters for the maximum cluster sizes (spatial and temporal) were done. The reason for this approach is that results are highly sensitive to these parameter choices and prior information often scarce (Chen et al., 2008). The original method by

Chen et al. (2008) was designed for the purely spatial approach, so had to be extended to incorporate a temporal dimension:

$$R_{it} = \frac{C_{it}}{S} \tag{1}$$

The variable C_{it} describes the number of scans for which the location i at time t was in a significant cluster and S the total number of scans. We also calculated a heterogeneity value to adjust the reliability in the case where location i at a given time t is part of a significant cluster, but shows a differential relative risk D_{it}:

$$H_{it} = \frac{D_{it}}{S} \tag{2}$$

Finally, these two indices were used to calculate an adjusted reliability index:

$$R_{it}\,adjusted = R_{it} - H_{it} \tag{3}$$

We chose a 5% increment starting with 5% of the population at risk (max. spatial cluster size), and 10% temporal cluster size in the case of the spatio-temporal cluster analysis, until the maximum values of 50% were reached. The spatio-temporal cluster analysis additionally accounted for a temporal trend non-parametrically, which removes all purely temporal clusters.

Inference testing was done via standard Monte Carlo hypothesis testing with 999 replications and a 5% significance level.

Study design

Christchurch - New Zealand comparison

The first model focussed on the interaction between different exposure groups (Christchurch vs. non-Christchurch residents) and earthquake phases – pre- (1 Jan 09 - 3 Sep 10), during- (4 Sep 10 - 22 Feb 11) and post-disaster (23 Feb 11 - 30 Jun 13) – to identify changes in mood and anxiety symptom treatments in the light of the Darfield and Christchurch earthquakes.

The second model compared temporal differences between different exposure groups on a finer temporal scale exchanging the earthquake phases with quarterly time periods using the second quarter in 2010, the quarter before the earthquakes, as a reference.

Identifying high risk groups

The third model assessed the three-way interaction between exposure groups (Christchurch vs. non-Christchurch residents), earthquake phases (pre-, during-, post-disaster) and age groups (0-14, 15-39, 40-64, 65+), to examine, if specific age groups were at greater risk of receiving care or treatment for moderate or severe mood or anxiety symptoms in the context of the earthquakes.

Spatio-temporal variation of quarterly mood and anxiety symptom treatments in Christchurch

Next, we focussed solely on Christchurch and assessed spatio-temporal patterns and pattern changes in quarterly mood and anxiety incident and relapsed symptom treatments in the Christchurch urban area based on its 115 CAUs between 1st January, 2009 and 30th June, 2013.

The fourth model, utilised Bayesian modelling techniques to create quarterly disease maps between the first quarter of 2009 and the second quarter of 2013. Simultaneously, this model examined the effects of distance of the CAU population-weighted centroids from the 2011 Christchurch earthquake epicentre categorised into tertiles, and CAU socio-economic deprivation based on the NZDep2006 (2009 Q1 – 2010 Q2), as well as NZDep2013 (2010 Q3 – 2013 Q2) Index of Deprivation, on mood and anxiety symptom treatments over time. Tertile distances from the epicentre were used, because they led to the best model fit based on the DIC. This best-fit model also investigated relative risk changes over time by calculating the ratio of the mean relative risks between the first (2009 Q1) and each later quarter till the end of the study (2013 Q2) for each area unit. The results of this model were compared to results from spatial-temporal cluster analysis and spatial variation in temporal

trends analysis implemented by the SaTScan^{TM} software and using an adjusted reliability index *R* to find the most reliable clusters.

Results

Descriptive statistics

The first analyses, which compared mood and anxiety symptom treatments between Christchurch residents and those from the rest of New Zealand, as well as examined high-risk groups in the context of the 2010/11 earthquakes, used daily counts of mood and anxiety symptom treatments and annual population estimates from Statistics New Zealand linearly interpolated to daily estimates.

In total, 733,274 daily mood and anxiety symptom treatments have been made in Christchurch and 5,542,971 in other parts of New Zealand between 1st January, 2009 and 30th June, 2013.

Daily mood/anxiety symptom treatment rates per 100,000 people in Christchurch and the rest of New Zealand revealed that higher rates were seen on weekdays mainly due to opening hours of health services like pharmacies and among Christchurch residents. Additionally, the linear temporal trend showed increasing treatment rates over time for both groups, although the strength of the increase seemed to be stronger among Christchurch residents (Figure 4.1).
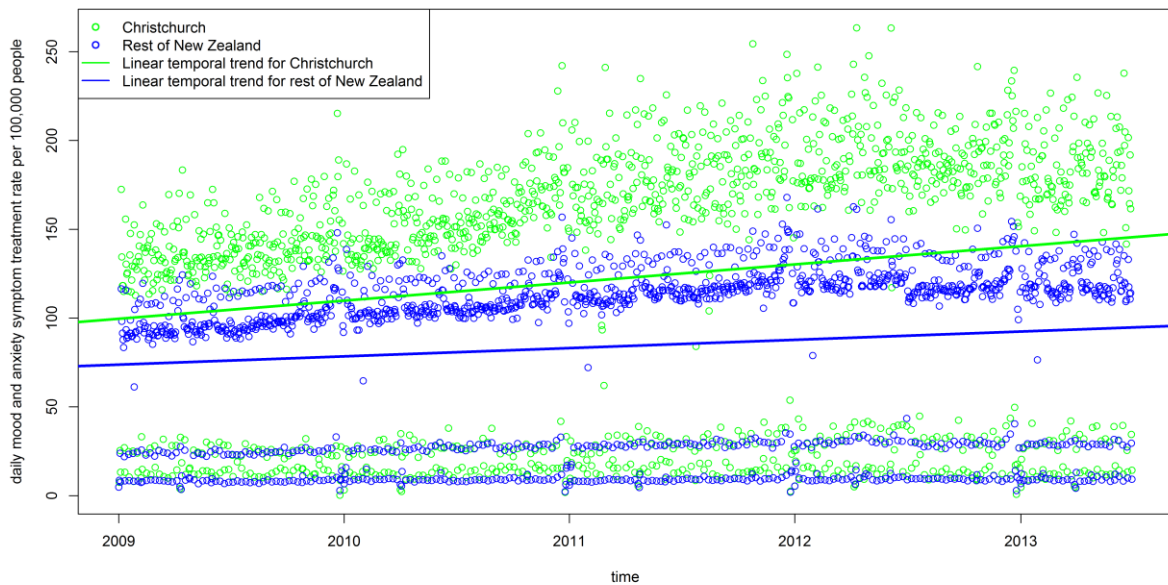
Figure 4.1: Daily mood and anxiety symptom treatment rates per 100,000 people among Christchurch and non-Christchurch residents between 1/1/2009 and 30/6/2013

To better examine the different strength of mood and anxiety symptom treatment increases between the two groups and a possible effect due to the Canterbury earthquakes, the daily treatment rates were aggregated to quarterly measures, which also correspond to the quarterly residential histories, and compared based on relative changes with reference to the last quarter before the Canterbury earthquake sequence began (2010 Q2). These quarterly changes in mood and anxiety symptom treatment rates showed similar strengths for Christchurch and the rest of New Zealand before the earthquakes, but were stronger in Christchurch after the earthquake sequence began (Figure 4.2). It is worth noting that a deviation in rate changes was particularly observed in Christchurch in the first quarter after the catastrophic February 2011 Christchurch earthquake.

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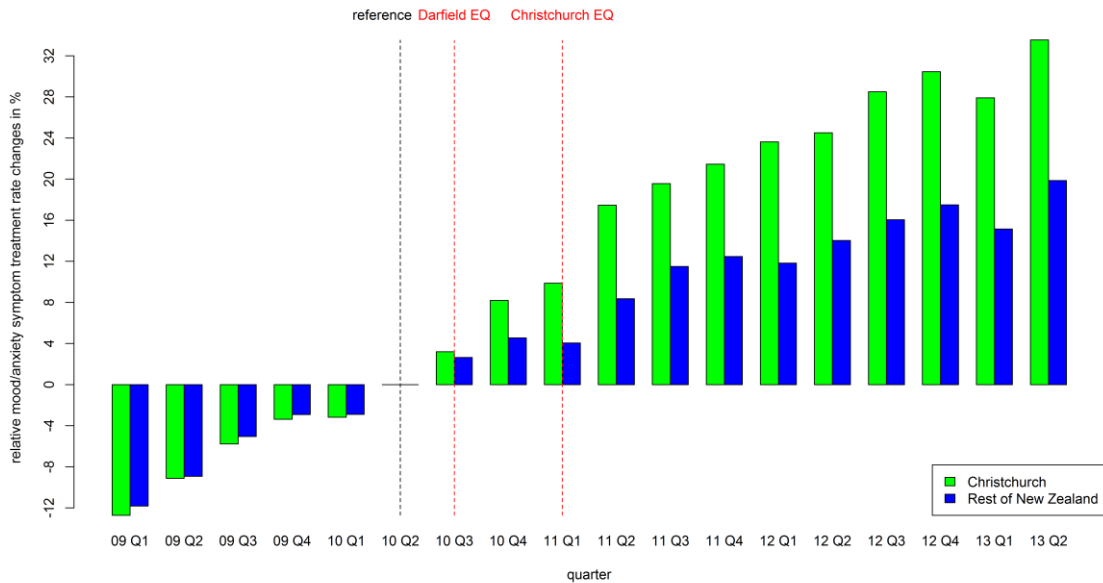
Figure 4.2: Relative quarterly changes of mood/anxiety symptom treatment rates compared to the 2nd quarter 2010 shortly before the 2010/11 Canterbury earthquake sequence

A further categorisation of the two groups based on demographic characteristics showed that higher mean daily mood and anxiety symptom treatment rates were found among females compared to males, as well as older compared to younger people and European compared to Maori, Asian, Pacific and MELAA people. Again, Christchurch residents showed in general higher rates than those from the rest of New Zealand (Table 4.1).

Table 4.1: Mean daily mood and anxiety symptom treatment rates per 100,000 people of Christchurch and non-Christchurch residents between 1/1/2009 and 30/6/2013

Demographic characteristics	Mean daily mood/anxiety symptoms treatment rate per 100,000	
	Christchurch	Non-Christchurch
Gender		
Female	155.2	105.7
Male	88.1	61.5
Age group		
0-14	1.2	1.1
15-39	85.7	65.8
40-64	171.6	120.8
65+	266.8	187.7
Ethnicity		
European	140.5	109.0
Maori	77.5	47.7
Pacific	28.0	16.0
Asian	15.3	16.0
Middle Eastern/Latin American/African	62.9	48.0
Other ethnicity	234.3	179.7

Christchurch - New Zealand comparison

The first multiple regression model showed that the post-earthquake risk of receiving care or treatment for moderate or severe mood or anxiety symptoms was 33% higher (IRR=1.33, p<.001, 95% CI [1.32, 1.34]) among Christchurch residents, although the risk was already elevated in the pre-earthquake phase (IRR=1.27, p<.001, 95% CI [1.25, 1.28]). However, comparing the average post-earthquake increase in adjusted risks of mood and anxiety symptom treatments between the two groups, an approx. 5% (IRR=1.05, p<.001,

95% CI [1.03, 1.06]) greater increase was found in Christchurch, which is only a weak effect, but may be attributed to the earthquakes.

The second model revealed greater increases in the risk of receiving care or treatment for moderate or severe mood or anxiety symptoms in Christchurch than in the rest of New Zealand since the third quarter of 2010 when the earthquake sequence started, although not every quarter saw a statistically significant rise (Figure 4.3).
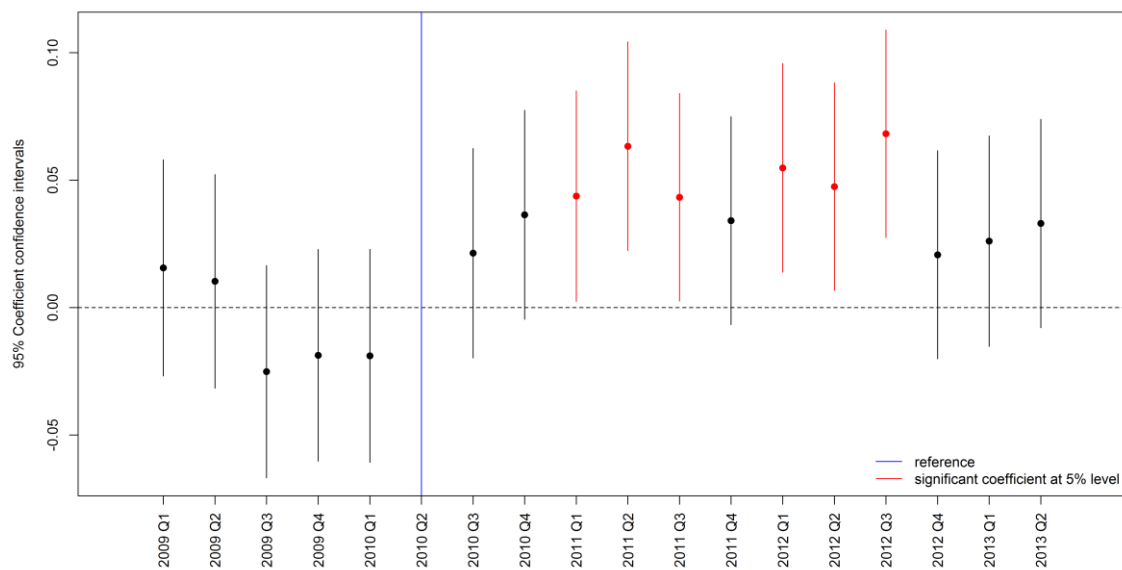
Figure 4.3: Coefficient plot showing increases in mood/anxiety symptom treatments in Christchurch compared to the rest of New Zealand between 2009 and mid-2013 on a quarterly basis

Compared to the last pre-earthquake quarter the increases in risk were approx. 4% (IRR=1.04, p<.05, 95% CI [1, 1.09]), 7% (IRR=1.07, p<.01, 95% CI [1.02, 1.11]) and again 4% (IRR=1.04, p<.05, 95% CI [1, 1.09]) greater in Christchurch than in the rest of New Zealand in the first, second and third quarter of 2011. In 2012, a similar pattern could be found with significant greater increases in risk of approx. 6% (IRR=1.06, p<.01, 95% CI

[1.01, 1.1]), 5% (IRR=1.05; p<.05, 95% CI [1.01, 1.09]) and 7% (IRR=1.07, p<.01, 95% CI [1.03, 1.12]) in the first, second and third quarter compared to the second quarter of 2010 among Christchurch residents compared to the rest of New Zealand (Figure 4.3).

High-risk groups

The main effects of model 3 revealed that general demographic risk factors for receiving care or treatment for mood or anxiety symptoms included being female, older age and European ethnicity compared to Maori, Pacific, Asian and Middle Eastern/Latin American/African ethnicity (Table 4.2).

Table 4.2: Main effects of gender, age and ethnicity on mood and anxiety symptom treatments

Independent variables	IRR (95% CI)
Gender	
Male	1
Female	1.56 (1.55, 1.57); p<.001
Age group	
0-14	1
15-39	54.86 (53.89, 55.87); p<.001
40-64	102.51 (100.69, 104.38); p<.001
65+	136.59 (134.29, 139.07); p<.001
Ethnicity	
European	1
Maori	0.65 (0.64, 0.65); p<.001
Pacific	0.23 (0.23, 0.24); p<.001
Asian	0.18 (0.18, 0.18); p<.001
Middle Eastern/Latin American/African	0.62 (0.62, 0.63); p<.001
Other ethnicity	1.85 (1.83, 1.86); p<.001

The third model had a statistically significant three-way interaction term (p<.001) and revealed that Christchurch children and elderly showed greater increases in risks compared to those from the control group in the post-earthquake phase. Christchurch elderly ($\geq$ 65 years) already had an over 1.2 times (IRR=1.23, p<.001, 95% CI [1.2, 1.26]) higher risk for mood and anxiety symptom treatments compared to elderly in other parts of New Zealand pre-earthquake, but the risk significantly elevated over time (IRR=1.14, p<.001, 95% CI [1.1, 1.17]) to a 1.4 times higher risk (IRR=1.4, p<.001, 95% CI [1.37, 1.43]) post-earthquake. For children the patterns were less clear. The pre-earthquake risk for children from Christchurch (0-14 years) was significantly lower (IRR=0.87, p<.01, 95% CI [0.79, 0.95]) than the risk for non-Christchurch children, but significantly increased in the post-earthquake phase (IRR=1.22, p<.01, 95% CI [1.08, 1.38]). As a result, these children 'catched-up' in receiving treatements compared to children from other parts of New Zealand, so that the risk did not show a statistically different effect after the disaster (IRR=1.06, p=.12, 95% CI [0.98-1.14]).

Spatio-temporal variations of quarterly mood and anxiety symptom treatments in Christchurch

Disease maps of the best-fit Bayesian model (Model 4) showed high relative risks forming a cluster from the centre to the southeast and east, whereas low relative risks predominantly occurred in the north, west and far south of the Christchurch urban area from the beginning till the end the study period (Figure 4.4), indicating little change in relative risks for most parts of the city.
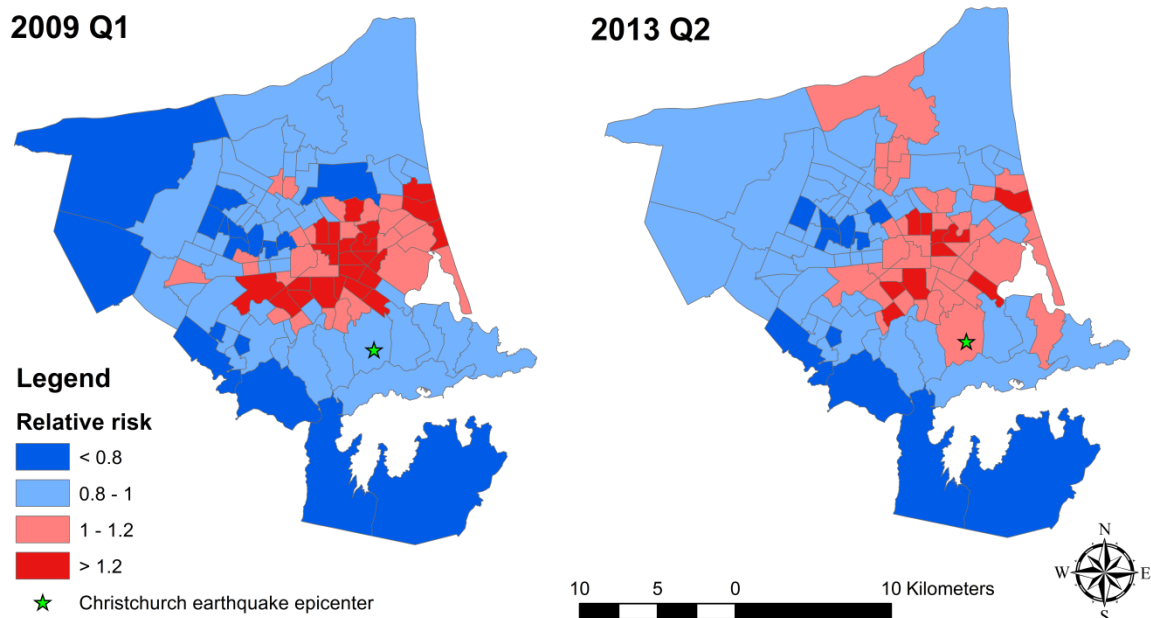
Figure 4.4: Disease maps at the start and end of study period based on the best-fit Bayesian model

Changes in relative risks examined by the same model could be identified throughout the city, but especially in the northern and eastern parts. Relative risk decreases mostly occurred in the severely affected eastern areas, but none of the decreases has been significant at a 5% credible interval. On the other hand, the relative risks increased in the northern area units, especially in the Northeast. The CAUs 'Russley' and 'Redwood South'

showed significant risk increases of 29% (95% CI [1, 1.66]) and 31% (95% CI [1.03, 1.64]) between the start and end of the study (Figure 4.5, right figure).

These spatial variations in temporal trends could largely be confirmed by the same-titled SaTScan^{TM} method, which identified the most reliable clusters (R > 0.5) with the smallest treatment rate increases in eastern areas and the greatest increases in the Northeast, as well as scattered area units north and northwest of the central city (Figure 4.5, left figure).
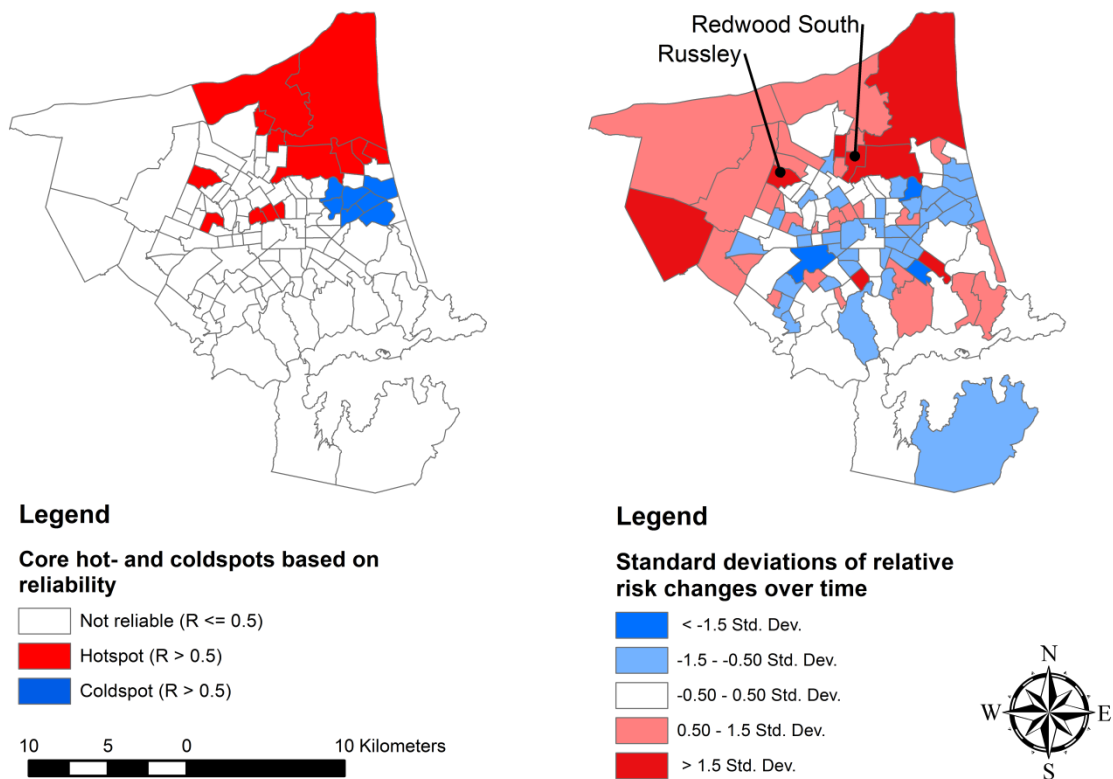
Figure 4.5: Core high-risk (red) and low-risk (blue) clusters of increasing mood and anxiety rates identified by the adjusted reliability index of the spatial variation in temporal trends analysis (left) compared to relative risk changes over time (Bayesian modelling) categorised into standard deviations (right)

On the other hand, adjusted reliability indices (R > 0.5) from spatio-temporal cluster analysis showed post-earthquake high-risk clusters (hotspots) of mood and anxiety symptom treatments spreading south and southeast of the central city. Also, post-earthquake low-risk clusters (coldspots) were identified in the western, northern and hilly southern parts of the Christchurch urban area (Figure 4.6).
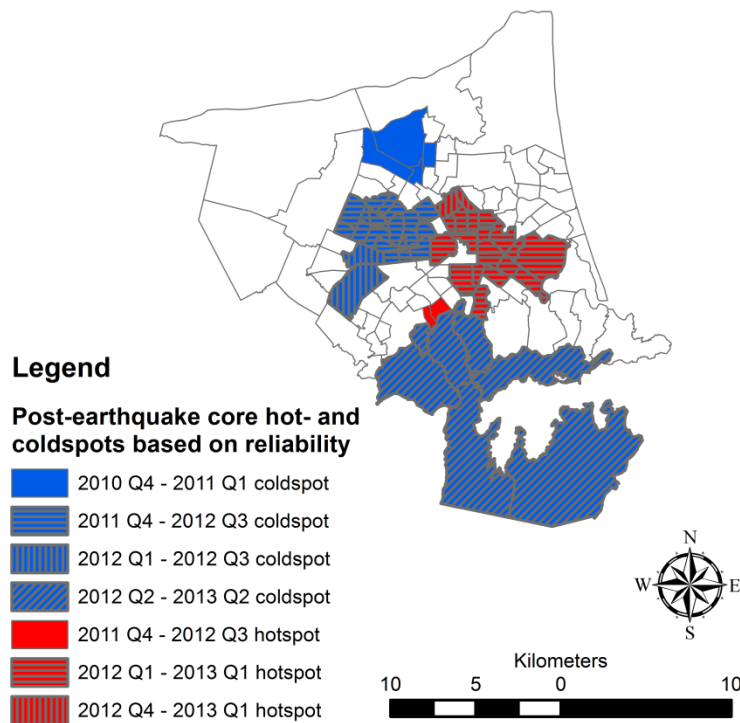
Figure 4.6: Post-earthquake core high-risk (red) and low-risk (blue) spatio-temporal clusters identified by the adjusted reliability index of the spatio-temporal cluster analysis

Examining the two covariates socio-economic deprivation and distance from the Christchurch earthquake epicentre, socio-economic deprivation showed in general a positive effect, meaning that the risk increased with higher deprivation score. Distance from the epicentre, which is typically the area of highest shaking and intensity, showed in general a negative effect, so that closer proximity was also assumed to be a risk factor for

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being treated for mood or anxiety symptoms at first sight. On the other hand, a closer look at the posterior estimates revealed that they both showed decreasing strengths of the effects over time, whereas in general little change occurred for socio-economic deprivation. However, the distances to the epicentre showed particularly weakened effects in the three quarters following the Christchurch earthquake (2011 Q2 – 2011 Q4) (Figure 4.7).
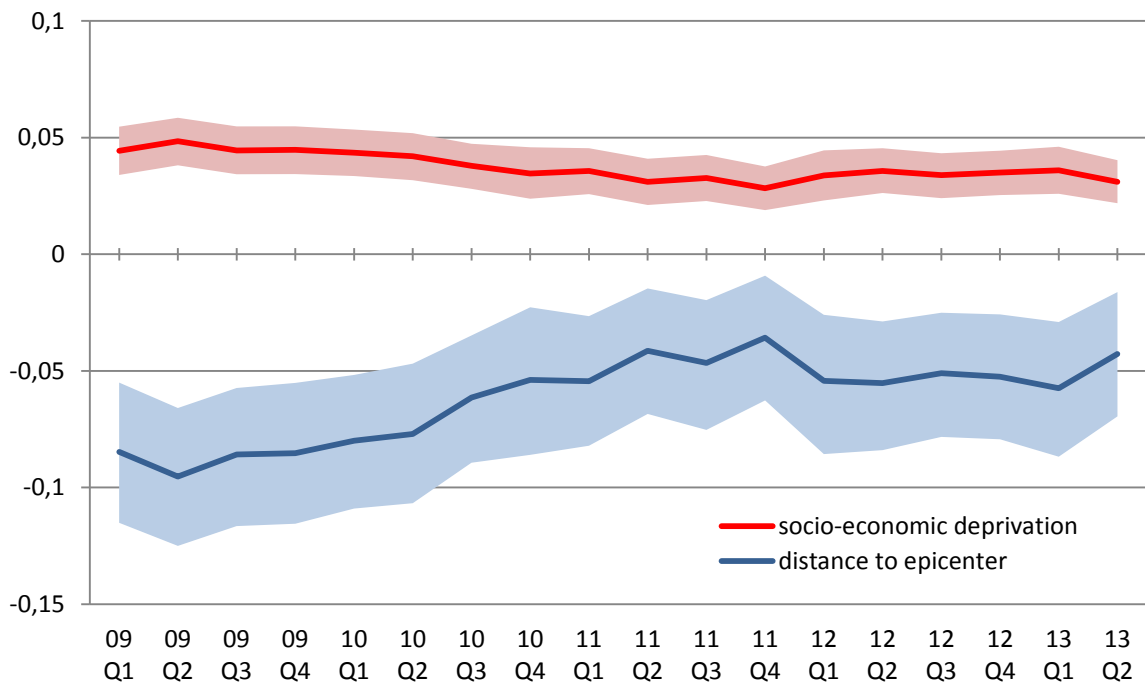
Figure 4.7: Posterior estimates and credible intervals of the quarterly relative risks of distance to the Christchurch earthquake epicentre and socio-economic deprivation in the Christchurch urban area

Discussion

In this study we found that there was a weak, but statistically significant increase in the risk of showing moderate or severe mood or anxiety symptoms among people receiving care or treatment in Christchurch compared to other parts of New Zealand after the Canterbury earthquake sequence, suggesting an earthquake exposure effect. This supports the research of Duncan et al. (2013) who found high levels of PTSD, anxiety and depression in treatment-seeking individuals using alternative counseling opportunities after the Christchurch earthquake. Spittlehouse et al. (2014) also reported higher rates of major depressive disorder in middle-aged adults after the Darfield earthquake compared to historical, local and national surveys, but these weren't statistically significant. Globally, numerous studies have reported elevated levels of mental disorders in exposed compared to less or unexposed populations after severe earthquakes (Bulut, 2006; Bödvarsdóttir & Elklit, 2004; Dell'Osso et al., 2012; Goenjian et al., 1994a; Kolaitis et al., 2003). Contrarily, Beaglehole, Bell, Beveridge and Frampton (2015a) found that psychiatric admissions based on mood disorders fell in the short and longer term following the Christchurch earthquake and questionned an increased need for mental health services after earthquakes. Elsewhere, it has been found that only a minority of exposed individuals show chronically elevated levels (Bonanno et al., 2010) and seek formal treatment (McFarlane, Van Hoof, & Goodhew, 2009), which may support our finding of a weak effect since mainly moderate and severe cases could be identified by the data sources applied. On the other hand, comparisons to our study are difficult as it included not only specialist services, but also hospital inpatient data, as well as pharamceutical information on subsidised medication, which may additionally include less severe cases of mood and anxiety symptoms being treated.

An important finding was that compared to the last pre-earthquake quarter significant post-earthquake rises in mood and anxiety treatments were observed especially in the quarter following the Christchurch earthquake, as well as the third quarter of 2012 indicating

exposure effects to the Christchurch earthquake and its impacts in the short, as well as long term. Secondary stressors like financial loss, damage to the property and ongoing difficulties with insurance reimbursements produced a lot of uncertainty and distress (Rowney et al., 2014). Feelings of uncertainty and loss of control were intensified by the large amount of small to medium magnitude aftershocks and also indiviual large events like the December 2011 earthquake led to a depletion of coping abilities and challenged the communities' resilience (Wilson, 2013). Infrastructure disruption, disruption of families, loss of social contact and networks, disruption of services due to loss of shops, businesses, cultural and leisure facilities, school and workplace relocations were further reported stressors (Annear et al., 2013; Gawith, 2011). Exposure to disruption has been linked to psychological symptoms (Carr et al., 1995) as social resources are often scarce when they are most needed (Norris et al., 2002b). On the other hand, the identified effects, while significant, were largely small, which might be explained by strong community bonding and resilience among Christchurch communities (Gawith, 2013), but also by direct and indirect exposure of the control group consisting of non-Christchurch New Zealand residents. Direct exposure may be present in the control group as the earthquake impacts observed in the Christchurch urban area were not strictly limited to this area, but to different extents also occurred in the urban hinterland. Additionally, the strongest earthquakes of the Canterbury earthquake sequence could be felt across the whole of the South Island and up to the lower North Island. Furthermore, the TV and media coverage of the Canterbury earthquake events was extensive and studies have shown that vicarious traumatization can lead to elevated psychological distress and traumatic reactions especially among children and adolescents (Bulut, 2006; Groome & Soureti, 2004; Roussos et al., 2005). Also the indirect disaster exposure of unaffected subjects, who have directly affected relatives or friends, has been strongly associated with psychological distress and trauma-related mental health consequences after the 2010 earthquake in Haiti as they experienced similar stress factors as their relatives or friends, which is called "mirror-imaging" (Shultz et al., 2012).

Nevertheless, the immediate post-earthquake rise in mood and anxiety symptom treatments until more than a year and a half after the Christchurch catastrophe highlights the need to identify where to target early interventions and recovery efforts to reduce stress and help prevent the exacerbation of adverse mental health symptoms in the most affected urban area. Gawith (2011) noted that the distribution of damage and ongoing difficulties varied spatially with more severe impacts in eastern and southern suburbs and Dorahy and Kannis-Dymand (2012) indicated a dose-response relationship between depression, as well as anxiety scores and level of affectedness after the Darfield earthquake. Hence, we examined the spatio-temporal variation within the city and found that the relative risks of being treated for moderate or severe mood and anxiety symptoms were generally higher in the central and southeast parts of the city after the beginning of the earthquake sequence.

Contrarily, assessing relative risks and their changes over time via Bayesian modeling, most areas in Christchurch did not show any significant changes again supporting the hypothesis of a generally strong resilience and good coping of Christchurch residents after the earthquakes (Gawith, 2013). On the other hand, two areas in the North and Northwest, which have been generally less affected, showed statistically significant relative risk increases and the spatial variation in temporal trends analysis found clusters of high rate changes in the North and Northeast and low rate changes in severely affected eastern parts of the city. These findings might partly be explained by inner-city relocations of highly affected populations since high levels of mobility with a population shift from severely to less affected areas have been observed after the Christchurch earthquake (Howden-Chapman et al., 2014). Disaster research has shown that relocation is often accompanied by stress and anxiety and that households with relatively low socio-economic status struggle the most (Morrow-Jones & Morrow-Jones, 1991). Applying this knowledge to the Christchurch case, inner-city movers from severely affected socio-economically deprived eastern suburbs might have been at greater risk of showing moderate or severe mood or anxiety symptoms. In addition, socioeconomic isolation might be another stressor as previous research in Auckland showed higher rates of mood and anxiety symptom

treatments among more isolated deprived communities (Pearson et al., 2013). However, more severely affected individuals reported stronger family and community relationships as a consequence of the disaster (Fergusson, Horwood, Boden, & Mulder, 2014), which in turn might have lead to an increased social cohesion in severely affected communities and helped reduce adverse mental health outcomes (Rowney et al., 2014). Another explanation for the identified risk changes might also be the "Psychological Typhoon Eye" effect where post-earthquake levels of concerns about safety and health increase with decreasing levels of devastation (Li et al., 2009) leading to the assumption that more affected survivors had a higher resilience due to cognitive dissonance (Li et al., 2010). These hypotheses merit further, more detailed investigation.

The literature also suggests a linkage between low socio-economic status and major depressive symptoms (Fortney et al., 2007; Saraceno, Levav, & Kohn, 2005), especially after disasters (Maguen et al., 2009; Norris et al., 2002a) and we found a similar relationship in the best-fit Bayesian model, but the effect showed only little variation over time. We also assessed the effects of proximity to the epicentre of the Christchurch earthquake on mood and anxiety symptom treatments since research has identified closer proximity to be a risk factor (Başoğlu et al., 2002, 2004; Dell'Osso et al., 2012; Goenjian et al., 1994a; Groome & Soureti, 2004; Pynoos et al., 1993; Roussos et al., 2005). The initial result seemed to be in line with this finding, but comparisions of relative risks over time showed that the effect was weakest in the aftermath of the Christchurch earthquake. Consequently, the identified adverse effect of closer proximity to the epicentre on mood and anxiety is questionable. The epicentre is typically the area of highest shaking, but the greatest destruction to buildings and the highest incidence of physical injury occurred in the CBD and areas affected by liquefaction and lateral spreading, rockfall and cliff collapse. This highlights the need to assess more complex irregular exposure patterns.

Results from the negative binomial regression analyses showed that women were particularly vulnerable, which was in line with literature (Bonanno et al., 2010; Galea et al., 2005; Livanou et al., 2002; Neria et al., 2009) and might support the assumptions that

women are emotionally more affected and have a greater tendency to seek help by seeing a doctor than men (Livanou et al., 2002).

An interesting finding in our study was that the risk generally increased with age, which might be due to a relapse of a past psychiatric illness and chronic health condition, as well as high vulnerability to experiencing a loss of social support and sense of control in older adults after natural disasters (Başoğlu et al., 2002, 2004; Kun et al., 2013; Neria et al., 2009; Norris et al., 2002a; Tuohy, Stephens, & Johnston, 2014). We also found that elderly (≥ 65 years) in Christchurch had a significantly greater increase in the risk of being treated for moderate or severe mood or anxiety symptoms between the pre-disaster and post-disaster period than elderly in other parts of New Zealand. This is supported by Annear et al. (2013) who found that sleeping pills and anti-depressants were the most commonly reported post-disaster prescriptions among elderly. The rationale is that the elderly might be at a greater risk as they are susceptible to loss of community and residence (Tuohy et al., 2014) and often face persistent financial problems (Ali et al., 2012), elevated physical health problems, as well as a rapid depletion of psychological resources as a result of disaster exposure (Neria et al., 2009). On the other hand, numerous studies report inverse effects suggesting that older adults show more resilience due to maturity and the experience that comes with age (Norris et al., 2002a).

In general, the first onset of mental disorders usually occurs in childhood or adolescents (Kessler et al., 2007), so we tested for increased onset among affected children after the earthquakes. We found that the risk was significantly lower among Christchurch children compared to children from the control group in the pre-earthquake phase, but it increased significantly and was slightly higher though insignificantly different afterwards. This is consistent with other studies that have shown more severe symptoms and higher rates of PTSD and depression in exposed compared to unexposed children (Bulut, 2006; Kolaitis et al., 2003). The increase in risk might be explained by the fear and exposure to traumatic earthquake-related experiences, as well as susequent advertisities from the

disaster (Giannopoulou et al., 2006; Groome & Soureti, 2004; Pynoos et al., 1993; Kolaitis et al., 2003; Roussos et al., 2005).

With regard to reducing the risk of being treated for moderate or severe mood and anxiety symptoms after severe earthquakes our findings suggest that a fast earthquake recovery characterized by fast insurance claim settlements, financial support, rapid infrastructure repairs and restoration of city services like water, wastewater or leisure facilities, as well as programmes to support community participation and social bonding might help reduce distress. Service providers should specifically focus on women, children and elderly and target areas that have already been at greater risk before the disaster and less affected areas that may experience an influx of more affected people. More research needs to be done to examine the role of disaster mobility and more complex disaster impacts like community disruption on the occurrence of moderate and severe mood and anxiety symptoms in affected populations.

Limitations

In our study we used treatment information about mood and anxiety symptoms from the New Zealand Ministry of Health databases, but only a very small proportion of these disorders is able to be identified through these. For example, they underestimate the prevalence of mood and anxiety disorders in the general population as only people receiving care or treatment can be identified as cases. This further carries the risk of confounding due to varying availability of health care resources and unknown care-seeking behaviour. As a result, it adds more uncertainty to use raw population information from the census as the at-risk population, e.g. in SaTScan analyses (Robertson, Nelson, MacNab, & Lawson, 2010), so we tried to minimise the inaccuracy by relying on Health Tracker information in spatio-temporal analyses. The health data is also particularly weak in identifying people with less severe mood and anxiety symptoms as only people receiving publically funded care or treatment were included. Additionally, the Pharmaceutical Claims

Data Mart (PHARMS) administrative data is a core source for identifying mood disorders, but only records publically funded drugs. Changes occur to the set of drugs publically funded, which also doesn't allow accurate estimation of the prevalence of mental disorders. Nonetheless, we overcame this weakness by comparing the mood and anxiety symptom treatment changes between Christchurch and non-Christchurch residents in New Zealand. It should also be mentioned that the data might underestimate rates for specific demographic groups. For example, ethnic minorities have been identified at high risk for psychological morbidity after natural disasters (Kun et al., 2013; Neria et al., 2009), whereas our results showed that Asians, Maori, Pacific people and Middle Eastern/Latin American/African people were at lower risk compared to Europeans.

When interpreting the data it should also be kept in mind that inferences to individual disorders like PTSD or depression can't be made since a mood and anxiety indicator has been used. Furthermore, due to the study design causal relationships could not be demonstrated and results might have been subject to confounding. Further research is needed to examine variables that might explain significant pattern changes identified by this study.

Conclusions

In summary, we found that severe mood and anxiety incident and relapsed treatment cases increased significantly among Christchurch residents compared to non-Christchurch residents after two severe earthquakes. Specifically, in the first quarter after the catastrophic Christchurch earthquake, a stronger increase of mood and anxiety symptom treatments was observed.

High-risk groups for receiving care or treatment for mood or anxiety symptoms included women, elderly and people with European ethnicity. After the earthquakes, a significant increase in receiving care or treatment for mood and anxiety symptoms was especially identified among Christchurch children and elderly.

Examining patterns of mood and anxiety symptom treatments revealed little change for most parts of the city, whereas a post-disaster hotspot stretching from the centre to the southeast of the city was identified. Risk changes over time showed that the greatest increases in risk occurred in the north of the CBD, whereas the greatest decreases were found in severely affected eastern parts of Christchurch, which seems to be counterintuitive, but might be linked to mobility activities and different levels of community cohesion in the wake of the disaster. Nonetheless, these patterns need to be further investigated.

Supplementary material

Best-fit Bayesian model (model 4), WinBUGS Code

```
model
{
        for(i in 1:N){
                for(t in 1:T){
                        O[i,t]~dpois(mu[i,t])
                        log(mu[i,t])<-log(E[i,t]) + alpha + beta1[t] * EPIDIST[i] +
                        beta2[t] * NZDEP[i,t] + s[i,t] + u[i,t]
                        # Area-specific relative risk (for maps)
                        RR[i,t]<-exp(alpha   + beta1[t] * EPIDIST[i] + beta2[t] *
                        NZDEP[i,t] + s[i,t] + u[i,t])


                        # Changes in relative risk over time with first quarter of 2009 as reference
                        RR_DIFF[i,t]<-exp(log(RR[i,t])-log(RR[i,1]))
                }
        }
        # CAR prior distribution for spatially-correlated random effect:
        for(t in 1:T){
                sp[t,1:N]~car.normal(adj[], weights[], num[], tau.s[t])
        }
        for(i in 1:N){
                for(t in 1:T){
                        s[i,t]<-sp[t,i]
                }
        }
```

```
# Prior distribution for the uncorrelated random effect:
for(i in 1:N){
          for(t in 1:T){
                    u[i,t]~dnorm(0, tau.u[t])
          }
}
# Other priors:
alpha~dflat()
for(t in 1:T){
          beta1[t]~dflat()
          beta2[t]~dflat()
          tau.s[t]~dgamma(0.5, 0.0005)     # prior on precision
          sigma.s[t]<-sqrt(1/tau.s[t])    # standard deviation
          tau.u[t]~dgamma(0.5, 0.0005)     # prior on precision
          sigma.u[t]<-sqrt(1/tau.u[t])       # standard deviation
}
}
```

Chapter Five: The effects of relocation and level of affectedness on mood and anxiety symptom treatments after the 2011 Christchurch earthquake

Preface

The previous two chapters (Chapters 3 & 4) assessed the spatio-temporal variation of mood and anxiety symptom treatments in the Christchurch urban area and possible earthquake impacts related to the increased incidence and relapse of those adverse mental health outcomes. In chapter 3, a dose-response relationship between disaster exposure and mood and anxiety symptom treatments could be identified for specific earthquake impacts including earthquake intensity, distance to liquefaction, distance to moderate to major lateral spreading and distance to minor or moderately affected areas, whereas only weak relationships were found, and none with distance to severely affected areas. Instead, spatio-temporal analyses in chapter 4 revealed that treatment rates increased most strongly in the less affected northern areas and the lowest increases were found in the severely affected eastern parts of the city.

These findings suggest a possible effect of mobility on mood and anxiety symptom treatment patterns as a population shift from the severely affected eastern to less affected western and northern areas in the city could be observed after the earthquakes. Thus, the research study in this chapter investigates the effects of relocation on mood and anxiety symptom treatments after the 2011 Christchurch earthquake. It examines whether different types of mobility have different effects on mood and anxiety symptom treatments and if they depend on different levels of affectedness from the 2011 Christchurch earthquake and its impacts. This helps to explore the roles of mobility and level of affectedness on adverse

mental health outcomes after a severe natural disaster contributing to the identification of key target groups for intervention programs and the development of appropriate mental disorder prevention strategies.

Abstract

In this longitudinal study, we compare the effects of different types of relocation and level of affectedness on the incidence and relapse of mood and anxiety symptom treatments identified by publically funded care or treatment one year before and one and two years after the '2011 Christchurch earthquake' in New Zealand. Based on a subset of Christchurch residents from differently affected areas of the city, identified by area-wide geotechnical land assessments (no to severe land damage), 'stayers', 'within-city movers', 'out-of-city movers' and 'returners' were identified to assess the interaction effect of different levels of affectedness and relocation on the incidence and relapse of mood and anxiety symptom treatments over time. Health and sample information were drawn from the New Zealand Ministry of Health's administrative databases allowing us to do a comparison of the pre-/post-disaster treatment status and follow-up on a large study sample.

Moving within the city and returning have been identified as general risk factors for receiving care or treatment for mood or anxiety symptoms. In the context of the 2011 Christchurch earthquake, moving within the city showed a protective effect over time, whereas returning was a significant risk factor in the first year post-disaster. Additionally, out-of-city movers from minor, moderately or severely damaged Christchurch's plain areas were identified as especially vulnerable two years post-disaster. Generally, no dose-response relationship between level of affectedness and mood or anxiety symptom treatments was identified, but the finding that similarly affected groups from the city's plain areas and the more affluent Port Hills showed different temporal treatment trends highlights the importance of including socio-economic status in exposure assessment. High-risk groups included females, older adults and those with a pre-existing mental illness. Consequently, mental health intervention programs should target these vulnerable groups, as well as out-of-city movers from affected areas in the long run.

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Introduction

After severe disasters, affected areas can lose many residents in the short-term aftermath of the disaster and the spatial distribution of residential housing often changes due to damage, migration and the recovery process. Examples include Kobe City (Japan) after the 1995 earthquake where it took 10 years to regain the city's pre-disaster population level and the population shifted to less affected suburban wards (Chang, 2010) and Christchurch (New Zealand) after the 2011 earthquake where a population decline of over 2% occurred in the short-term aftermath and another 1.5% in the following year (Statistics New Zealand, 2014), despite the influx of workers seeking employment opportunities in reconstruction (Belcher & Bates, 1983). The within-city mobility was even higher with over 5% of the population redirecting their mail to an alternative address (Newell et al., 2012). Also a population shift from severely affected eastern and central city suburbs to the less affected western and northern suburbs occurred (Howden-Chapman et al., 2014; Statistics New Zealand, 2014), which is a common post-disaster observation (Belcher & Bates, 1983; Gray, Frankenberg, Gillespie, Sumantri, & Thomas, 2009). However, relocation should not be confused with evacuation, although the boundaries can become blurred since evacuation can turn into permanent relocation (Norris & Wind, 2009).

According to the conceptual framework developed by Usher-Pines (2009), relocated disaster victims face unique challenges including health care disruption, social network changes, living condition changes and psychological stressors along with the stressful primary disaster-experiences. Health care disruptions and psychological stressors like the loss of home, social networks, social/cultural identity and a sense of control when moving into a new neighbourhood or community with different economic, social and cultural attachments showed negative impacts on mental health (Mileti & Passerini, 1996; Uscher-Pines, 2009), whereas changes in social networks and living condition can also have mitigating effects (Uscher-Pines, 2009). Literature suggests that the aggregate effect is negative as high levels of stress and anxiety are commonly observed in relocated disaster

survivors with studies reporting an association between permanent relocation and psychological morbidity (Bland et al., 1997; Fussell & Lowe, 2014; Kılıç et al., 2006; Lonigan et al., 1994; Najarian et al., 2001; Uscher-Pines, 2009; Watanabe, Okumura, Chiu, & Wakai, 2004). On the other hand, results vary with socio-demographic characteristics as low socio-economic groups are more likely to be affected by disaster impacts and relocate due to their higher likelihood of living in hazard prone areas (Mileti & Passerini, 1996; Morrow-Jones & Morrow-Jones, 1991) and less political power to defend their properties (Howden-Chapman et al., 2014).

As a result, disaster-affected movers from low-income groups often have to deal with potentially more stress factors than those with higher socio-economic status, whereas affluent people often relocate by choice due to dissatisfaction with their economic and/or living situation after a disaster (Belcher & Bates, 1983). Study results may also vary by age and type of relocation as Kılıç et al. (2006) associated relocation with depression, but not PTSD in adult survivors after the 1999 earthquakes in Turkey, whereas Lonigan et al. (1994) found an association between PTSD symptoms and continued displacement of children after Hurricane Hugo. After Hurricane Katrina Fussell and Lowe (2014) also identified higher general psychological distress and perceived stress among relocated compared to returned low-income parents and also those living in unstable temporary housing conditions faced elevated perceived stress. On the other hand, there are studies that could not find an effect of post-disaster mobility on psychological distress (Goenjian et al., 2001; Najarian, Goenjian, Pelcovitz, Mandel, & Najarian, 1996; Riad & Norris, 1996; Thienkrua et al., 2006). Nevertheless, a relationship between the number of relocations and increased psychological distress has been reported (Riad & Norris, 1996) and the general assumption confirmed that disaster movers usually relocate to places with a lower living standard causing frustration, anxiety and stress as movers tend to measure their recovery success by comparing their post- with pre-disaster standard of living (Mileti & Passerini, 1996; Morrow-Jones & Morrow-Jones, 1991). However, stayers can also face high levels of stress and anxiety as the reconstruction of damaged homes can be an uncertain, conflict-

prone and long-term process that requires adaptation (Chang, 2010). Furthermore, reconstruction is commonly done at the pre-disaster location, which involves the danger of a recurring disaster and further damage (Mileti & Passerini, 1996).

Study aims

In summary, there are mixed results for understanding the effects of post-disaster relocation on mental health, because there is a lack of generalizability of events as every disaster is unique. Furthermore, there is a lack of longitudinal studies with quasi-experimental design characterized by pre- and post-disaster comparison, as well as large sample sizes (Usher-Pines, 2009). Thus, our longitudinal study addresses these issues by using traceable patient information and mood and anxiety treatment data to examine the effects of relocation on mental health before and after the 2011 Christchurch earthquake, which triggered a strong mobility activity in the city. Most relocatees come from the severely affected 'Red Zone' areas, where properties were deemed unsafe/uneconomic to rebuild or repair and residents were encouraged to accept a government purchase offer and leave their homes. This demonstrates the interaction between relocation and the level of affectedness, which has repeatedly been identified as a risk factor for psychological morbidity after severe earthquakes (Bulut et al., 2005; Dorahy et al., 2015; Goenjian et al., 2001; Norris, et al., 2002a; Ying et al., 2013). Additionally, secondary stressors like the uncertainty due to thousands of aftershocks that posed an ongoing threat to life and further damage, being reminded of the catastrophe in everyday life, living in a damaged home or dealing with the slow reconstruction and insurance claims processes were contributing factors to the development of adverse stress-related health outcomes (Richardson, 2013). Thus, we hypothesise that residents from severely earthquake-affected areas measured by Canterbury Earthquake Recovery Authority (CERA) land assessments and technical categorisations were more likely to receive care or treatment for mood or anxiety symptoms than residents from less or unaffected ones after the Christchurch earthquake. Furthermore, we

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hypothesise that relocation from severely to less damaged neighbourhoods had a protective effect on receiving care or treatment for mood or anxiety symptoms.

To our knowledge these questions haven't been addressed by previous research, but give a unique insight into the effect of localised relocation and associated stressors on mood and anxiety symptom treatments based on the level of affectedness after a severe natural disaster. Furthermore, vulnerable groups most likely to receive care or treatment for mood or anxiety symptoms are identified. This should help to better understand and create awareness of the effects of localised relocation on coping and recovery in a disaster-affected city in a developed country, as well as what kind of post-disaster intervention programs should be initiated by governmental authorities and who should be targeted in particular to avoid the development of adverse mental health outcomes. On the other hand, it needs to be kept in mind that we measure adverse mental health effects based on treatment information, which is strongly influenced by treatment seeking behaviour and not only a function of case identification. It has been found that women, ethnic majorities and middle-aged people are most likely to seek help (Livanou et al., 2002), whereas younger, as well as older people, ethnic minorities and uninsured have been found to be undertreated after a natural disaster (Wang et al., 2007). Reasons may be financial strain or structural loss of facilities after a disaster, but there are also attitudinal barriers like low perceived need for treatment, the fear of re-experiencing painful memories, negative attitudes towards mental health treatment due to prior treatment (Brown et al., 2010) or the perceived public stigma attached to utilizing mental health services that may hinder distressed people from seeking help (Schwarz & Kowalski, 1992; Wang et al., 2007).

Method

Study design

A longitudinal study design was used to compare the treatment status for mood and anxiety symptoms between different mobility groups from differently affected residential areas in Christchurch pre-disaster and post-disaster. The pre-disaster period ranged from July 1, 2009 to June 30, 2010, whereas the post-disaster periods ranged from April 1, 2011 to March 31, 2012 and April 1, 2012 to March 31, 2013.

Study sample

Our study sample was drawn from the Primary Health Organisations (PHO) register where over 90% of the New Zealand population is registered. It allowed us to track registered people quarterly at a meshblock level in a similar way as Exeter et al. (2015) did. We included residents of Christchurch, who were living in areas with different levels of affectedness from the 22nd February 2011 Christchurch earthquake based on Canterbury Earthquake Recovery Authority (CERA) land zones, but only considered those, whose meshblock of residence could be assigned to exactly one CERA land zone. Furthermore, patients with missing demographic information like gender, age or ethnicity were excluded. The sample could be tracked forward based on PHO visits and was further categorized into four different mobility groups 'stayers', 'within-city movers', 'out-of-city movers' and 'returners'. Due to out-migration the post-disaster follow-up sample sizes were smaller than the pre-disaster one.

Measures

The dependent variable was specified as a dichotomous treatment status (yes/no) for mood or anxiety symptoms within the 12 month time periods before and after the Christchurch earthquake. It allows identifying people, who received publically funded care or treatment for moderate or severe mood and anxiety symptoms. The dichotomous variable was retrieved from the New Zealand Ministry of Health, who build mood and anxiety indicators based on International Classification of Diseases (ICD) and chemical codes from different administrative databases, including publically funded secondary mental health (inpatient, outpatient or community), laboratory test information and subsidised pharmaceutical dispensing for mood or anxiety related symptoms (see Table A.1). These were linked by the Ministry of Health's New Zealand Health Tracker (NZHT) via the National Health Index (NHI) - a unique patient identifier. We then aggregated these mood and anxiety treatment indicators for each patient to annual indicators. Such an indicator is different from most research on changes in disaster impacts on mental health, which typically use screening tools to assess mental disorder prevalence. Measuring prevalence is not possible with the used treatment information, however all New Zealand permanent residents and most temporary visa holders are eligible for publically funded health services[10], so the treatment information represents a rich source for identifying those, who received mental health treatment before and after the earthquakes in New Zealand allowing us to apply a quasi-experimental study design and draw a large sample to measure area-wide health disparities. On the other hand, it has to be noted that only a small proportion of people who show adverse mental health sequelae receive treatment for their mental health symptoms often attributed to treatment seeking behaviour (De la Fuente & Vale, 1990). Gender, ethnic, as well as age-related disparities in seeking help have been identified after disasters with men (Livanou et al., 2002), ethnic minorities and elderly more likely to experience

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[10] Eligible for publically funded health services in New Zealand are New Zealand permanent residents, citizens, work visa holders for two or more years, interim visa holders, commonwealth scholarship or NZ aid programme students, foreign language teaching assistants, refugees and children under 18 with an eligible legal guardian like a parent.

under treatment (Boscarino, Adams, Stuber, & Galea, 2005; Wang et al., 2007). However, those with more severe symptoms tend to use more mental health services (Wang et al., 2007) and as the vast majority of New Zealand residents is eligible for these services there is a marginal bias of eligibility on treatment seeking.

Different earthquake hazard exposure groups based on the first CERA land assessments and technical categorizations in 2011 were used as proxies for different levels of affectedness and vulnerability from the Christchurch earthquake. The CERA land zones categorised residential properties based on earthquake damage from liquefaction and lateral spreading and expected damage in future earthquakes. Several studies have shown that such crude location based proxies can be good measures for level of exposure to disaster impacts and associated stress factors (Bulut, 2005; Dorahy et al., 2015; Dorahy & Kannis-Dymand, 2012; Goenjian et al., 1994a, 1994b; Goenjian et al., 2001), although it measures residential exposure not personal exposure. The 2011 Christchurch earthquake struck the city at midday, so it is assumed that many people were not at home at this time of the day. Their residential exposure may be secondary due to housing damage, disruption of services and routines or loss of loved ones, whereas those who were at home may have suffered primary traumas.

The land zones were spatially joined to 2006 Census meshblocks, to identify if mood and anxiety symptom treatments differed based on level of exposure to physical earthquake impacts at a neighbourhood level. To also account for area-wide economic inequality, an additional categorisation into the 'Canterbury Plains', a term characterizing the plain areas in the Canterbury region and used to describe the plain parts of the Christchurch urban area as they are a part of it, and the generally more affluent Port Hills areas was done.

This led to the following categories indicating the level of affectedness:

- No damage (TC1) (Canterbury Plains) (= reference in analysis)
- Minor damage (TC2) (Canterbury Plains)
- Moderate damage (TC3) (Canterbury Plains)
- Minor to moderate damage in affluent area (Green Zone) (Port Hills)
- Severe damage (Red Zone) (Canterbury Plains)
- Severe damage in affluent area (Red Zone) (Port Hills)

Furthermore, the sample was categorised into 'stayers', 'within-city movers', 'out-of-city movers' and 'returners' based on residential records from the PHO register. A person was considered a 'mover', if the meshblock of residence changed within a 12 month study period. Within-city movers and out-of-city movers were distinguished by testing if the meshblocks of residence in a 12 month period were part of the Christchurch urban area. If a subject's meshblock of residence was not part of the Christchurch urban area at the end of a 12 month period, he or she was considered an out-of-city mover. On the contrary, a returner was someone, who moved outside of the Christchurch urban area and returned within the 12 month period. The exact date of relocation was not known, but the subjects could be tracked based on a quarterly measure.

Further individual variables consisted of gender, age (0–14, 15–39, 40–64 and 65+), ethnicity (European, Maori, Pacific, Asian, Middle Eastern/Latin American/African (MELAA), other and residual categories), history of mood/anxiety symptom treatments (yes/no) and previous treatment for other mental health symptoms (yes/no). The 2006 New Zealand neighbourhood deprivation index at a meshblock level was used as a contextual variable to account for the socio-economic deprivation in the neighbourhood in the pre-disaster period, whereas the 2013 New Zealand neighbourhood deprivation index was used for the post-disaster period.

Data analysis

Multivariate mixed-effects analyses applying generalised linear models and assuming a binomial distribution were used to assess the relationships between the different mobility groups, as well as level of affectedness and mood/anxiety symptom treatments before and after the 2011 Christchurch earthquake. Models were compared using the Akaike Information Criterion (AIC) and those chosen with the lowest score. Our mixed-effects models included a subject-specific random effect to quantify both population-level and individual-level effects (Hogan, Roy, & Korkontzelou, 2004). Research suggests that such likelihood-based mixed-effects repeated measures analyses are the method of choice to account for dropouts in longitudinal studies (Mallinckrodt, Clark, & David, 2001). Tukey's Honest Significant Difference (HSD) test has been additionally used to reduce the likelihood of a type-I error arising from multiple pairwise comparisons.

The first model assessed the main effect of individual (gender, age, ethnicity, pre-existing mood, anxiety or other mental health treatment, mobility groups) and contextual variables (neighbourhood deprivation, level of affectedness) on receiving care or treatment for mood or anxiety symptoms. The next three models used interaction terms to get a detailed insight into the associations between different mobility groups, as well as levels of affectedness and treated mood and anxiety outcomes over time. They were adjusted for gender, age, ethnicity, history of mood/anxiety or other mental health symptom treatments and neighbourhood deprivation.

The first two models examined the interactions between level of affectedness and time, as well as mobility and time on treatment of mood or anxiety symptoms, whereas the last model assessed the effects of the three-way interaction between level of affectedness, mobility and time on receiving care or treatment for mood or anxiety symptoms excluding returners due to missing samples for specific subgroups.

Results

Sample characteristics

The study sample consisted of 138,592 pre-disaster, as well as 120,344 first year and 111,229 second year post-disaster subjects (~1/3 of the Christchurch population) out of 319,343 potential PHO registered participants. The most restricting criterion was that the meshblock of residence should not intersect with more than one CERA land zone to get the most accurate measure for level of affectedness followed by missing geographic locator or unspecific gender, date of birth or ethnicity (Figure 5.1).
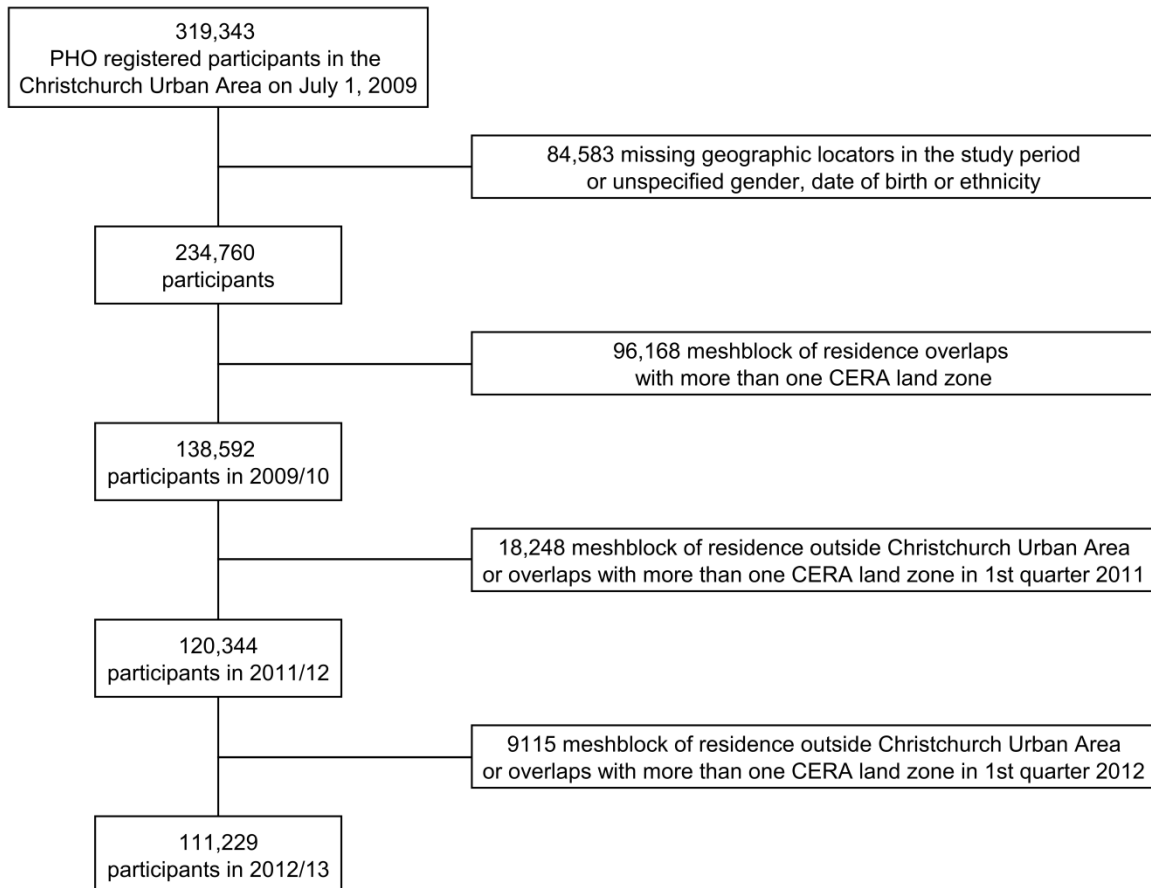
Figure 5.1: Participants eligibility flowchart with selection criteria for the study sample

Looking at the distribution of post-disaster movers based on their level of affectedness, a dose-response relationship could be seen as higher proportions of movers were identified among more severely affected groups after the disaster (Table 5.1).

Table 5.1: Proportion of movers (within-city, out-of-city or returners) among groups with different levels of affectedness

Level of affectedness	% Movers pre-disaster year (2009/10)	% Movers 1st post-disaster year (2011/12)	% Movers 2nd post-disaster year (2012/13)
No damage (Canterbury Plains)	13.3%	9.7%	8.9%
Minor damage (Canterbury Plains)	15.7%	12.8%	10.5%
Moderate damage (Canterbury Plains)	15.5%	15.2%	10.9%
Minor to moderate affluent (Port Hills) area	9.1%	13.5%	9.3%
Severe damage (Canterbury Plains)	11.8%	37.1%	62.4%
Severe damage affluent (Port Hills) area	10%	26.4%	15.9%

Comparing the socio-economic deprivation of differently affected areas based on the New Zealand Deprivation Index (NZDep) 2013 (least deprived decile=1, most deprived decile=10) a difference between the flat and Port Hills areas could be observed. The median deprivation deciles in flat areas varied between 4 (severe damage area) and 6 (minor or moderate), whereas the affluent Port Hills areas showed less deprivation with median deciles of 2 (severe damage) and 1 (minor to moderate).

The individual demographic characteristics of the sample significantly deviated from the 2013 Census for the selected areas with an overrepresentation of women (54.3% vs. 50.8%) (χ^2=666, p<.001), older adults ($\geq$ 40 years) (50.1% vs. 45.8%) (χ^2=920, p<.001) and Europeans (80.1% vs. 75.5%) (χ^2=1589, p<.001). Further sample characteristics can be seen in Table 5.2.

Treatment rates for mood and anxiety symptoms

Mood and anxiety treatment rates for the study sample showed an increase over time with 6.6% in 2009/10, 7.8% in 2011/12 and 8% in 2012/13, which can partly be attributed to an extension of the set of subsidised medications. Categorised into level of affectedness, it is seen that mood or anxiety symptom treatment rates increased for all land zones over time showing similar trajectories. An exception was the severely affected affluent area group, where the rates most steeply increased from 2009/10 to 2011/12 followed by a slight decrease. In general, the treatment rates were highest among residents originating from severely affected areas in 2011/12 (Figure 5.2).
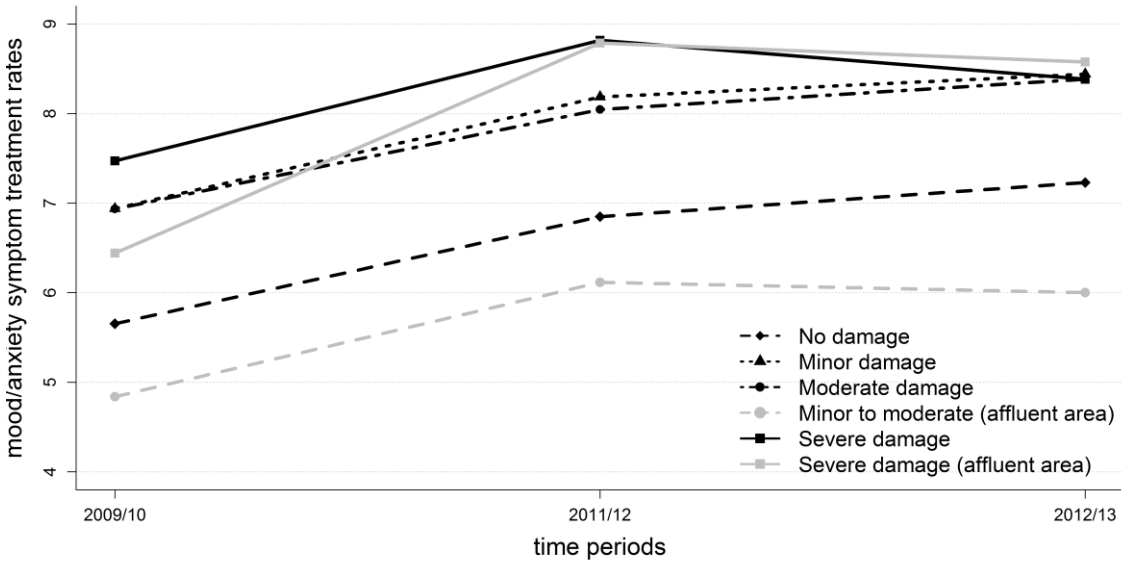
Figure 5.2: Mood or anxiety symptom treatment rates among Christchurch residents from differently affected areas in the pre-disaster year (2009/10) and the 1ˢᵗ (2011/12) and 2ⁿᵈ (2012/13) year post-disaster

A categorization into mobility groups revealed that stayers in particular showed lower treatment rates for mood and anxiety symptoms, but these increased continuously over time. Generally, similar treatment rate trajectories could be seen among movers with returners showing the steepest increase between 2009/10 and 2011/12 followed by a relatively strong decrease in 2012/13 (Figure 5.3).
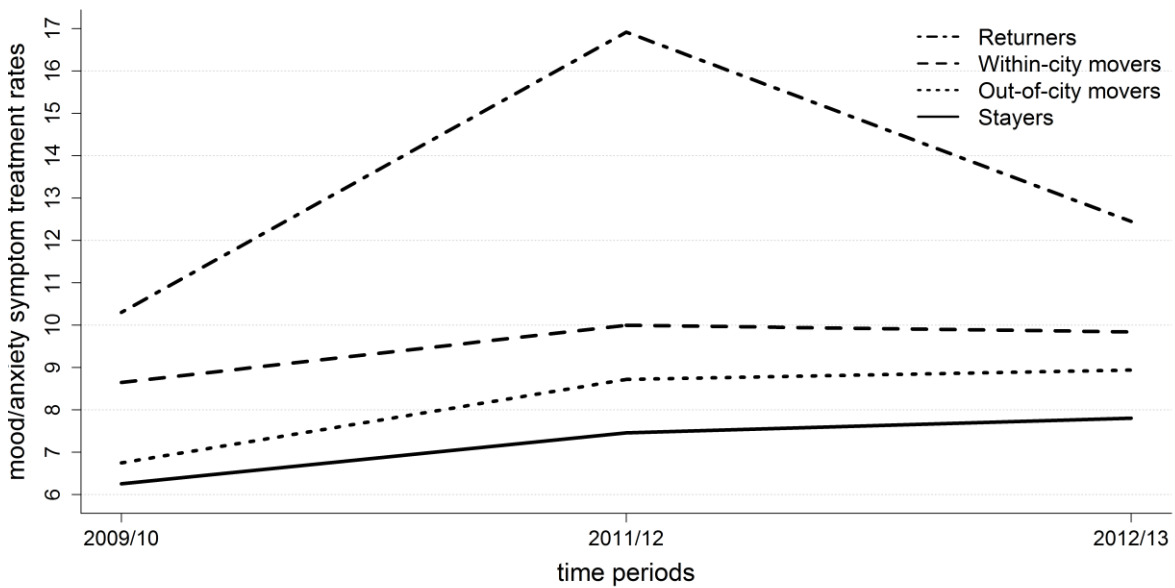
Figure 5.3: Mood or anxiety symptom treatment rates among Christchurch residents classified by mobility group in the pre-disaster year (2009/10) and the 1st (2011/12) and 2nd (2012/13) year post-disaster

Main effects

The first mixed effects model testing the main effects of explanatory variables on being treated for mood or anxiety symptoms showed that men compared to women and Maori, Pacific, Asian, as well as MELAA ethnicity compared to European were protective factors (Table 5.2). Identified risk factors included older age as children (0–14) were least likely to

be treated for mood or anxiety symptoms and previous treatment for mood/anxiety or other mental health symptoms. Neighbourhood deprivation did not show a statistically significant effect, but was used in further models to account for neighbourhood deprivation inequalities. Interestingly, within-city movers, as well as returners were more likely to be treated for mood or anxiety symptoms than stayers, whereas out-of-city movers did not show a statistically significant effect. Moreover, living in an affluent minor to moderate damage area on the Port Hills was identified as a protective factor for receiving care or treatment for mood or anxiety symptoms compared to living in a no damage area, however, the level of affectedness did not show a significant effect among the other groups. Finally, the likelihood of receiving care or treatment for mood or anxiety symptoms generally increased over time (Table 5.2).

Table 5.2: Sample characteristics based on the pre-disaster information and results of first mixed-effect regression model

Explanatory variable	N with/without treatment in 2010 or mean value with/without treatment	Mixed effects logistic regression analysis results for main effects OR (95% CI)
Gender		
Female	6095/69,113	1
Male	2995/60,389	0.76 (0.7-0.81); p<.001
Age group		
0-14	60/25,532	1
15-39	3241/40,269	2.45 (1.92-3.13); p<.001
40-64	4213/44,844	3.29 (2.58-4.21); p<.001
65+	1576/18,857	3.58 (2.78-4.6); p<.001
Ethnicity		
European	7882/103,137	1
Maori	441/7488	0.64 (0.55-0.74); p<.001

Explanatory variable	N with/without treatment in 2010 or mean value with/without treatment	Mixed effects logistic regression analysis results for main effects OR (95% CI)
Pacific	51/3422	0.37 (0.26-0.55); p<.001
Asian	177/7400	0.71 (0.56-0.88); p<.01
MELAA	59/1133	0.59 (0.41-0.87); p<.01
Other	27/652	0.7 (0.39-1.25); p=.23
Residual Categories	453/6270	0.92 (0.79-1.08); p=.31
History of mood/anxiety symptom treatments		
No	26/114,693	1
Yes	9064/14,809	1222.67 (1029.14-1452.58); p<.001
Previous other mental health treatments		
No	4804/111,101	1
Yes	4286/18,401	1.9 (1.78-2.03); p<.001
NZ Deprivation Index	5.19/5.58	0.99 (0.98-1); p=.08
Mobility group		
Stayers	7409/111,084	1
Within-city movers	1415/14,952	1.21 (1.13-1.3); p<.001
Out-of-city movers	225/3109	1.04 (0.92-1.18); p=.54
Returners	41/357	1.79 (1.32-2.43); p<.001
Level of affectedness		
No damage (Canterbury Plains)	1692/28,236	1
Minor damage (Canterbury Plains)	4930/66,125	0.99 (0.91-1.08); p=.80
Moderate damage (Canterbury Plains)	1496/20,074	0.96 (0.86-1.07); p=.44
Minor to moderate (affluent area)	383/7531	0.82 (0.69-0.97); p<.05
Severe damage (Canterbury Plains)	476/5895	1.05 (0.89-1.23); p=.56
Severe damage (affluent area)	113/1641	1.07 (0.8-1.43); p=.67

Explanatory variable	N with/without treatment in 2010 or mean value with/without treatment	Mixed effects logistic regression analysis results for main effects OR (95% CI)
Time		
Pre-disaster year	9090/129,502	1
1st post-disaster year	9370/110,974	1.73 (1.65-1.82); p<.001
2nd post-disaster year	8921/102,308	1.95 (1.85-2.05); p<.001

Interaction terms

The interaction between mobility and time showed interesting results. The likelihood of receiving care or treatment for mood or anxiety symptoms was significantly higher among within-city movers compared to stayers in the pre-disaster year (2009/10) (OR: 1.36; p<.001; CI: 1.23-1.52) and the first post-disaster year (2011/12) (OR: 1.18; p<.01; CI: 1.05-1.33), whereas no statistically significant difference was found in the second post-disaster year (2012/13) (OR: 1.06; p=.37; CI: 0.93-1.21). These results and the strength of the effect, which was strongest in 2009/10, already indicated a decrease in the likelihood of receiving care or treatment for mood or anxiety symptoms between the start (2009/10) and end of the study (2012/13) among within-city movers compared to stayers, which was confirmed on the multiplicative scale (Ratio of ORs: 0.78; p<.01; CI: 0.66-0.92). Additionally, the likelihood of receiving care or treatment for mood or anxiety symptoms was nearly three times higher among returners compared to stayers in 2011/12 (OR: 2.71; p<.001; CI: 1.71-4.31) (see also Table 5.3 in Supplementary material).

The interaction between level of affectedness and time revealed that the likelihood of receiving care or treatment for mood or anxiety symptoms was significantly lower among Christchurch residents from minor to moderately damaged affluent (Port Hills) areas compared to those from undamaged areas in the Canterbury Plains in 2009/10 (OR: 0.74; p<.01; CI: 0.59-0.92). Furthermore, Christchurch residents from minor damaged areas in

the Canterbury Plains showed a significant decrease in the likelihood of receiving care or treatment for mood or anxiety symptoms between 2009/10 and 2012/13 compared to those from undamaged areas (Ratio of ORs: 0.85; p<.05; CI: 0.75-0.97) (see also Table 5.4 in Supplementary material).

The three-way interaction between mobility, level of affectedness and time revealed that stayers from minor to moderately damaged affluent (Port Hills) areas were less likely to receive care or treatment for mood or anxiety symptoms than stayers from undamaged areas in 2009/10 (OR: 0.85; p<.05; CI: 0.73-0.99). Furthermore, stayers from minor damaged areas in the Canterbury Plains showed a significant decrease in the likelihood of receiving care or treatment for mood or anxiety symptoms between 2009/10 and 2012/13 compared to those from undamaged areas (Ratio of ORs: 0.88; p<.05; CI: 0.79-0.99). A contrary effect was found among out-of-city movers from those areas in the same time period (Ratio of ORs: 2.14; p<.05; CI: 1.16-3.96). Similarly, out-of-city movers from moderately damaged areas showed a significant increase in the odds of being treated for mood or anxiety symptoms between 2009/10 and 2012/13 (Ratio of ORs: 4.04; p<.001; CI: 1.82-8.93). Consequently, out-of-city movers from minor (OR: 1.67; p<.05; CI: 1.05-2.66) and moderately (OR: 2.69; p<.01; CI: 1.49-4.87), but also severely damaged areas (OR: 1.95; p<.05; CI: 1.09-3.48) in the Canterbury Plains showed significantly increased likelihoods of being treated for mood or anxiety symptoms than out-of-city movers from undamaged areas in 2012/13. Within-city movers from severely damaged areas in the Canterbury Plains were also more likely to be treated for mood or anxiety symptoms than within-city movers from undamaged areas in 2009/10 (OR: 1.49; p<.05; CI: 1.04-2.12), whereas no statistically significant difference could be identified in 2011/12 (OR: 1.05; p=.77; CI: 0.77-1.42) or 2012/13 (OR: 1.21; p=.25; CI: 0.87-1.67). Interestingly, no statistically significant effect was found among differently affected returners over time, which may be due to low subgroup sizes reducing the statistical power.

Discussion

Our longitudinal study provides a unique insight into the effects of relocation on receiving care or treatment for mood or anxiety symptoms after the 2011 Christchurch earthquake. Moving within the city or temporary relocation classified as returning were in general risk factors for receiving mood and anxiety symptom treatments compared to staying in Christchurch, but showed different effects in the context of the 2011 Christchurch earthquake.

In detail, relocating within the city was only identified as a risk factor in the pre-disaster (2009/10) and first post-disaster year (2011/12) with a larger pre-disaster effect size and a significant decrease in likelihood of being treated for mood or anxiety symptoms between 2009/10 and 2012/13 revealing a long-term mitigating effect of moving within the city in the context of the disaster. This interesting finding follows the conceptual framework of Uscher-Pines (2009), who associated less psychopathology with changes in social networks and living condition. It also largely confirms our hypothesis that moving to less or unaffected areas had a protective post-disaster effect since the population mainly shifted from severely to less affected areas (Howden-Chapman et al., 2014) where better living conditions and less exposure to stressful potential traumatic reminders of the earthquakes may have had a mitigating mental health effect (Ying et al., 2013).

On the other hand, temporary relocation out of the damaged plain areas in the city showed an adverse effect on being treated for mood or anxiety symptoms in 2011/12 confirming previous research findings (Fussell & Lowe, 2014; Watanabe et al., 2004). Generally, research suggests that relocation after a disaster is associated with exacerbated ecological and social stress (Riad & Norris, 1996) as relocatees out of a disaster area may face higher levels of social network disruption and loss of cultural identity compared to non-relocatees (Bland et al., 1997; Kılıç et al., 2006). Movers escape the traumatic reminders of the event, but leave their social networks, social support and friends behind, which can result in additional psychological stress and outweigh the effect of living in a less damaged

environment (Bland et al., 1997; Kılıç et al., 2006; Najarian et al., 2001). A loss of social networks and friends can lead to isolation, as well as loss of control and result in feelings of fear and depression (Bulut et al., 2005; Mileti & Passerini, 1996). It has been shown that high social capital in a community can help to conserve individual psychosocial resources and reduce posttraumatic stress after a natural disaster (Wind & Komproe, 2012), so losing social support and also social participation, which are key elements of disaster recovery and also factors contributing to displacement (Gray et al., 2009), may lead to a depletion of individual psychosocial resources and challenge the recovery from distress (Watanabe et al., 2004). Consequently, relocation and displacement (Fussell & Lowe, 2014; Kılıç et al., 2006; Lonigan et al., 1994; Najarian et al., 2001) are often reported as risk factors for depression after disasters in the literature. Another explanation for our finding may be that subjects, particularly those who have been severely affected emotionally by the impacts of the earthquakes and therefore seeking treatment for mood or anxiety symptoms, used temporary relocation as a coping strategy to get away from the stressors associated with living in a severely disrupted environment. However, our study cannot test this hypothesis as individual reasons for relocation were not known.

In general, permanent relocation classified as out-of-city moving did not show a significant effect over time, which is not surprising as there are also studies, which could not confirm an adverse effect of relocation on mental health after natural disasters (Goenjian et al., 2001; Najarian et al., 1996). In the context of the disaster, moving out of the affected city may improve the living condition and help avoid direct trauma exposure, but the loss of social networks and vicarious traumatisation due to the long-lasting media coverage of the event and its impacts (Lau et al., 2010) may not mitigate the mental health impacts. As different findings for temporary or permanent relocation have been found, it needs to be further investigated under which circumstances temporary or permanent relocation may have an effect on mental health after natural disasters.

Our main effect model revealed that children were generally less likely to receive care or treatment for mood or anxiety symptoms than adults. This seems to be partly contrary to

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other studies, which report the highest risk for psychopathology among younger, but also middle aged adults after natural disasters (Acierno, Ruggiero, Kilpatrick, Resnick, & Galea, 2006; Norris et al., 2002a). Our finding may be due to the fact that children are generally less likely to be diagnosed with a mental disorder and therefore treated for it than adults in New Zealand (Ministry of Health, 2012a, 2012b). The finding that Maori, as well as Pacific and Asian people, were also less likely to receive care or treatment for mood or anxiety symptoms may have a similar explanation, since prior research has shown that Maori are less likely to be clients of mental health services than non-Maori (Baxter, 2008).

Identified socio-demographic and medical risk factors included female gender and prior mood/anxiety or other mental health symptom treatments, which are commonly reported as risk factors (Galea et al., 2005). Neighbourhood deprivation did not show an effect, but those with fewer resources normally tend to avoid seeking treatment due to structural and financial barriers after disasters (Wang et al., 2007). Our finding that residents from affluent minor to moderately damaged Port Hills areas, which had the lowest median deprivation scores, were generally less likely to receive care or treatment for mood or anxiety symptoms than residents from undamaged areas in the Canterbury Plains, which exhibit higher neighbourhood deprivation scores, seems to contradict this assumption.

The interaction between level of affectedness and time gave a more detailed insight and revealed that residents from affluent minor to moderately damaged Port Hills areas were less likely to receive care or treatment for mood or anxiety symptoms than those from undamaged areas in 2009/10, but not post-disaster, whereas subjects from the minor damage group showed a decrease in the likelihood of being treated for mood or anxiety symptoms compared to those from the no damage group between 2009/10 and 2012/13. This indicates a bias of socio-economic status when assessing the relationship between disaster exposure and adverse mental health outcomes. Furthermore, subjects from severely damaged areas showed the highest mood and anxiety symptom treatment rates shortly after the disaster in 2011/12, which seemed to confirm previous research reporting that residents from more affected suburbs have been more likely to have accessed mental health and

social services after the 2011 Christchurch earthquake (Dorahy et al., 2015), but no statistically significant difference to residents from undamaged areas was found in our study. Consequently, the hypothesised dose-response relationship, where the trauma severity is related to the degree of earthquake exposure (Bulut, 2005; Goenjian et al., 2001; Norris et al., 2002a; Ying et al., 2013), could not be confirmed. More complex exposure trajectories may have been present and have been investigated by the interaction between mobility, level of affectedness and time.

This three-way interaction showed that within-city movers from severely affected areas in the Canterbury Plains were more likely to being treated for mood or anxiety symptoms in 2009/10, but not in the post-disaster years, which partly confirms our hypothesis that relocation from severely earthquake-affected neighbourhoods to less or unaffected ones has a protective effect. It may be explained by a reduction of stress due to the relatively fast insurance settlement and possibility to move to less affected areas in the city in the first year after the 2011 Christchurch earthquake since the government decided to clear severely damaged areas classified as the 'Red Zone' urging its residents to accept a government offer for their property and relocate. However, severely affected within-city movers from the affluent Port Hills areas did not show this effect, possibly due to the fact that forced relocation is one of the most disruptive and stressful adversities experienced by disaster victims (McKenzie-McLean & Levy, 2011; Norris & Wind, 2009; Oliver-Smith, 1991; Riad & Norris, 1996). Additionally, the disaster and its adversities may have had a greater psychological impact on residents from less deprived affluent neighbourhoods compared to residents, who already lived in vulnerable and deprived neighbourhoods before the disaster. The findings that minor to moderately affected stayers from the affluent Port Hills were less likely to be treated for mood or anxiety symptoms in 2009/10, but not in the post-disaster years, whereas stayers from the minor damaged areas in the Canterbury Plains showed a significant decrease in the likelihood between 2009/10 and 2012/13 supports this hypothesis, but needs further investigation. Another explanation may be a different access to health services as a consequence of relocation.

Finally, out-of-city movers from minor, moderately and severely damaged areas in the Canterbury Plains showed a strong positive association with mood or anxiety symptom treatments in 2012/13 compared to out-of-city movers from undamaged areas indicating a time lag and long-term adverse mental health effect on earthquake survivors from damaged areas, who relocate to other places and seek help two years after disaster exposure. We can only suspect that many of these subjects may have relocated to seek psychological recovery from the disaster, but it needs to be kept in mind that psychological recovery is closely tied to economic recovery after relocation as the latter is used as a measure of recovery success (Mileti & Passerini, 1996). Factors that stop people from relocating after a disaster are material concerns and psychological, as well as cultural conservatism (Oliver-Smith, 1991). As a result, relocation is normally done by people who have the necessary resources (Oliver-Smith, 1991). So, we suspect that these movers may mostly have had the human, social and financial resources to achieve a good recovery success, but also faced high levels of distress as a result of cumulative stress exposure that needed psychological treatment. This hypothesis merits further research as well.

In conclusion, our results suggest that mental health treatment programs and early intervention should focus on more vulnerable groups including females, older people and those with pre-existing mental illnesses and consider support programs, specifically in the short term after a natural disaster, for temporary relocatees, and in the longer term, for permanent relocatees from damaged areas. Another important finding is that the level of affectedness may have different effects on adverse mental health outcomes depending on the socio-economic status of earthquake survivors. To our knowledge, this has been the first study to assess the relationship between level of affectedness, different mobility groups including stayers, localised within-city relocatees, out-of-city relocatees and returners, and mood/anxiety symptom treatments after a natural disaster, so more research has to be done in this field.

Limitations

Our study has some limitations that should be taken into account when interpreting the results. Causal relationships between relocation or level of affectedness and mood and anxiety symptoms should be interpreted with some caution. As a consequence of data aggregation, it wasn't exactly known in every case, if a treatment happened before or after relocation. Residential location geocoded at a meshblock level is based on a person's visits to Primary Health Organisations (PHO) and summarised to a quarterly measure leading to uncertainty about the exact time of relocation. This in turn contributed to uncertainty in determining, where a person lived when a treatment has actually happened.

Administrative data about mood and anxiety disorders from the New Zealand Ministry of Health were used, but only a very small proportion of these disorders can be identified through these as not everybody, who shows adverse mental health symptoms receives treatment. Therefore, the available data is particularly weak in identifying people with less severe mental health symptoms mainly due to treatment seeking (De la Fuente & Vale, 1990), which is more prevalent in women (Livanou et al., 2002), ethnic majorities and middle-aged people (40 up to 65 years of age) (Boscarino et al., 2005; Wang et al., 2007). Furthermore, the Pharmaceutical Claims Data Mart (PHARMS) administrative data was a core source for identifying mood disorders, but only records publically funded drugs. The set was extended in December 2010 leading to a data driven increase of mood and anxiety symptom treatments between the two study phases. Consequently, we overcame this weakness by focussing on differences between pre- and post-disaster mood and anxiety trajectories and relative changes instead of directly comparing pre- and post-disaster mood and anxiety treatment rates.

Another limitation concerning the treatments was that they have been aggregated to an indicator, which didn't allow making inferences to individual disorders like PTSD, depression or anxiety. It has also to be noted that the level of affectedness based on CERA land zones is a contextual variable related to structural damage to the property and home

and doesn't represent the individuals' perceived level of affectedness. Moreover, it should be considered that the sample consisted of registered PHO help seekers, so the treatment rates may be confounded by the availability of health care resources, as well as help-seeking behaviour. The demographic characteristics of the samples were also significantly different from the 2013 Census for the selected areas underestimating specific demographic groups like ethnic minorities, men and younger people as they are less likely to seek help or treatment for mental health issues. Finally, the Christchurch earthquake was a long-duration disaster with ongoing aftershocks maintaining high levels of stress, so the results may be different and less applicable to short duration disasters.

Conclusion

This longitudinal study found general adverse effects of moving within the city and temporary relocation on mood and anxiety symptom treatments, but the temporal trend showed that moving within the city had a mitigating effect up to two years after the 2011 Christchurch earthquake, whereas temporary relocation was a risk factor in 2011/12. Moreover, no clear post-disaster dose-response relationship on mood and anxiety symptom treatments could be identified, but residents from minor damaged areas in Christchurch's plain areas (Canterbury Plains) showed a decrease in likelihood of receiving mood or anxiety symptom treatments up to two years after the disaster. Out-of-city movers from minor to severely damaged areas in the Canterbury Plains were especially at risk in 2012/13. Further identified high-risk groups included females, older people and those with a pre-existing mental illness.

In conclusion, intervention programs should target these highly vulnerable groups, as well as permanent relocatees from affected areas in the long term and temporary relocatees in the short-term aftermath of a natural disaster. As this study is the first of its kind, further research needs to be done.

Table 5.3: Mixed effects model result of mobility x time interaction

	Time periods						ORs (95%CI) for 1st post-disaster year within strata of mobility	ORs (95%CI) for 2nd post-disaster year within strata of mobility
	Pre-disaster year (2009/10)		1st post-disaster year (2011/12)		2nd post-disaster year (2012/13)			
	N with/without treatment	OR (95%CI)	N with/without treatment	OR (95%CI)	N with/without treatment	OR (95%CI)		
Stayers	7409/111,084	1.0	7742/96,060	**1.75 (1.66-1.85);p<.001**	7661/90,515	**2 (1.89-2.11);p<.001**	**1.75 (1.66-1.85); p<.001**	2 (1.89-2.11); p<.001
Within-city movers	1415/14,952	**1.36 (1.23-1.52);p<.001**	1154/10,390	**2.07 (1.84-2.32);p<.001**	928/8502	**2.12 (1.87-2.4);p<.001**	**1.51 (1.31-1.75); p<.001**	**1.55 (1.33-1.81); p<.001**
Out-of-city movers	225/3109	0.92 (0.71-1.19);p=.53	395/4136	**1.84 (1.52-2.22);p<.001**	303/3087	**2.25 (1.81-2.8);p<.001**	**1.99 (1.45-2.73); p<.001**	**2.44 (1.75-3.41); p<.001**
Returners	41/357	1.36 (0.81-2.31);p=.25	79/388	**4.75 (2.99-7.54);p<.001**	29/204	**2.4 (1.25-4.61);p<.001**	**3.48 (1.73-6.99); p<.001**	1.76 (0.76-4.06); p=.19
ORs (95%CI) for within-city movers within strata of time	**1.36 (1.23-1.52);p<.001**		**1.18 (1.05-1.33);p<.01**		1.06 (0.93-1.21);p=.37			
ORs (95%CI) for out-of-city movers within strata of time	0.92 (0.71-1.19);p=.53		1.05 (0.86-1.27);p=.64		1.13 (0.91-1.4);p=.28			
ORs (95%CI) for returners within strata of time	1.36 (0.81-2.31);p=.25		**2.71 (1.71-4.31);p<.001**		1.2 (0.62-2.31);p=.59			
Measure of interaction on multiplicative scale for within-city movers: Ratio of ORs (95%CI)			0.86 (0.74-1);p=.07		**0.78 (0.66-0.92);p<.01**			
Measure of interaction on multiplicative scale for out-of-city movers: Ratio of ORs (95%CI)			1.14 (0.82-1.57);p=.43		1.22 (0.87-1.71);p=.24			
Measure of interaction on multiplicative scale for returners: Ratio of ORs (95%CI)			1.99 (0.99-4);p=.05		0.88 (0.38-2.04);p=.76			

ORs are adjusted for gender, age, ethnicity, previous mood/anxiety or other mental health symptom treatments, neighbourhood deprivation and level of affectedness

Table 5.4: Mixed effects model result of level of affectedness x time interaction

	Pre-disaster year (2009/10)		1st post-disaster year (2011/12)		2nd post-disaster year (2012/13)		ORs (95%CI) for 1st post-disaster year within strata of level of damage	ORs (95%CI) for 2nd post-disaster year within strata of level of damage
	N with/without treatment	OR (95%CI)	N with/without treatment	OR (95%CI)	N with/without treatment	OR (95%CI)		
No damage	1692/28,236	1.0	1765/24,004	**1.8 (1.61-2); p<.001**	1763/22,624	**2.13 (1.9-2.38);p<.001**	**1.8 (1.61-2); p<.001**	**2.13 (1.9-2.38);p<.001**
Minor damage	4930/66,125	1.06 (0.95-1.18);p=.30	5045/56,586	**1.78 (1.59-1.98);p<.001**	4922/53,391	**1.93 (1.73-2.15);p<.001**	**1.68 (1.57-1.79); p<.001**	**1.82 (1.7-1.94); p<.001**
Moderate damage	1496/20,074	1.02 (0.89-1.17);p=.82	1525/17,431	**1.65 (1.44-1.91);p<.001**	1458/15,929	**1.99 (1.72-2.29);p<.001**	**1.62 (1.45-1.83); p<.001**	**1.95 (1.73-2.21); p<.001**
Minor to moderate damage in affluent areas	383/7531	**0.74 (0.59-0.92);p<.01**	448/6878	**1.67 (1.33-2.08);p<.001**	399/6250	**1.7 (1.35-2.14);p<.001**	**2.25 (1.8-2.82); p<.001**	**2.29 (1.81-2.9); p<.001**
Severe damage	476/5895	1 (0.82-1.23);p=.96	450/4653	**1.88 (1.51-2.33);p<.001**	276/3016	**2.55 (1.95-3.34);p<.001**	**1.87 (1.51-2.32); p<.001**	**2.54 (1.94-3.33); p<.001**
Severe damage in affluent areas	113/1641	0.92 (0.63-1.33);p=.65	137/1422	**2.2 (1.51-3.21);p<.001**	103/1098	**2.39 (1.56-3.66);p<.001**	**2.4 (1.59-3.62); p<.001**	**2.61 (1.64-4.13); p<.001**
ORs (95%CI) for minor damage group within strata of time	1.06 (0.95-1.18);p=.30		0.99 (0.88-1.11);p=.85		0.91 (0.8-1.02);p=.10			
ORs (95%CI) for moderate damage group within strata of time	1.02 (0.89-1.17);p=.82		0.92 (0.8-1.06);p=.27		0.93 (0.8-1.08);p=.36			
ORs (95%CI) for minor to moderate damage in affluent areas group within strata of time	**0.74 (0.59-0.92);p<.01**		0.93 (0.74-1.16);p=.50		0.8 (0.63-1);p=.06			

ORs (95%CI) for severe damage group within strata of time	1 (0.82-1.23);p=.96	1.05 (0.84-1.3);p=.69	1.2 (0.91-1.57);p=.19
ORs (95%CI) for severe damage in affluent areas group within strata of time	0.92 (0.63-1.33);p=.65	1.22 (0.84-1.79);p=.30	1.12 (0.73-1.72);p=.60
Measure of interaction on multiplicative scale for minor damage group: Ratio of ORs (95%CI)	0.93 (0.82-1.06);p=.29	**0.85 (0.75-0.97);p<.05**	
Measure of interaction on multiplicative scale for moderate damage group: Ratio of ORs (95%CI)	0.91 (0.77-1.06);p=.23	0.92 (0.78-1.08);p=.31	
Measure of interaction on multiplicative scale for minor to moderate damage in affluent areas group: Ratio of ORs (95%CI)	1.25 (0.97-1.61);p=.08	1.08 (0.83-1.4);p=.58	
Measure of interaction on multiplicative scale for severe damage group: Ratio of ORs (95%CI)	1.04 (0.82-1.33); p=.75	1.19 (0.89-1.6); p=.23	
Measure of interaction on multiplicative scale for severe damage in affluent areas group: Ratio of ORs (95%CI)	1.33 (0.87-2.04); p=.18	1.22 (0.76-1.96); p=.40	

ORs are adjusted for gender, age, ethnicity, previous mood/anxiety or other mental health symptom treatments, neighbourhood deprivation and mobility

Chapter Six: The effects of spatially varying earthquake impacts on mood and anxiety symptom treatments among long-term Christchurch residents following the 2010/11 Canterbury earthquakes, New Zealand

Preface

In this final analytical chapter the associations between the performance of, and disruptions to, different community environments, as well as community resilience and mood and anxiety symptom treatments among long-term Christchurch residents are examined. Additionally, a cumulative earthquake intensity measure based on felt reports is created to test the effect of felt earthquake intensities on adverse mental health outcomes. To exclude any mobility bias identified in the previous chapter (Chapter 5) only 'stayers' are included in the study. This gives a unique insight into the impacts of living in communities with differently disrupted environments, as well as different levels of resilience and felt earthquake intensities on mood and anxiety symptom treatments. This has rarely been done as measures of community disruption, resilience and felt earthquake intensities are often unavailable after disaster events. Consequently, this study provides a basis for further research on the investigated relationships as these are complex and still not fully understood.

Abstract

Earthquake events and their physical impacts can cause severe disruptions to different community environments and challenge the adaptive capability of communities. Nevertheless, the nature of the relationship between exposure to such disruptive events and the emotional functioning of affected populations is still open to debate. In this paper, we explore the associations between different impacts to community environments, community resilience and 'felt' earthquake intensities on the incidence or relapse of mood and anxiety symptom treatments among long-term Christchurch residents in the context of the devastating Canterbury earthquake sequence.

Spatio-temporal cluster analysis was used to explore annual changes in mood and anxiety symptom treatments among stayers in different Christchurch communities between September 2009 and August 2012. Bayesian modelling was applied to examine the effects of exposure to different community environment disruptions, community resilience, as well as cumulative earthquake intensities on mood and anxiety symptom treatments. For this purpose, a cumulative earthquake intensity measure (CEI) based on felt reports was developed.

A weak protective effect of living in a better physical environment and a weak negative effect of living in a better social community environment on care-seeking for moderate or severe mood or anxiety symptoms was found after the beginning of the earthquake sequence. Living in a community exhibiting strong community resilience was identified as a risk factor in the first year of the earthquake sequence, whereas improvement of the physical community environment and disruption to the social community environment were identified as risk factors for receiving care or treatment in the following year. Exposure to different levels of earthquake intensity wasn't associated with treatments for adverse mental health outcomes. These results may be biased by treatment-seeking behaviour and pre-existing mood and anxiety symptom treatment patterns that have partly been intensified as a result of the earthquakes.

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The findings of this study indicate that the incidence and relapse of treatments for moderate to severe mood or anxiety symptoms can be found in communities with worse physical or stronger social environment or community resilience post-disaster and do not necessarily follow felt intensities. Post-disaster recovery efforts like improvement of the physical environment or strengthening the social environment and community resilience may not mitigate these effects, but unfold psychopathology in targeted communities up to 2 years after the initial event. So identifying hazard-prone communities and building adaptive capability need to be integral parts of disaster recovery plans.

Introduction

Exposure to severe earthquakes and their impacts have often been associated with depression and anxiety reactions (Bonanno et al., 2010). A dose-response relationship is commonly observed, where the degree of exposure determines the symptom severity (Bulut et al., 2005). Examples include the 1988 Armenian earthquake (Armenian et al., 2000, 2002; Goenjian et al., 1994a, 1994b), the 1999 Marmara Earthquake in Turkey (Bal, 2008; Bulut et al., 2005) or the 2008 Wenchuan earthquake in China (Jin et al., 2014; Liu et al., 2010). During the devastating Canterbury earthquake sequence in New Zealand this effect seemed to be prevalent as well, but a closer look reveals the complex nature of the phenomenon. In the initial months after the September 4, 2010 Darfield earthquake and following the February 22, 2011 Christchurch event, which caused the most severe disruptions in this long lasting series of thousands of aftershocks, residents from more affected communities in the severely affected city of Christchurch have been found to show more severe acute stress, depression and anxiety symptoms than those from less affected communities (Dorahy & Kannis-Dymand, 2012; Dorahy et al., 2015). Nearly two years after the start of the earthquake series, a dose-response relationship between individual earthquake exposure measured by the felt intensity of the earthquakes and social readjustment and major depression, PTSD, anxiety, as well as levels of distress could still be observed among 35-year old adults (Fergusson et al., 2014, 2015). At the same time a sample of 50 year old Canterbury residents showed worse post-disaster mental health status compared to pre-earthquake population norms and prevalence rates of mood disorders in historical and national surveys, although the effects were not statistically significant (Spittlehouse et al., 2014). Also, a short-term increase of anxiolytics and sedatives/hypnotics dispensing was observed after the catastrophic Christchurch earthquake, whereas no increase in antidepressant or antipsychotic dispensing could be found and reduced acute psychiatric admissions indicated decreasing demand for acute inpatient psychiatric services after this event (Beaglehole et al., 2015a; Beaglehole, Bell,

Frampton, Hamilton, & McKean, 2015b). Moreover, Greaves et al. (2015) didn't find a dose-response pattern between psychological distress and overall damage in the community among the 267 Christchurch participants from the New Zealand Attitudes and Values Study (NZAVS) in the year of the Christchurch earthquake. On the other hand, levels of psychological distress showed a greater drop in the least damaged region compared to the moderately damaged one by late 2012, whereas this wasn't the case when compared to the most damaged region (Greaves et al., 2015). These ambiguous results highlight the complexity of the relationship between earthquake exposure and mental health as there are various risk and protective factors that come into play. Different types of impacts may have different effects on mental health. For example, the traumatic experience of the Christchurch earthquake and its physical impacts resulted in secondary stressors like living in a damaged environment, economic strain and social disruption, and the uncertainty and vicarious traumatisation associated with the on-going aftershocks have repeatedly been reported to cause a lot of stress threatening the recovery (Gawith, 2013; Rowney et al., 2014; Wilson, 2013). On the other hand, research has shown that factors like sense of community (Huang & Wong, 2014; Li et al., 2011), social support and participation (Oyama et al., 2012; Paxson, Fussell, Rhodes, & Waters, 2012; Watanabe et al., 2004; Zahran et al., 2011; Zhang et al., 2012), individual (Ali et al., 2012), as well as community social capital (Wind & Komproe, 2012) and economic capability (Xu & He, 2012) play an important role in mitigating adverse mental health effects after natural disasters. For example, elderly survivors of the 2008 Wenchuan earthquake showed reduced levels of distress and better recovery with higher sense of community 3 months following the event (Li, Sun, He, & Chan, 2011) and even after 4 years a positive association between sense of community and psychological status has been found among survivors as participation and interaction can foster psychosocial wellbeing by producing a sense of identity, safety and shared values in the community (Huang & Wong, 2014). Generally, social capital is a complex construct that can be divided into structural social capital characterised by the actions to build and maintain social relations in a community, and cognitive capital

quantifying the perception of social support, reciprocity, sharing and trust (Harpham, Grant, & Thomas, 2002). Components of structural social capital like connectedness and participation are often part of disaster recovery plans like the Integrated Recovery Planning Guide concerning the Canterbury earthquakes (The Canterbury District Health Board, 2011). Implementing those concepts should help build cognitive social capital as this has been shown to lead to trust in the community, the employment of less individual psychosocial resources and better psychological wellbeing (Huang & Wong, 2014; Wind, Fordham, & Komproe, 2011; Wind & Komproe, 2012). Feelings of connectedness and unity are also part of social cohesion, which has been positively linked to community resilience (Townshend, Awosoga, Kulig, & Fan, 2015), which is "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaption after a disturbance" (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008, p. 131). Additionally to the findings that individuals from communities with high social capital (cognitive and structural) have been found to suffer less from PTSD (Wind & Komproe, 2012), as well as experience lower perceived community problems (Wickes, Zahnow, Taylor, & Piquero, 2015), Wickes et al. (2015) reported that economic capability enabling communities to access government support seemed to be important for community resilience in the post-disaster context.

In the context of the Canterbury earthquake sequence strong individual resilience was found among highly exposed middle-aged Christchurch residents, who often reported positive emotional strength and social bonding as a consequence of the earthquakes (Fergusson et al., 2015). Emotionally stable residents coped well (Osborne & Sibley, 2013) and community bonding and resilience have been repeatedly reported in the first year after the Christchurch earthquake (Gawith, 2013). On the other hand, it seems that collective resilience has been lost to some extent due to the lack of earthquake-related resilience before the events, secondary stressors from the catastrophic February 22, 2011 earthquake, uncertainty from on-going aftershocks and lack of community involvement in the recovery

process and decision-making (Cooper-Cabell, 2013; Gawith, 2013; Thornley, Ball, Signal, Lawson-Te Aho, & Rawson, 2015; Wilson, 2013).

Disruptions to the social, built, economic and natural environment, as well as the uncertainty due to thousands of aftershocks, may have a negative effect on stress-related mental health outcomes of earthquake-affected populations, but it remains unclear which influence each of these variables has and if post-disaster community support and resilience were able to mitigate adverse mental health effects. Therefore, we investigated the effects of varying disruptions to community environments, felt intensities of major earthquakes and their aftershocks, and community resilience, on mood and anxiety symptom treatments among affected long-term Christchurch residents. This should help identify what role different community environments, felt earthquake intensities and community resilience play in the incidence and relapse of post-disaster stress-related mental health disorders up to 2 years after the initial event, and so inform governmental authorities how to better address adverse mental health effects as part of the recovery process.

Methods

Study area

The Christchurch City Council divided the greater city's seven administrative wards into 49 different community profile areas and measured earthquake impacts and resilience at a community level. In our study, we included 45 of these 49 communities, as the 'Akaroa', 'Akaroa Harbour', 'Birdlings Flat' and 'Little River' communities are not part of the greater Christchurch urban area and didn't allow us to draw large samples.

Study sample

The study sample was drawn from the Primary Health Organisations (PHO) register, which includes health care providers supporting the provision of primary health care services

through general practices. Over 90% of New Zealanders are enrolled as they gain benefits like cheaper doctors' visits and prescription medicines. Every patient has a unique identifier, the National Health Index (NHI), allowing the linkage to mental health information. A quarterly measure for the residential location enabled us to locate and track patients at a meshblock level, which is the smallest geographic unit defined by Statistics New Zealand. To capture long-term residents bonded to their communities, we only considered those who stayed within the boundary of their community throughout the study period, which ranged from September 2009 till the end of August 2012. This also excluded any mobility bias.

Mood and anxiety information

Measures of mood and anxiety consisted of treatment information especially able to identify moderate to severe mood or anxiety symptoms among care seekers enrolled in a PHO. It needs to be kept in mind that this measure includes treatments for diagnosed mood and anxiety disorders, but also treatments of mood and anxiety symptomatology. For simplicity, we just refer to "mood and anxiety symptom treatment". The data was obtained from the Ministry of Health's New Zealand Health Tracker (NZHT), which links different administrative databases including publically funded secondary mental health (inpatient, outpatient or community), publically funded hospital inpatient care, laboratory test information and subsidised pharmaceutical dispensing, via the National Health Index (NHI), which has been anonymised for reasons of confidentiality. For each patient yearly indicators for receiving care or treatment for mood or anxiety symptoms were created for the pre-disaster year (Sep 09 to Aug 10), as well as the first (Sep 10 to Aug 11) and second (Sep 11 to Aug 12) years of the Canterbury earthquake sequence. Multiple treatments of a patient were counted once in each phase. These individual level indicators were then further aggregated to the community level to get yearly counts of mood and anxiety symptom treatments per community.

Explanatory variables

Community resilience and environments

One community resilience, as well as two community environment performance and disruption measures, were built from the community resilience mapping and earthquake impact analysis sections of the 2011 and 2012 community profiles published by the Christchurch City Council (CCC). In these profiles, community resilience was assessed in 2011 and 2012 and consisted of 15 measures rated on a 5-point performance scale from 1 (low) to 5 (high) (3="normal/average") and categorised into 5 components, whereas community environment performance consisted of 12 measures of community disruption for 4 different environments rated in the same way and assessed in 2010, 2011 and 2012 (see Figure 6.1 and Supplementary material for further details).
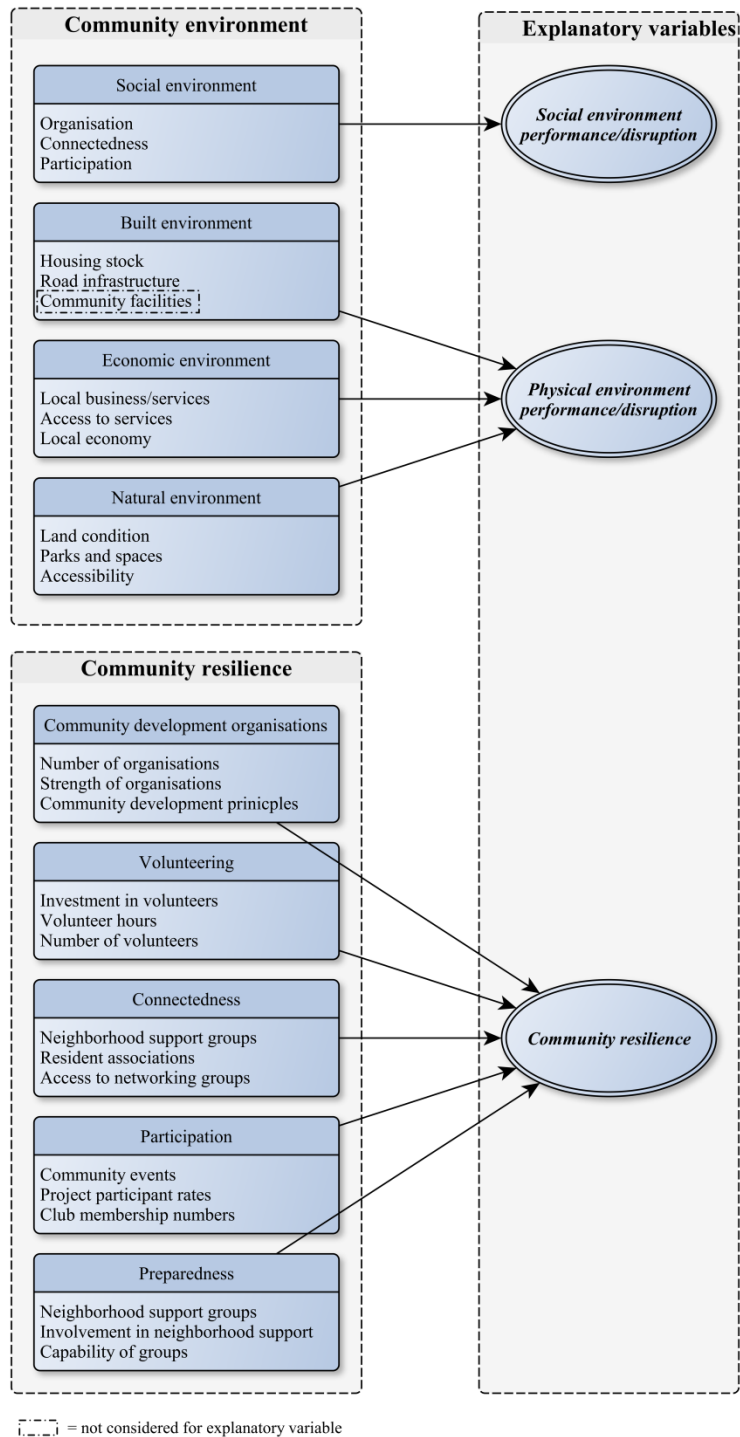
Figure 6.1: Community environment and resilience measures and corresponding explanatory variables build by averaging

We applied factor analysis to identify independent underlying components of resilience and community environments since intercorrelations between measures have been identified. Principal Component Analysis (PCA) without rotation indicated two environmental components with eigenvalues greater than 1.0. These explained 67% (2011) and 65% (2012) of the variance showing similar variable loadings on components. The first component loaded on housing units, road infrastructure, local businesses, access to local businesses, local economy, land condition, parks and spaces and access to natural environment, which all describe the availability and accessibility of physical infrastructure, so this component was called physical environment. The second component included the three measures for social environment, so this name remained (Figure 6.1). Community facilities conditions crossloaded on more than one component and was therefore not considered.

Average measures were built for the two components 'physical' and 'social' environment in 2010, 2011 and 2012 and measures of disruptions to these environments were also calculated for 2011 and 2012 by subtracting the actual average measures from the previous, e.g. social environment disruption 2011 = social environment measure 2010 − social environment measure 2011. Values greater than 0 indicate disruption, 0 indicates no disruption and values smaller than 0 indicate improvement.

Applying PCA on community resilience, four components with eigenvalues greater than 1.0 explaining 72% (2011) and 69% (2012) of the variance were identified. After rotating the initial solution using a varimax rotation most variables loaded on different components in both years. Since a clear structure was missing, we dismissed the PCA results and built an overall measure of community resilience by averaging all 15 resilience measure to average scores for 2011 and 2012 (Figure 6.1).

Cumulative Earthquake Intensity (CEI)

A Cumulative Earthquake Intensity (CEI) measure based on felt reports was built to assess the effect of aftershocks on mood and anxiety symptom treatments. The felt reports were derived from GeoNet, a collaborative project between the Earthquake Commission and GNS Science to monitor geological hazards in New Zealand. Each recorded earthquake event in New Zealand is published online on the GeoNet website and people can indicate its intensity on a simplified scale between weak (3) and severe (7) based on the Modified Mercalli Intensity (MMI) scale to describe weak to very strong shaking or if it hasn't been felt (0). We used these felt reports with attached locations, where the earthquake has been felt (a user can choose from a list of official place names), to build a cumulative intensity measure for communities in Christchurch by summing up the average intensity of each seismic event in a community within a specific period of time (see Supplementary material for more details on the methodology). We used two different time periods 2010/11 (Sep 10 – Aug 11) and 2011/12 (Sep 11 – Aug 12) to create cumulative intensity measures for communities in the Christchurch urban area. The resulting raw CEI scores were standardized by calculating z-scores, which show deviations from the mean.

Statistical analysis

The representativeness of the sample was assessed with a chi square goodness of fit test relating the demographic characteristics (gender, age and ethnicity) of the sample to the corresponding 2013 census information for Christchurch. Spatio-temporal cluster analysis via scan statistics with SaTScan[TM] v9.1.1 software was applied to examine clusters of high or low mood and anxiety symptom treatment rates among stayers in Christchurch. We ran a discrete Poisson-based retrospective space-time model using observed and expected counts while controlling for age and gender as these factors have been associated with negative mental health outcomes after severe earthquakes (Armenian et al., 2002; Xu & He, 2012). We also adjusted for a log linear temporal trend automatically calculated from the data and known relative risks for communities in 2010 to take the artificial increase of treatments

due to the extension of the set of subsidised medication and pre-earthquake risks into account. The known relative risks for communities in 2010 were produced by calculating the ratio between mood/anxiety symptom treatment rates in each community and the rest of the city (Altman, 1991). The maximum spatial cluster size was chosen to be 50% of the population at risk and the maximum temporal cluster size could range up to two of the three study periods. Monte Carlo hypothesis testing with 999 replications was used to test for significant clusters at a 5% significance level.

The effects of community resilience, community environment performance, disruptions to community environments and cumulative earthquake intensity on mood and anxiety symptom treatments were assessed via hierarchical Bayesian spatio-temporal modelling using the WinBUGS software package (v1.4) again adjusting for gender and age. We utilized a space-time extension of the well-known 'Besag, York and Mollie' (BYM) model for mapping the risk from a disease (Besag et al., 1991), where the observed cases O_{it} in an area i at a specific time t are described as a Poisson distribution with the mean $\rho_{it}E_{it}$ representing the unknown relative risk (RR) and the known gender and age adjusted expected number of cases in an area i at a specific time t assuming that mood and anxiety symptom treatments varied over space and time (DiMaggio et al., 2010; Richardson, Abellan, & Best, 2006):

$$O_{it} \sim Poisson(\rho_{it}E_{it}) \tag{4}$$

The gender and age adjusted expected number of cases E_{it} in an area i for a specific time t was calculated using internal standardization where the specific population in an area i was multiplied with the overall mood and anxiety symptom treatment rate for the specific population in the whole study region per time period t (Banerjee, Carlin, & Gelfand, 2004, p. 158). A spatial structure λ_i was added using the conditional autoregressive Gaussian distribution (CAR) as a latent gamma random variables, which improves local area estimates by accounting for random effects via spatial smoothing (Rojas, 2011).

The distribution was based on a neighbourhood weighting matrix *W* of communities with precision τ for random effects:

$$\log \rho_{it} = \alpha + \lambda_i + \phi_t + \beta_{1_t} X_{1_{it}} + ... + \beta_{N_t} X_{N_{it}} \tag{5}$$

$$\lambda_i \sim \text{CARNormal}(W, \tau) \tag{6}$$

An unstructured random effect over time ϕ_t was also considered to account for unexplained heterogeneity in the model. Model fit was assessed via the deviance information criterion (DIC), which is the sum of the posterior mean deviance (lower values showing better model fit) (Best, Richardson, & Thomson, 2005). Finally, parameters of interest β_{1_t} to β_{N_t} were added sequentially to estimate covariate effects and compare the model fit (see Supplementary material for Bayesian best-fit model, WinBUGS Code). A regression coefficient was deemed statistically significant at a 5% level when its 95% credible interval did not include zero. Prior distributions for covariates were chosen to be flat to apply a data driven model where the posterior distribution is dominated by likelihood (DiMaggio et al., 2010). Three parallel Markov Chains Monte Carlo (MCMC) with 50,000 iterations and a burn-in of 10,000 were run. Convergence was assessed by graphical examination of trace histories and conducting the Gelman-Rubin diagnostics.

Study design

At first, Eastwood, Jalaludin, Kemp and Phung's (2014) approach of considering different combinations of the spatial and temporal error terms for model fit was applied. Next, we added exposure variables one at a time testing for significant associations and model fit. Since community environment measures have been collected in 2010, 2011 and 2012, whereas resilience and cumulative earthquake intensity could only be assessed in 2011 and 2012 a two-step approach has been applied.

In a first model, we examined the associations between average social and physical environment ratings and mood and anxiety symptom treatments in 2010, 2011 and 2012 and in a second model we focused on the 2011 and 2012 earthquake sequence time periods

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examining the effects of average social and physical environment ratings, disruptions to the social and physical environments, average community resilience rating and CEI using z-scores on mood and anxiety symptom treatments.

Results

Exploratory data analysis

Study sample

The study sample included 172,284 Christchurch long-term stayers including only those who stayed in their community between July 2009 and September 2012. The demographic characteristics of the sample including gender (x^2=463.11, $p < 0.001$), age (x^2=8353.26, $p < 0.001$) and ethnicity (x^2=833.67, $p < 0.001$) were significantly different from census 2013 information over-representing women (53.5% vs. 50.8%), middle-aged residents between 40 and 64 years (41% vs. 32.4%), elderly older than 64 years (17.2% vs. 14.7%) and residents with European ethnicity (82.8% vs. 80%).

Mood and anxiety symptom treatments

Gender and age adjusted mood and anxiety symptom treatment rates in the study area were 6.1%, 6.8% and 7.3% in 2010, 2011 and 2012 showing an increase over time among Christchurch stayers, which may partly be attributed to an extension in the set of subsidised drugs at the end of 2010. Analysing age, gender and temporally adjusted mood and anxiety treatment rates over time, applying spatio-temporal cluster analysis using the SaTScan™ software, revealed that communities in the northeast exhibited the highest treatment rates, whereas eastern communities adjacent to the central city exhibited the lowest treatment rates compared to the rest of the city in 2011 and 2012. Further secondary clusters could be identified, but weren't statistically significant (Figure 6.2).

Legend

SaTScan spatio-temporal clusters

☐ non-significant

■ sig. high rates cluster in 2011/12 (RR=1.21, p < 0.001)

■ sig. low rates cluster in 2011/12 (RR=0.87, p < 0.05)

▨ non-sig. high rates cluster in 2011/12 (RR=1.3, p=0.095)

▨ non-sig. low rates cluster in 2012 (RR=0.93, p=0.234)

▨ non-sig. high rates cluster in 2011/12(RR=1.08, p=0.907)

N
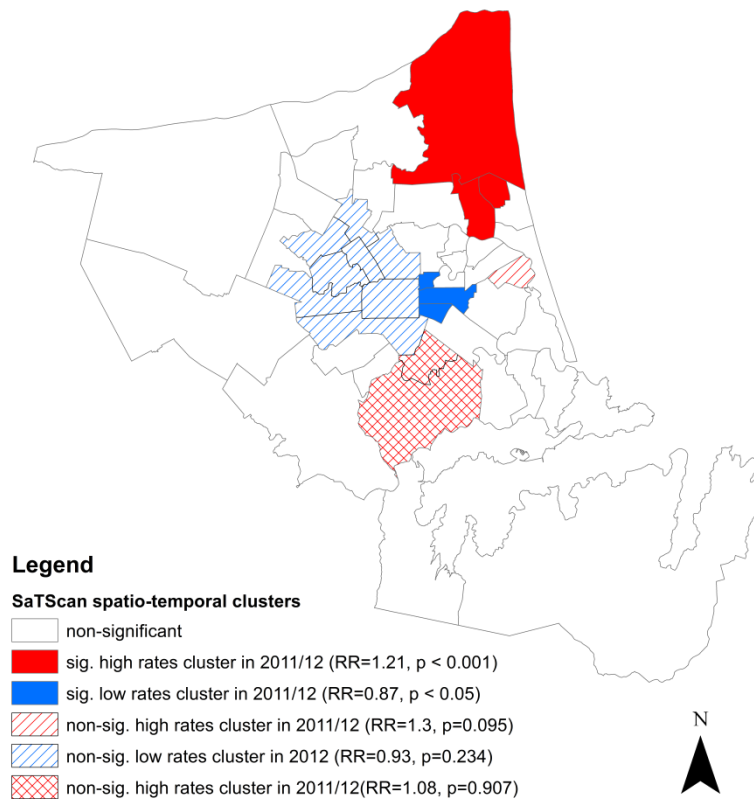
Figure 6.2: High (hotspots) and low (coldspots) rate clusters of mood and anxiety symptom treatments identified by spatio-temporal cluster analysis

Community and environment

The mean social environment ratings slightly increased between 2010 and 2011 (2010=3.4, 2011=3.7 and 2012=3.7), whereas the mean physical environment ratings (2010=4, 2011=2.7, 2012=3) dramatically decreased during this time period, but slightly improved on average in the second earthquake sequence year. The spatio-temporal distribution of physical environment ratings revealed that communities in the West, South and East had high ratings in 2010, but those in the East experienced a massive deterioration of their physical environment in 2011 as a consequence of the catastrophic February 22, 2011 Christchurch earthquake and its physical impacts (Figure 6.3).

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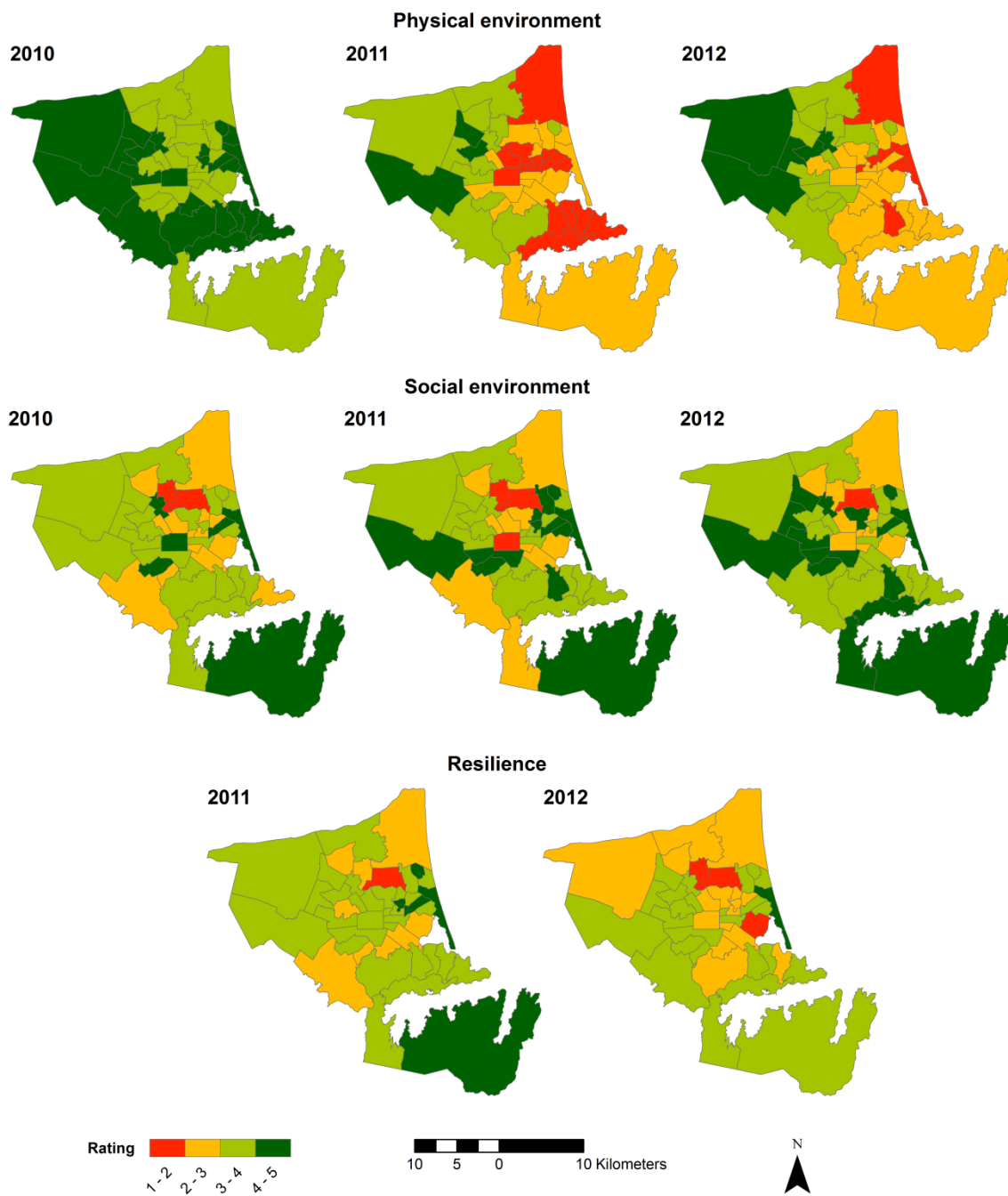
Figure 6.3: Spatial distribution of physical/social environment and resilience ratings (1=worst, 5=best) in Christchurch between 2010 and 2012

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On the other hand, social environment ratings seemed to increase especially in eastern communities, but a clear pattern change like that seen for physical environment couldn't be observed. Community resilience ratings, which were only measured post-disaster in 2011 and 2012, also didn't show such a clear pattern change, but relatively high resilience ratings with an average of 3.5 were observed in 2011, which decreased to 3.1 in 2012 (Figure 6.3).

Earthquake intensity

Mapping the Cumulative Earthquake Intensity (CEI) showed that higher cumulative earthquake intensities could be observed at closer proximity to earthquake epicentres with the highest magnitudes and energy released (Figure 6.4). The raw CEI scores of Christchurch communities ranged from 1688.2 to 1717.5 in the first and 458.5 to 471.6 in the second year, which corresponds to an average intensity ranging from 3.9 to 4 per event indicating little intensity variation in the study region.
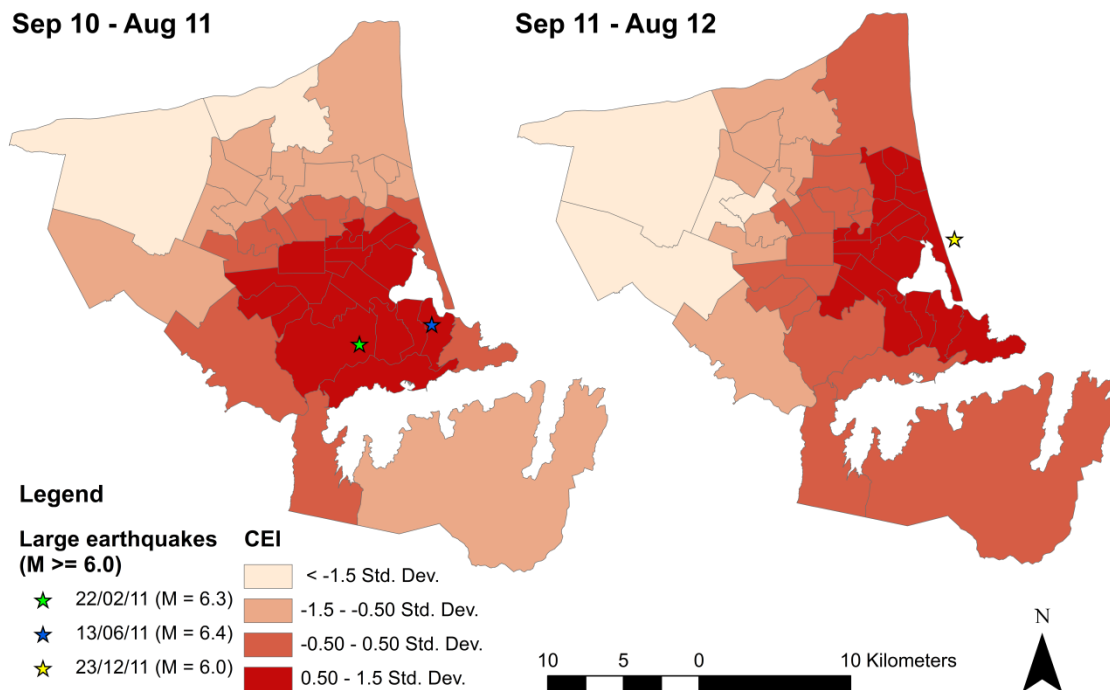
Figure 6.4: Cumulative Earthquake Intensity (CEI) scores above or below the mean in the first and second year of the Canterbury earthquake sequence

Bayesian linear regression

Bayesian regression modelling revealed some interesting results. The first model examined the associations between social and physical environment ratings and mood and anxiety symptom treatments in 2010, 2011 and 2012 and showed weak, but significant positive associations between social environment ratings and mood and anxiety symptom treatments in 2011 and 2012, as well as a weak negative association between physical environment ratings and mood and anxiety symptom treatments in 2012 (Table 6.1).

Table 6.1: Posterior statistics of the first model for the estimates of average social and physical environment ratings in 2010 (pre-disaster), 2011 (first year post-disaster) and 2012 (second year post-disaster)

Node	Mean	SD[†]	2.5%	97.5%
alpha	0.00408	0.2708	-0.4844	0.799
Social env. 2010	0.03256	0.01864	-0.003982	0.06868
Social env. 2011	0.03167	0.01247	0.007338	0.05621
Social env. 2012	0.03158	0.01492	0.00169	0.06055
Physical env. 2010	-0.02742	0.03172	-0.09513	0.03245
Physical env. 2011	-0.0228	0.01249	-0.04718	0.001902
Physical env. 2012	-0.02437	0.01239	-0.04886	-0.00028

[†] SD = standard deviation

The second model examined the effects of the performance of the social and physical community environments, disruptions to these environments, community resilience, as well as CEI on mood and anxiety symptom treatments in 2011 and 2012 and showed some weak, but significant effects. It revealed that better mean social environment ratings were associated with higher levels of mood and anxiety symptom treatments in 2012, whereas better physical environment ratings showed significant reverse effects in 2011 and 2012,

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meaning that living in a community with better physical environment was associated with smaller levels of mood and anxiety symptom treatments in the first two years of the Canterbury earthquake sequence. On the other hand, greater disruption to the social environment between 2011 and 2012 was identified as a risk factor for receiving treatment for moderate or severe mood or anxiety symptoms, whereas disruption to the physical environment between 2011 and 2012 was identified as a protective factor. Furthermore, community resilience was identified as a risk factor in 2011 meaning that stronger community resilience was associated with more mood and anxiety symptom treatments in a community, but again showed only a weak association. Finally, Cumulative Earthquake Intensity (CEI) did not show a statistically significant effect (Table 6.2).

Table 6.2: Posterior statistics of the second model for the estimates of average social and physical environment ratings, as well as disruptions, average community resilience ratings and CEI scores in 2011 and 2012

Node	Mean	SD†	2.5%	97.5%
Alpha	-4.255	3.605	-13.49	0.06933
Social env. 2011	0.04238	0.03014	-0.01809	0.09993
Social env. 2012	0.0628	0.02666	0.01069	0.1143
Physical env. 2011	-0.1357	0.04999	-0.2356	-0.03752
Physical env. 2012	-0.07466	0.02593	-0.1256	-0.02424
Social env. disruption 2010-11	-0.00797	0.02812	-0.06331	0.04704
Social env. disruption 2011-12	0.06781	0.02634	0.01587	0.1192
Physical env. disruption 2010-11	-0.06816	0.05173	-0.1722	0.03159
Physical env. disruption 2011-12	-0.07162	0.0333	-0.1367	-0.00636
Community resilience 2011	0.08076	0.0348	0.01347	0.1496
Community resilience 2012	0.02781	0.03347	-0.03774	0.09408
CEI 2011 (z-score)	0.01539	0.01662	-0.01711	0.04785
CEI 2012 (z-score)	0.01504	0.02032	-0.02494	0.05519

† SD = standard deviation

Discussion

In this ecological study we assessed the effects of exposure to different community environment disruptions, resilience and felt earthquake intensities on mood and anxiety symptom treatments in Christchurch communities in the context of the Canterbury earthquake sequence and found a weak protective effect of living in a community with better physical environment ratings in 2011 (second model only) and 2012 (first and second model). This seems to be in line with previous studies reporting that damage exposure due to living in a more affected/disrupted community (Dorahy & Kannis-Dymand, 2012; Dorahy et al., 2015; Fergusson et al., 2015) or experiencing home damage/destruction and/or material loss caused by severe earthquakes contributed to more severe post-traumatic stress, anxiety and depression symptoms (Bergiannaki et al., 2003; Chan et al., 2011; Chen et al., 2001; Paxson et al., 2012; Sattler et al., 2006; Ying et al., 2013), as well as sleep problems (Iwadare et al., 2014). It also confirms research showing that living in neighbourhoods with better built environment and less structural housing problems promotes psychological wellbeing (Truong & Ma, 2006). On the other hand, changes in the physical environment ratings, as well as pre-existing spatial disparities in mood and anxiety symptom treatments, may have influenced our finding since it is not uncommon that natural disasters like the Canterbury earthquake sequence exacerbate pre-existing differences in mental health (Osborne & Sibley, 2013) and affect especially those with a pre-existing mental illness (Başoğlu et al., 2002; Kuijer, Marshall, & Bishop, 2014; La Greca et al., 1998), as well as socially vulnerable and disadvantaged populations (Zahran et al., 2011), who often live in hazard-prone areas and are less able to recover from disaster impacts as a consequence of lack of economic, political and social resources (Schmidtlein, Shafer, Berry, & Cutter, 2011). Also pre-disaster structural conditions may contribute to post-disaster community problems (Wickes et al., 2015). Therefore, we also assessed changes in the physical environment and found that living in a community that experienced higher physical environment disruption between 2011 and 2012 was a protective factor in

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2012, which seems to partially contradict our assumption. However, the majority of communities didn't experience a further disruption of the physical environment in this time period as ratings had already started to improve. So the latter finding may be best interpreted as stronger improvement of the physical environment between 2011 and 2012 being associated with more mood and anxiety symptom treatments in 2012. Since we investigate treatment and not symptom or disorder prevalence, we suspect that communities at the centre of the physical recovery may have additionally been the focus of mental health interventions leading to relatively high treatment rates. The spatio-temporal cluster analysis accounting for pre-earthquake relative risks partially confirms this assumption as stayers from the severely affected communities in the northeast were significantly more likely to receive treatment for mood or anxiety symptoms in 2011 and 2012 than the rest of the city and before the earthquakes, whereas a significant low risk cluster of mood and anxiety symptom treatments was also found among three physically severely disrupted eastern communities at the same time. On the other hand, the found effects were only weak and there are also studies showing that living in a severely damaged or disrupted physical environment due to severe earthquakes does not necessarily lead to negative mental health impacts in the general population (Greaves et al., 2015; Zhou et al., 2013) or help-seekers (Roncone et al., 2013; Soldatos et al., 2006), which merits further research.

A more surprising result was the significantly positive association between social environment ratings and mood and anxiety symptom treatments in 2011 (only first model) and 2012 (first and second model). At a first glance, this seems to contradict several previous studies, which found a protective effect of sense of community (Huang & Wong, 2014; Li et al., 2011), social support and participation (Oyama et al., 2012; Paxson et al., 2012; Watanabe et al., 2004; Zahran et al., 2011; Zhang et al., 2012b), as well as social capital (Ali et al., 2012; Wind & Komproe, 2012) on post-disaster adverse mental health effects assuming that communities equipped with high social capital allow their residents to rely on social support from the community helping them to employ individual psychosocial

resources (Wind & Komproe, 2012). On the other hand, structural social capital can also be identified a risk factor for experiencing anxiety (Wind et al., 2011) and in case of the Canterbury earthquake sequence this may have been the case. Another explanation for our finding may be that strong provision of care and treatment options may improve treatment accessibility, care seeking activity and awareness of stress-related health outcomes resulting in higher than expected treatment rates. This may have especially applied to the hard-hit eastern communities, where relatively high mood and anxiety symptom treatment rates occurred contributing to a positive post-disaster association between social environment and mood and anxiety symptom treatments. On the other hand, a weak positive association between social environment disruption from 2011 to 2012 and mood and anxiety treatments in 2012 has been found, which is in line with research findings highlighting the protective effect of social support (Ali et al., 2012; Huang & Wong, 2014; Li et al., 2011; Oyama et al., 2012; Paxson et al., 2012; Watanabe et al., 2004; Wind & Komproe, 2012; Zahran et al., 2011; Zhang et al., 2012b). It still needs to be kept in mind that comparisons to those studies are quite difficult due to the different nature of the outcome variable and the complexity of assessing community support due to the lack of standardised assessment tools, which may also contribute to mixed research findings. This also applies to community resilience, which showed a weak positive association with mood and anxiety symptom treatments in 2011. This is similar to the social environment finding, which is not surprising as community resilience includes all three measures of social environment among others and has been found to correlate with social cohesion after a natural disaster (Townshend et al., 2015). Nonetheless, our finding is generally counterintuitive, because community resilience is strongly linked to psychological recovery or lack of psychopathology as it can be achieved by restoring high levels of mental and behavioural health, functioning and quality of life (Norris et al., 2008). Consequently, a high level of community resilience is meant to describe strong adaptive capacity of a community to cope with a natural disaster and expected to show a positive effect on mental health. However, research concerning the Canterbury earthquakes shows evidence for both

resilience and vulnerability at the same time (Annear et al., 2013; Gawith, 2011, 2013; McColl & Burkle, 2012; Osborne & Sibley, 2013; Rowney et al., 2014). For example, McColl and Burkle (2012) and also Gawith (2011, 2013) mention many stress factors, but also increased community activities (McColl & Burkle, 2012), community bonding and resilience (Gawith, 2013), as well as stronger preparedness, participation and connectedness (McColl & Burkle, 2012; Gawith, 2011). Nevertheless, individual resilience does not imply community resilience and vice versa (Norris et al., 2008), so there may be individuals, who do not benefit from strong development, connectedness and preparedness of community support groups, since this largely depends on individual community engagement and especially depressed persons avoid structural involvement in social networks (Wind & Komproe, 2011). Furthermore, there are several studies that challenge the picture of strong collective resilience in Christchurch communities. Despite the great work of community organisations there has been a lot of uncertainty and distress caused by the severe disruptions to the built and economic environments, as well as a loss of trust in the recovery and political decision-making as a result of poor communication, inappropriate support and lack of community involvement in decision-making (Cooper-Cabell, 2013; Thornley et al., 2015; Wilson, 2013). Our result also raises the question, whether the benefits of living in a community with strong collective resilience can reduce moderate to severe mood and anxiety symptoms by outweighing the psychological distress associated with living in a severely disrupted environment and facing daily hardship among long-term residents. However, it needs to be kept in mind that we investigated treatments, which makes it difficult to answer this question and draw inferences. Moreover, it is also possible that community resilience has just developed as a result of the earthquakes, and thus could not have a mitigating effect on adverse mental health outcomes in this short period of time. Christchurch has been perceived as one of New Zealand's safest cities regarding natural hazards before the earthquake sequence making it especially vulnerable and leading to a lack of social memory (Wilson, 2013). This learning process has been initiated by the earthquakes and longer term research is needed to assess if the newly

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developed adaptive capacity of Christchurch communities can have a positive effect on mental health in the long term. On the other hand, mental health outcomes may have been worse if there had been less community support and resilience, but this cannot be inferred from our findings.

Finally, felt cumulative earthquake intensity (CEI) didn't show a significant association with mood and anxiety symptom treatments, and thus couldn't confirm that stronger felt earthquake intensities lead to more severe mood or anxiety symptoms among treatment seekers. On the other hand, this result also doesn't contradict previous studies showing that fear of aftershocks predicts PTSD, depression or anxiety (Bödvarsdóttir & Elklit, 2004; Dorahy & Kannis-Dymand, 2012; Kuwabara et al., 2008; Roncone et al., 2013). Living with the ongoing aftershocks from the 2010 Darfield earthquake has been associated with worry and concern (Kannis-Dymand et al., 2015) and the uncontrollability of response to ongoing aftershocks predicted acute stress, but doesn't necessarily differ based on the different levels of aftershock exposure (Dorahy & Kannis-Dymand, 2012). The different levels of shaking may not be as important as the personality or emotional stability of a person that feels the aftershocks, because low levels of optimism and self-control and higher levels of neuroticism (Kuijer et al., 2014), as well as lower emotional stability as a proxy for responsiveness to threat (Osborne & Sibley, 2013), have been identified as factors predicting adverse mental health outcomes in affected individuals of the Canterbury earthquake sequence. The quality of the physical environment in a community has, however, been identified as a protective factor by our study, and thus suggests it may be more important than the intensity and geographical variation in felt shaking. Nevertheless, to our knowledge the CEI demonstrated a first approach to measure cumulative earthquake intensity and relate it to adverse mental health outcomes, having the potential of being a trigger for further research on this topic.

Limitations

The use of administrative data from the New Zealand Ministry of Health measuring mood and anxiety symptom treatments in Christchurch communities allowed us to retrieve a large enough sample to measure area-wide mood and anxiety outcomes over time, but only a small proportion of these disorders can be identified through these as only publically funded care or treatment is recorded. Treatment for mood or anxiety symptoms is normally given to those care seekers who show moderate or severe mood or anxiety symptom levels. Thus the data is particularly weak in identifying people with lower symptom levels and may not reflect the actual morbidity in the population. The core data source of pharmaceutical claims was also subject to changes in the set of drugs receiving public funding, which further added inaccuracy in estimating actual morbidity. Moreover, traumatic settings can paradoxically pose a barrier for referral to care when disorder symptoms are deemed normal (McFarlane & Van Hoof, 2015). Also the treatment-seeking behaviour can vary between different demographic groups and regions due to service accessibility. In this respect, our PHO based sample also slightly overrepresented specific demographic groups including women, older people and those with European ethnicity compared to 2013 census information, but to minimise the age and gender bias, mood and anxiety symptom treatment rates have been adjusted accordingly. To minimise any mobility bias due to out-migration, we only investigated those who stayed in their community for the whole study period.

Another limitation of our study is the use of community profiles to measure exposure to differently affected community environments, as well as community resilience. These measures are a mix of statistical analysis and community advisor's expertise, so there may be a subjective bias. On the other hand, the intention was to capture a people-centred picture of the state of a suburb with community advisors having the necessary insight to give a professional opinion on the state of community environments and resilience. Furthermore, there was no standard definition of community disaster resilience, nor a

validated tool to assess the quality of community environments or community resilience at the community level instead of the individual level at the time of the earthquakes (Arbon, 2014), so the results may vary depending on the method used. Nevertheless, an interview with one of the community advisors revealed that community groups and residents strongly agreed with the ratings in the Christchurch community profiles.

Next, the CEI measure also has some limitations that need to be considered. First of all, the location information of felt reports consists of official place names defined by Land Information New Zealand (LINZ), which doesn't normally correspond to the actual place, where the earthquake has been felt. Further uncertainty was added by averaging felt report intensities when multiple ones have been reported for one place name. Automated ordinary kriging may also not lead to the best interpolation result, but was chosen due to its easy application and robustness. Additionally, a great number of earthquake events couldn't be considered in the analysis since too few felt reports have been submitted to achieve a good spread of locations for interpolation, but may be a result of low moment magnitude earthquakes that could hardly be felt and diurnal variation in reporting. Despite all these limitations and to the best of the authors' knowledge, the developed method was the first approach to measure overall earthquake intensity of a large earthquake sequence based on felt reports and provides a basis for further research.

Finally, the ecological study design doesn't allow establishing causal relationships due to the danger of incorrect extrapolation to individuals from regional data. Also weak associations are likely to be influenced by confounding or bias (Bonita, Beaglehole, & Kjellström, 2006). It should be noted that the results from the sample-based Markov Chain Monte Carlo (MCMC) method bases Bayesian inference on a presumed stationary Markov Chain indicated by convergence of parallel chains leading to a result that may slightly vary between simulations (DiMaggio et al., 2010).

Conclusion

In summary, this study unfolds the complex interactions between stressful disaster impacts, community resilience and adverse mental health outcomes, which play an important role in disaster recovery. We found a weak protective effect of living in a community with higher physical environment ratings on mood and anxiety symptom treatments post-disaster, but the effect may be confounded by pre-existing spatial patterns of mood and anxiety symptom treatments and intensified treatment-seeking behaviour due to an increase of social support interventions in severely affected eastern communities. In contrast, a weak positive association has been found between social environment ratings and mood and anxiety symptom treatments post-disaster, which contradicts the notion that high structural social capital has a protective effect on mood and anxiety symptoms being treated after a severe disturbance. In the same vein, community resilience was found to be positively associated with mood and anxiety symptom treatments in the first year post-disaster leading to the assumption that resilience wasn't large enough to mitigate the initial adverse stress-related mental health outcomes. However, an improvement of the social community environment between the first and second post-disaster year was identified as a protective factor, whereas an improvement of the physical community environment showed an inverse effect, which merits further research.

A first approach to build an area-wide cumulative measure for multiple felt earthquakes was demonstrated, but no significant association with mood and anxiety symptom treatments could be identified.

The findings indicate that response officials should direct their attention to severely affected communities, which have often already been the most vulnerable ones in the pre-disaster context. Nonetheless, strengthening the social capital of those communities is only one of many interventions that need to be initiated to prevent increased incidence and relapse of adverse stress-related mental health outcomes needing treatment, because a positive association between better social environment and mood and anxiety symptom

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treatments was found up to two years after the beginning of the Canterbury earthquake sequence, whereas an improvement of the social capital had a mitigating effect in the second year post-disaster.

Supplementary material

Earthquake impact analysis measures

To measure the earthquake impacts and identify disruptions to different community environments the earthquake impact analysis includes 12 measures assessing the performance of the social, built, economic and natural environment in 2010, as well as at the end of 2011 and 2012. These 4 environments are derived from the national Civil Defence and Emergency Management (CDEM) recovery framework. The social environment includes a rating for community organisations based on the number of organisations, their strength and application of community development principles in a community, a rating for community connectedness based on active networks and the number of neighbourhood support groups, and a rating for community participation considering the levels of local participation with community development, engagement and recreation. The built environment is defined by a rating for the number of social housing units and privately owned residences with prohibited access due to red zoning or a red sticker, a rating for road infrastructure based on drivability and closures, and a rating for the condition of community facilities considering the loss of venues due to damage or geotechnical assessments. The economic environment includes a rating for local businesses/services considering the range of businesses, business losses along with growth of new establishments that were displaced from CBD and other areas, a rating for access to local services based on the range of basic needs like chemist, health postal services or banks, and a local economy rating considering the known vibrancy of local businesses including empty or underutilised premises, as well as increase or decrease in patronage due to migration of businesses/residents. Finally, the natural environment is defined by ratings for the land condition based on geotechnical assessments after the February 22, 2011 Christchurch earthquake, parks and spaces measured by the number and size of green spaces and the proportion closed, and the accessibility to natural environment taking into

account green spaces that are closed and/or damaged limiting access to open areas such as playing fields.

Community resilience measures

The community resilience measure of the Christchurch City Council (CCC) community profile consists of 5 different components including community support, volunteering, connectedness, participation and preparedness. The 'community support' component consists of ratings for the number of organisations (1=under 10, 2=10-20, 3=20-30, 4=30-40 and 5=over 40), strength of organisations based on their community development, engagement and recreation activities, and community development principles based on the proportion of existing organisations that espouse and apply community development theory. The second component 'volunteering' is measured by the investment in volunteers based on the combination of volunteer hours from grant funded projects and the 2006 census, the number of volunteer hours from grant funded projects (1=0-100, 2=101-200, 3=201-300, 4=301-400, 5=over 400), and the number of volunteer hours from the census in relation to the population in the profile area (1=under 3%, 2=4-9%, 3=10-14%, 4=15-19%, 5=over 19%). The third component 'connectedness' encompasses the number of neighbourhood support groups based on the population/size of a profile area, coverage of the profile area by residents' associations (1=no associations, 3=some associations, 5=whole profile area covered by associations), and access to networking groups/forums ranked according to the number of networking forum opportunities accessed by community groups. The fourth component 'participation' includes a comparative ranking for the number of different community events, a ranking of participation numbers for funded projects (1=0-19, 2=20-39, 3=40-59, 4=60-79, 5=80-100+), and a ranking of club membership numbers based on the observed number of members and their investment of time (1=lack of participation, 2=small/under resourced but sustaining activities for small numbers, 3=reasonably patronised and steady operations, 4=mostly well patronised and showing well sustained or increasing participation, 5=often full capacity and a large

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catchment of participants). The last component 'preparedness' consists of rankings for the number of neighbourhood support groups (1=under 10, 2=10-20, 3=20-30, 4=30-40, 5=over 40), the proportion of households belonging to a neighbourhood support group (1=under 5%, 2=6-10%, 3=11-15%, 4=16-20%, 5=over 20%), and the capability of groups to lead local response in an emergency (1=very weak, 2=weak, 3=moderate, 4=strong, 5=very strong).

Cumulative Earthquake Intensity (CEI) calculation

In a first step, an average intensity measure for each felt report location and earthquake event was built as one location can have more than one assigned felt report due to the strategy how location has been recorded on the GeoNet website. The location where an earthquake has been felt could be defined based on official place names for suburbs and localities defined by Land Information New Zealand (LINZ). In total there have been 136 places in and around the Christchurch urban area that had felt reports attached.

In the second step, the average intensity measures at different locations were used to create area-wide intensity measures for each earthquake event. Therefore, ordinary kriging was applied as it only requires the data and knowledge of the variogram function and is very robust even if an optimal one has not been chosen (Oliver & Webster, 2014). To get better interpolation results in the outskirts, we also included places in close proximity to the Christchurch urban area. However, none of the earthquake events had felt reports for all these locations, e.g. the September 4, 2010 Darfield earthquake had 2189 felt reports at 98 of these locations and the February 22, 2011 Christchurch earthquake had 1216 felt reports at 89 of these locations. To achieve a good spread of locations for interpolation and the recommendation of a minimum 7 nearest neighbours (Oliver & Webster, 2014), we selected only those earthquakes, which had felt reports at one or more locations in each of the 7 Christchurch administrative wards. Thus, 551 of 3329 Canterbury earthquake events that had felt reports attached and occurred between September 1, 2010 and August 30, 2012 (434 from Sep 10 to Aug 11, 117 from Sep 11 to Aug 12) remained. This selection

included the four strongest earthquakes of the Canterbury earthquake sequence with magnitudes of 7.1 (Sep 4, 2010), 6.3 (Feb 22, 2011), 6.4 (Jun 13, 2011) and 6.0 (Dec 23, 2011), as well as 23 earthquakes with magnitudes between 5 and 6, 188 with magnitudes between 4 and 5, 322 with magnitudes between 3 and 4 and 14 with magnitudes between 2 and 3 according to the Richter scale. To speed up the interpolation process and avoid manual processing of all these events, we applied the automated ordinary kriging method implemented in the automap package for R.

Next, the resulting grids of interpolated intensity measures for different earthquake events were overlaid and summed up to create a cumulative intensity measure for all earthquake events in a specified time period resulting in a cumulated value for each grid cell.

In a final step, the mean function of zonal statistics was applied to calculate the mean cumulative intensities (= raw CEI score) for different communities in the study area.

Bayesian best-fit model, WinBUGS Code

```
model
{
        for(i in 1:R){
                for(t in 1:T){
                        O[i,t]~dpois(mu[i,t])
                        log(mu[i,t])<-log(E[i,t]) + alpha + beta1[t] * covariate1[i,t] +
                        beta2[t] * covariate2[i,t] + s[i] + v[t]
                        RR[i,t]<-exp(alpha + beta1[t] * covariate1[i,t] + beta2[t] *
                        covariate2[i,t] + s[i] + v[t]
                }
        }
```

```
# Priors:
alpha~dflat()

for(t in 1:T){
        tau.v[t]~dgamma(0.5, 0.0005)
        sigma.v[t]<-sqrt(1/tau.v[t])
        v[t]~dnorm(0,tau.v[t])
        beta1[t]~dflat()
        beta2[t]~dflat()
}

# CAR prior distribution for random effects:
tau.s~dgamma(0.5, 0.0005)     # prior on precision
sigma.s<-sqrt(1/tau.s)        # standard deviation
s[1:R]~car.normal(adj[], weights[], num[], tau.s)
}
```

Chapter Seven: Conclusions

This thesis investigated the effects of different degrees of exposure to the 2010/11 Canterbury earthquakes and their impacts on adverse mental health outcomes in the urban area of Christchurch, New Zealand. Community-wide impact information was used to assess exposure, and spatial analysis techniques were applied to relate it to mood and anxiety symptom treatments recorded by the New Zealand Ministry of Health.

The health treatment information was chosen because it is the best data available for our purpose. In the New Zealand health system different coding systems are used in General Practice, hospital, private psychiatry and other counselling and mental health provider services, and much of the mental health burden we are interested in (PTSD, anxiety, depression) is managed by General Practitioners and these diagnoses will often be 'hidden' among the package of health care a GP provides for a patient, so using the Ministry of Health's repository of coded treatment events is the most reliable and allows regional comparison. Spatial analysis techniques were used since geographic location plays an integral part in determining the level of disaster exposure and where post-disaster adverse mental health outcomes occur (Chapter 2). Additionally, the relationship between different levels of disaster exposure and mental health is still not fully understood, while the Ministry of Health's administrative data represents a unique source in determining the mental health treatment status in a large population.

The main hypothesis of the thesis that more severely affected Christchurch residents were more likely to receive care or treatment for moderate or severe mood and anxiety symptoms than less affected ones could only partially be confirmed.

The first analytical chapter (Chapter 3) found a large cluster of high mood and anxiety symptom treatment rates in the more severely affected areas in Christchurch in the post-disaster year of 2011/12. This indicated a dose-response relationship between exposure to the earthquakes and their impacts and adverse mental health outcomes being treated. Also, living in closer proximity to minor (TC2) and moderately (TC3) affected areas, areas

suffering from minor to moderate or severe liquefaction, as well as areas affected by moderate to major lateral spreading, were found to be risk factors for receiving care or treatment for mood and anxiety symptoms in the post-disaster year. Moreover, living in areas that experienced stronger shaking intensity from the 2011 Christchurch earthquake was identified as a post-disaster risk factor indicating a dose-response relationship as well. On the other hand, these effects were only weak and living in closer proximity to the most severely affected areas (classified as 'Red Zone') did not show a statistically significant effect, which may be attributed to the strong migration activity in Christchurch after the catastrophic 22nd February 2011 earthquake. Furthermore, pre-earthquake spatial variation and a temporal trend of mood and anxiety symptom treatments, due to the extension of the set of subsidised medication at the end of 2010, may have biased the outcomes of this study.

A more detailed investigation into the spatio-temporal variation of mood and anxiety symptom treatments in Christchurch and the rest of New Zealand (Chapter 4) revealed a possible earthquake exposure effect as the treatments showed a significantly stronger increase among Christchurch residents compared to other New Zealand residents after the beginning of the earthquake sequence and especially after the 2011 Christchurch catastrophe.

Identified high-risk groups for being treated for mood or anxiety symptoms included women, elderly and people with European ethnicity. In addition, this study found that children and elderly had an increased risk in the context of the Canterbury earthquakes. Neighbourhood socio-economic deprivation and closer proximity to the 2011 Christchurch earthquake epicentre were identified as general risk factors as well, whereas only slight changes in the effects were found after the beginning of the earthquake sequence indicating little post-disaster impact of these variables on treated adverse mental health outcomes.

Spatio-temporal cluster analysis accounting for the overall temporal trend of increasing treatments, found a cluster of higher rates of mood and anxiety symptom treatments stretching from the central city to the southeast after the Christchurch earthquake to the end

of the study. This cluster largely corresponded to the one found in the previously, but did not include the most severely affected Red Zone areas in the East. These areas were found to have experienced the highest decreases in mood and anxiety symptom treatments in the city, whereas the strongest increases occurred in the less affected northern parts of the city. These findings indicated stronger adverse mental health effects on less earthquake-affected individuals, but could also be due to residential mobility influencing the post-disaster patterns of mood and anxiety symptom treatments in Christchurch since residents from the Red Zone areas were urged to sell their property and relocate leading to a population shift from severely affected eastern to less affected western and northern parts of Christchurch. Investigating the effects of mobility on mood and anxiety symptom treatments (Chapter 5) revealed that temporary relocation was a risk factor in the short term following the Christchurch earthquake, whereas relocation out of the city from minor, moderately and severely affected plain areas of Christchurch showed a long-term adverse mental health effect two years after the catastrophic event. On the other hand, moving within the city showed a protective effect over time indicating that relocation can serve as a coping strategy after a severe disaster, when community attachment is less disrupted, whereas residents moving out of the disaster-affected city may lose their social networks, social support, friends and cultural identity, which may outweigh the effect of living in a less damaged environment.

Furthermore, residents from the more affluent, minor to moderately affected Port Hills areas in the city were less likely to be treated for mood or anxiety symptoms only in the pre-disaster year (2009/10), whereas residents from the less affluent, minor affected plain areas of the city showed a significant decrease in mood and anxiety symptom treatments between 2009/10 and 2012/13. This leads to the suggestion that socio-economic status in association with level of affectedness has an important impact on mental health as more affluent residents seem to cope worse emotionally with adverse living conditions caused by the earthquakes and their impacts than less affluent people, who seem to adapt better to a rudimentary post-disaster lifestyle.

In the last research study the effects of different levels of the physical and social community environment, as well as community resilience and felt intensities of thousands of earthquakes shaking the city in the first two years of the sequence on mood and anxiety symptom treatments were examined among long-term residents, who stayed in their local communities within the Christchurch urban area (Chapter 6). It was found that living in a community with better physical environment was protective for receiving care or treatment for mood or anxiety symptoms, whereas better social environment was associated with more mood and anxiety symptom treatments up to two years post-disaster. Similarly, community resilience showed a positive association with mood and anxiety symptom treatments in 2011. These results indicate an exacerbation of pre-disaster inequalities in mental health as the most severely earthquake-affected communities, which unsurprisingly showed the lowest post-disaster physical environment ratings, are traditionally those that accommodate hazard-prone and socially vulnerable populations. Additionally, these areas exhibited higher social environment and community resilience ratings post-disaster, which may be due to increased social support received after the Christchurch earthquake. Also, the finding that an improvement in the physical environment ratings between 2011 and 2012 was identified as a risk factor in 2012 seems to be in line with our assumption, as physically more affected communities are normally in the centre of recovery efforts. On the other hand, an improvement in social environment ratings between 2011 and 2012 was identified as a protective factor in 2012, confirming that social support may have a long-term mitigating effect after a natural disaster. Finally, felt earthquake intensities could not be associated with adverse mood and anxiety symptom treatments, but the cumulative earthquake intensity (CEI) measure demonstrated a first approach to build an aggregated earthquake intensity measure from multiple felt reports and earthquake events over time.

In summary, the findings of this thesis have important implications on mental health policy and planning resources as they can help to improve targeting of mental health services after severe future seismic events. For example, when someone attends their GP based on the post-earthquake moves, and previous home location, the GP can identify likely mental

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health risk and recommend mental health treatment. Consistent with previous research, elevated levels of adverse mental health outcomes can generally be found in the more severely affected areas compared to less affected and unaffected ones after a severe earthquake, so this should not only be the centre of the physical, but also the emotional recovery. On a local scale, residents from more affected areas should be the focus of early intervention programs promoting mental health as they have often already been the most vulnerable ones for adverse mental health outcomes before the disaster. Socially vulnerable groups including women, children and elderly, as well as those with a history of receiving care or treatment for adverse mental health symptoms, should be targeted. Additionally, mobility should be considered in health intervention plans since strong migration activities to less or unaffected areas are often observed after a natural disaster and those who relocate permanently from affected areas in the long-term or temporarily in the short-term after the disaster face unique challenges that may have adverse mental health effects requiring treatment. Consequently, areas that are less affected by the event may still experience an unexpected increase in treatment-seeking for adverse mental health outcomes. The thesis also showed how spatio-temporal analysis techniques can identify such areas, so that public health care planners can take appropriate measures to prevent the further development of mental health disorders.

On the basis of this thesis, future research may focus on models that predict areas of high or low risk for developing adverse mental health symptoms when a serious disruption to the functioning of the community occurs.

Appendix

Table A.1: Diagnostic codes/therapeutic groups used to define the mood and anxiety treatment flag

Diagnostic code/ Therapeutic group	Description
F30	Manic episode
F31	Bipolar affective disorder
F32	Depressive episode
F33	Recurrent depressive disorder
F34	Persistent mood disorders
F38	Other mood disorder
F39	Unspecific mood disorder
F40	Phobic anxiety disorder
F41	Other anxiety disorders
F42	Obsessive-compulsive disorder
F43	Reaction to severe stress, and adjustment disorders
F44	Dissociative disorders
F45	Somatoform disorders
F48	Other neurotic disorders
296	Episodic mood disorders
300.00	Anxiety state, unspecified
300.01	Panic disorder with agoraphobia
300.02	Generalized anxiety disorder
300.09	Other anxiety states
300.10	Hysteria, unspecified
300.11	Conversion disorder
300.12	Dissociative amnesia
300.13	Dissociative fugue
300.14	Dissociative identity disorder

Diagnostic code/ Therapeutic group	Description
300.15	Dissociative disorder or reaction, unspecified
300.20	Phobic disorders
300.30	Obsessive-compulsive disorders
300.40	Dysthymic disorder
300.50	Neurasthenia
300.60	Depersonalization disorder
300.70	Hypochondriasis
300.80	Somatoform disorders
300.90	Unspecified nonpsychotic mental disorder
301.13	Cyclothymic disorder
306.00	Musculoskeletal malfunction arising from mental factors
306.10	Respiratory malfunction arising from mental factors
306.20	Cardiovascular malfunction arising from mental factors
306.30	Skin disorder arising from mental factors
306.40	Gastrointestinal malfunction arising from mental factors
306.50	Psychogenic genitourinary malfunction, unspecified
306.52	Psychogenic dysmenorrhea
306.53	Psychogenic dysuria
306.59	Other genitourinary malfunction arising from mental factors
306.60	Endocrine disorder arising from mental factors
306.70	Disorder of organs of special sense arising from mental factors
306.80	Other specified psychophysiological malfunction
306.90	Unspecified psychophysiological malfunction
307.80	Psychogenic pain, site unspecified
307.89	Other pain disorders related to psychological factors
308.00	Predominant disturbance of emotions
308.10	Predominant disturbance of consciousness
308.20	Predominant psychomotor disturbance

Diagnostic code/ Therapeutic group	Description
308.30	Other acute reactions to stress
308.40	Mixed disorders as reaction to stress
308.90	Unspecified acute reaction to stress
309.00	Adjustment disorder with depressed mood
309.10	Prolonged depressive reaction
309.22	Emancipation disorder of adolescence and early adult life
309.23	Specific academic or work inhibition
309.24	Adjustment disorder with anxiety
309.28	Adjustment disorder with mixed anxiety and depressed mood
309.29	Other adjustment reactions with predominant disturbance of other emotions
309.30	Adjustment disorder with disturbance of conduct
309.40	Adjustment disorder with mixed disturbance of emotions and conduct
309.81	Posttraumatic stress disorder
309.82	Adjustment reaction with physical symptoms
309.89	Other specified adjustment reactions
309.90	Dysthymic disorder
311	Depressive disorder, not elsewhere defined
Citalopram	Used for mood/anxiety symptom treatments (not dementia)

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