Mental health following the volcanic eruption in Eyjafjallajökull volcano in Iceland in 2010

A population-based study

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Thesis for the degree of Master of Public Health Sciences
Centre of Public Health
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Andleg líðan í kjölfar eldgossins í Eyjafjallajökli 2010

Lýðgrunduð rannsókn

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Ritgerð til meistaragráðu í lýðheilsuvísindum
Umsjónarkennari: Arna Hauksdóttir
Meistaranámsnefnd: Edda Björg Þórðardóttir og Guðrún Pétursdóttir

Læknadeild
Námsbraut í lýðheilsuvísindum
Heilbrigðisvísindasvið Háskóla Íslands
Útskriftarmánuður júní 2015
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June 2015
Abstract

Volcanic eruptions and other natural disasters have a great impact on a large number of people throughout the world every year. Being exposed to a volcanic eruption can entail physical consequences, such as mortality, injuries or communicable diseases, and psychological consequences, such as post-traumatic stress disorder (PTSD) or depression. The aim of this study was to examine the mental health effects of the 2010 Eyjafjallajökull volcanic eruption in Iceland on nearby residents, six to nine months after the eruption ended. A further aim was to examine whether potential mental health effects differentiated by level of exposure and having experienced the volcanic eruption directly. This cross sectional study included 1,615 residents living in an area close to the Eyjafjallajökull volcano at the time of the eruption and a sample of 697 residents from a non-exposed area in North Iceland. In fall of 2010, six to nine months after the eruption ended, all consenting participants received a questionnaire, containing questions on physical and mental well-being (General Health Questionnaire - 12-item version (GHQ-12), Perceived stress scale (PSS-4) and Primary care PTSD (PC-PTSD)). Additional questions regarding experience of the volcanic eruption were also included for the exposed group. Questionnaires were received from 1,146 participants in the exposed group (71%) and 510 participants in the non-exposed group (73%). Results showed that participants living in the high-exposed area were at increased risk of experiencing mental distress (GHQ-12 score ≥3) 6-9 months following the eruption (OR 1.39%; 95% CI 1.06 to 1.83), compared to the non-exposed group. High-exposed participants were furthermore at increased risk of experiencing symptoms of post-traumatic stress disorder (PTSD), compared to those living in the low-exposed area (OR 3.74; 95% CI 1.16 to 12.11). Lastly, for the exposed group, the following predictors for symptoms of mental distress, PTSD symptoms and perceived stress were identified: own property damaged (mental distress: OR 2.70; 95% CI 2.02 to 3.60, PTSD symptoms: OR 5.21; 95% CI 2.98 to 9.11 and perceived stress: OR 1.37; 95% CI 1.02 to 1.85), having felt insecure during the eruption (mental distress: OR 3.56; 95% CI 2.40 to 5.26, PTSD symptoms: OR 11.35; 95% CI 6.67 to 19.31 and perceived stress symptoms: OR 2.33; 95% CI 1.55 to 3.49), having had to use protective equipment outside during the eruption (mental distress: OR 1.53; 95% CI 1.11 to 2.11 and PTSD symptoms: OR 2.39; 95% CI 1.23 to 4.62), having had to stay outdoors in ash fall due to work or other duties (mental distress: OR 1.59; 95% CI 1.17 to 2.15, PTSD symptoms: OR 4.77; 95% CI 2.39 to 9.52 and perceived stress symptoms: OR 1.54; 95% CI 1.12 to 2.12), and having had a view of the volcanic eruption from their home (mental distress: OR 3.08; 95% CI 1.89 to 5.04, PTSD symptoms: OR 14.22; 95% CI 1.96 to 103.27 and perceived stress symptoms: OR 1.78; 95% CI 1.13 to 2.80). These findings of increased psychological morbidity following the volcanic eruption claims that future studies and interventions should aim at further identifying vulnerable groups following volcanic eruptions.
Ágrip

Eldgos og aðrar náttúruhamfarir hafa áhrif á fjölda fólks um heim allan á ári hverju. Eldgos geta haft í för með sér alvarlegar heilsufarslegar afleiðingar, bæði líkamlegar og sálrænar. Líkamlegar afleiðingar geta meðal annars verið dauði, slys eða smítsjukdómar og sálrænar afleiðingar geta meðal annars verið áfallastreituróskun (ÁSR) eða þunglyndi. Markmið rannsóknar okkar var að kanna sálræna liðan einstaklinga sem bjuggu á nálaegu svæði við eldgosið í Eyjafjallajökli, sex til niú mánuðum eftir goslok. Ennfremur, að kanna hvort munur væri á andlegri liðan út frá búsetu þátttakenda og eftir því hvort þeir upplifdu eldgosið með atvinnum hætti. Í þessari þversniðsrannsókn töku þátt 1615 ibúar sem bjuggu á svæði nálaegt eldgosinu á þeim tíma sem eldgosið átti sér stað (eldgosahópur) og úrtak 697 ibúa úr Skagafirði sem sem ekki urðu fyrir áhriðum eldgosins (samanburðarhópur). Haustið 2010 fengu allir þátttakendur senda spurningarlista með spurningum um líkamlega og andlega liðan (General Health Questionnaire - 12-item version (GHQ-12), Perceived stress scale (PSS-4) og Primary care PTSD (PC-PTSD)). Þar fyrir utan fékk eldgosahópurinn spurningar tengdar reynslu af eldgosinu. 1146 þátttakendur í eldgosahópnum (71%) og 510 þátttakendur í samanburðarhópnum (73%) svörtuðu spurningarlistanum. Niðurstöður sýndu að hluti eldgosahópsins sem bjó næst eldstöðvunum var hættara við að upplifa andlega vanlíðan sex til niú mánuðum eftir goslok (OR 1.39%; 95% CI 1.06 til 1.83), samanborið við samanburðarhópinn. Þátttakendur sem bjuggu næst eldstöðvunum var ennframur hættara við að finna fyrir einkennum ÁSR samanborið við þátttakendur sem bjuggu fjær (OR 3.74; 95% CI 1.16 til 12.11). Fyrir eldgosahópinn í heild sinni, sýndu niðurstöður að þeir sem urðu fyrir beinum áhriðum eldgosins, þ.e. þeir sem urðu fyrir skemmdum á eignum (andleg vanlíðan: OR 2.70; 95% CI 2.02 til 3.60, einkenni ÁSR: OR 5.21; 95% CI 2.98 til 9.11 og streita: OR 1.37; 95% CI 1.02 til 1.85), fundu fyrir öðryggi á meðan á eldgosinu stóð (andleg vanlíðan: OR 3.56; 95% CI 2.40 til 5.26, einkenni ÁSR: OR 11.35; 95% CI 6.67 til 19.31 og streita: OR 2.33; 95% CI 1.55 til 3.49), þurftu að nota hlíðarþúnað úti á meðan eldgosinu stóð (andleg vanlíðan: OR 1.53; 95% CI 1.11 til 2.11 og einkenni ÁSR: OR 2.39; 95% CI 1.23 til 4.62), þurftu að vera utanfyrir í öskufalli vegna vinnu eða annars skyldustarf (andleg vanlíðan: OR 1.59; 95% CI 1.17 til 2.15, einkenni ÁSR: OR 4.77; 95% CI 2.39 til 9.52 og streita: OR 1.54; 95% CI 1.12 to 2.12), eða sáu eldgosið frá himilí sínu (andleg vanlíðan: OR 3.08; 95% CI 1.89 til 5.04, einkenni ÁSR: OR 14.22; 95% CI 1.96 til 103.27, streita: OR 1.78; 95% CI 1.13 til 2.80), voru líklegur til að upplifa andlega vanlíðan, einkenni ÁSR og streitu, samanborið við aðra í úsetta hópnum. Niðurstöður sýna að afmarkaður hópur getur átt hættu á andlegri vanlíðan, einkennum ÁSR og streitu eftir upplifun af eldgosi í nálaegð. Frekari rannsóknir þurfa að beinast að þeim hópi með áherslu að að greina hópa sem geta verið í aukinni áhættu, með tilliti til stuðnings og eftirfylgni.
Acknowledgements

First and foremost, I would like to thank my supervisor Arna Hauksdóttir deeply for good guidance, encouragement, understanding and support during the studies. She is a great inspiration.

Also, my co-supervisors Guðrún Pétursdóttir, for excellent linguistic inputs on the thesis and good instructions, and Edda Björk Þórðardóttir for valuable advices and critical comments, and the Institute for Sustainability Studies for letting me be a part of this exciting project.

Jóhanna Eyrún Torfadóttir provided great help in statistical analysis and Dóra Ragnheiður Ólafsdóttir endless positive attitude and was always ready to assist.

I would also like to thank my dear fellow students, Heiðrún Hlóðversdóttir and Bryndís Kristjánsdóttir, for good advice, moral support and great time during the studies.

Finally, my dear Andri Andrason. Thanks for your support, understanding and positive attitude in the last meters.
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Introduction

Disasters and health

Disasters are defined as an event that disrupts the entire community and greatly exceeds the coping capacity of the affected community. They can be divided into two groups, natural disasters and man-made disasters. Natural disasters are for example volcanic eruptions, earthquakes, floods, fires and hurricanes. Man-made disasters are caused by human failure, accidents, violence or war (Noji, 1996).

Every year, both man-made and natural disasters have a massive impact on a large number of people throughout the world, endangering people’s lives and causing both physical and psychological consequences (Kokai et al., 2004; World Health Organization, 1992). The physical consequences can entail injury and adverse health effects, such as communicable diseases and exposures to toxins such as ash fall. The psychological consequences may be the result of various factors such as threat to one’s life, loss of family or friends, physical injury, worries about the future or own or other’s health, damage to possessions or economic loss (Norris et al., 2002a). The psychological consequences of disasters are for example depression, post-traumatic stress disorder (PTSD), somatic complaints, generalized anxiety, and nightmares (Noji, 1996; Pan American Health Organization, 2000; Shore et al., 1986). Norris et al. (2002a) published a review of 160 studies on 60,000 individuals who were exposed to disasters (e.g. volcanic eruptions, earthquakes, plane crashes and nuclear accidents) during the years 1981-2001. The review showed that psychological problems most often observed in these studies were PTSD, depression and anxiety.

Studies have shown that the prevalence of PTSD is often higher following man-made disasters than natural disasters. This may be due to how the study groups are selected. In studies following man-made disasters participants of interest are usually direct victims (for example people who witnessed the September 11th World Trade Center attacks), while studies following natural disasters often include all residents of a community exposed to a natural disaster (for example all people living within a defined distance from a volcano). Natural disaster samples are more likely to include both people directly and indirectly exposed to the disaster (Galea et al., 2005; Neria et al., 2008).

The theoretical background of this thesis consists of studies on the mental health effects of being exposed to a natural disaster, with a special focus on volcanic eruptions. Firstly, studies on natural disasters and health will be described in general. Then volcanic eruptions and other natural disasters (earthquakes, avalanches, tsunamis and hurricanes) will be discussed including studies on mental health following these types of events. In addition, predictive factors for psychological morbidity following natural disasters will be presented. Finally, natural disasters in Iceland and the volcanic eruption in Eyjafjallajökull in 2010 will be discussed.
Natural disasters and health

Every year, natural disasters affect many people throughout the world. In 2012, 9,655 persons were estimated to have lost their lives due to natural disasters, considerably fewer than in any year between 2002-2011 (Guha-Sapir, 2012; Noji, 1996). Some major natural catastrophes occurred in that decade such as the Haiti earthquake in 2010 and the Indian Ocean tsunami in 2004, which rendered the decade’s average annual mortality number due to natural disasters as high as 107,000 (Guha-Sapir, 2012). The numbers of victims otherwise affected by natural disasters are much higher, with an estimated annual average of 267.9 million in the decade 2002-2011 (Guha-Sapir, 2012), emphasizing the importance of understanding the effects such events may have on the people exposed. This applies not only to physical health effects (e.g. respiratory health, injuries and diseases) but also to mental health effects.

Asia is the most disaster prone area of the world with 86.3% of worldwide reported disaster mortality in 2011 (Guha-Sapir, 2012; Noji, 1996). One reason for the high incidence of disasters in Asia is its geographic characteristics that render it more prone to earthquakes, floods and hurricanes than other places in the world (Kokai et al., 2004).

During the last two decades, there has been an increase in the numbers of disasters, including the number of victims affected by them (Noji, 1996; World Health Organization, 2002). Therefore, it is important that disasters receive recognition as a major public health problem and that studies aim to understand the psychological impacts various natural disasters have on those exposed and how they may be alleviated (Noji, 1996; World Health Organization, 2002). Until recently, studies on the psychological effects of natural disasters have been limited. However, in the past two decades an increased number of papers related to disaster psychiatry has been published worldwide (Neria et al., 2008; Norris et al., 2002a). Most of these studies are conducted following natural disasters in Asia that have dramatic consequences and entail injuries, deaths and evacuations of a number of people. These studies have shown that survivors of natural disasters are prone to show symptoms of psychological morbidity, such as PTSD, depression and anxiety (Carlsen et al., 2012; Chen et al., 2001; Goto et al., 2006; Kokai et al., 2004; Ohta et al., 2003; Pan American Health Organization, 2000; Shore et al., 1986; Yang et al., 2003). According to studies following natural disasters PTSD prevalence ranges from 3.7% to 60% but usually the prevalence is in the lower half of this range (Neria et al., 2008). Furthermore, studies indicate that the prevalence of PTSD among direct victims of natural disasters is about 30-40%; 10-20% among rescue workers and 5-10% in the general population (Galea et al., 2005; Neria et al., 2008).

Several studies have examined the longitudinal course of psychological morbidity following a natural disaster. Most of them have shown a decrease in psychological morbidity over time (Carr et al., 1997; Norris et al., 2002a; Ohta et al., 2003). For example the study of Carr et al. (1997) found that psychological morbidity decreased by about half in the first two years following an earthquake. According to the review of Norris et al. (2002a), symptoms generally peak over the first year before decreasing significantly. However, contrary to these results, a few studies have found an increase in psychological morbidity over time. For example Wang et al. (2000), who
assessed PTSD symptoms following an earthquake in China, found an increase in PTSD symptoms in two villages nine months after the earthquake.

**Exposure to natural disasters and effects on health**

Floods are the most common natural disasters, e.g. affecting 75% of natural disaster victims in 1990-1999. However, windstorms (hurricanes and tornadoes) cause the greatest number of deaths worldwide (35%) (Noji, 2000; World Health Organization, 2002).

In the past 20 years, earthquakes have caused more than a million deaths and injuries worldwide (Noji, 2000). A large earthquake often injures or kills a number of people and usually the morbidity/mortality ratio is 3:1 (World Health Organization, 1992). The number of people injured or dead is greatly influenced by three factors: type of housing, time of day and population density. All around the world, buildings are highly unstable and can be easily destroyed. Earthquakes occurring during the night cause more fatalities where homes are made of poor building materials. Conversely earthquakes during the day cause more fatalities in urban areas with poorly constructed schools and offices. Lastly, more deaths and injuries are expected in cities with higher population density (Pan American Health Organization, 2000). A study conducted following the devastating 2011 Van earthquake in Turkey, which measured psychological morbidity among surviving children and adolescents, found PTSD symptoms among 41% of the participants, anxiety among 53% and depression among 37% (Kadak et al., 2013). Several studies have been conducted following the Chi-Chi earthquake (magnitude 7.3) that struck Taiwan in 1999. The earthquake caused around 2,300 deaths, damaged or destroyed several thousand homes and resulted in the evacuation of more than 100 thousand people (Chen et al., 2001; Seplaki et al., 2006; Yang et al., 2003). Chen et al. (2001) assessed mental distress in 525 survivors of the Chi-Chi earthquake and found that 89.9% suffered mental distress in the first month following the earthquake. Other frequently encountered psychological symptoms were insomnia (69%), depressed mood (56%), dizziness and headache (53%), nervousness (63%) and chest tightness (51%). Results also showed frequent PTSD symptoms, particularly symptoms of re-experiencing the earthquake and increased arousal. Another study following the Chi-Chi earthquake used data from a national, longitudinal survey where 1160 persons were interviewed before (in 1999) and after the earthquake (in 2000) (Seplaki et al., 2006). The study showed that depressive symptoms were more frequent in the latter interview, and more severe among females, those who experienced property damage and the elderly. Yang et al. (2003) screened 663 participants for psychological morbidity three months following the Chi-Chi earthquake and found mental distress among 24.5% of the participants as well as PTSD symptoms (11.3%) and partial PTSD symptoms (32%).

A few studies have been conducted on psychological morbidity following avalanches. In 1995, avalanches struck the towns of Súðavík and Flateyri in northwest Iceland, resulting in 34 deaths, as well as causing severe injuries and a great deal of economic damage. A study conducted in Flateyri (N=104; 3-4 months post- avalanche), and Súðavík (N=73; 12-14 months post-avalanche),
with Raufarhöfn in northeast of Iceland as a non-exposed group (N=94), showed significantly higher rates of PTSD symptoms in the exposed group than the non-exposed group. Prevalence of PTSD symptoms was 48% in Flateyri and 35% in Súðavík but only 9% in Raufarhöfn (Ásmundsson et al., 2000). Another study 10 weeks after the avalanche in Flateyri, measured psychological morbidity among 104 residents of Flateyri and 87 residents of the neighbouring village Píngeyri, which was also heavily affected by the avalanche through friendship and family ties and taking part in the rescue operations. The study showed significantly higher rates of mental distress measured with GHQ-30 among residents of Flateyri (25%) than Píngeyri (12.5%). Intrusion, tension, anxiety, irritability, startle symptoms and sleeping problems where the most common symptoms in Flateyri with more than half of the residents suffering from these symptoms (Finnsdottir et al., 2002). Also, In a 16 year follow-up 16% of avalanche survivors were experiencing PTSD symptoms (Thordardottir et al., 2015).

Tsunamis generally cause many deaths, mainly from drowning, but also from injuries (Pan American Health Organization, 2000). In previous years there have been many deadly tsunamis in Asia, for example the Indian Ocean tsunami following the Sumatra-Andaman earthquake in 2004 that killed over 250,000 people and displaced more than 500,000 people (Frankenberg et al., 2008). A study conducted on 20,000 adult survivors of the tsunami showed that post-traumatic stress reaction (PTSR) scores were highest among those living in heavily damaged areas. Furthermore, PTSR scores were significantly higher among those who experienced property damage due to the tsunami (Frankenberg et al., 2008). Another study conducted eight weeks after the tsunami showed higher levels of depression and anxiety among individuals affected by the tsunami in southern Thailand. Findings showed higher levels of psychological morbidity among participants who were displaced due to the tsunami than those who were not displaced. In a nine month follow-up the number of those reporting psychological morbidity had decreased in both groups but was still higher among participants who had been displaced (Griensven et al., 2006).

Health consequences following hurricanes mostly result from heavy rain or floods rather than the wind (Pan American Health Organization, 2000). Such secondary effects of hurricanes can cause enormously high rates of morbidity and mortality (Noji, 2000). In 2004 four hurricanes struck Florida causing at least 100 deaths and enormous property damage, and hence economic damage. Following the hurricane 3.6% of residents were experiencing PTSD symptoms, 5.5% were experienced generalized anxiety and 6.1% suffered from depression (Acierno et al., 2007). A study conducted after the hurricane Mitch in Nicaragua in 1998, where more than 2,000 people were killed, showed that the prevalence of PTSD symptoms ranged from 4.5% in the less damaged areas to 9% in the worst affected areas (Caldera et al., 2001).

As these studies show, symptoms of psychological morbidity, especially PTSD symptoms, depression and anxiety, are widespread following disasters.
**Volcanic eruptions and effects on health**

It is estimated that 221,907 people have lost their lives worldwide since 1783 because of volcanic activity (Tanguy et al., 1998). Witham published a review in 2005 on all volcanic events that affected humans in the 20th century, reporting human mortality and morbidity (Witham, 2005). There it is estimated that 91,724 people lost their lives in 491 volcanic events and that individuals otherwise affected number up to 5.6 million. Of the 491 volcanic eruptions in the review, 53% resulted in deaths (Witham, 2005). Regarding deaths due to volcanic events since 1783 an estimated 91.1% were caused by four factors: famine and epidemic disease (30.3%), pyroclastic flows (26.8%), lahars (17.1%), and tsunamis (16.9%) (Tanguy et al., 1998). Also, only four eruptions accounted for more than 66% of these deaths, in Tambora 1815, Krakatau 1883, Montagne Pelée 1902 and Ruiz 1985 (Tanguy et al., 1998).

Being exposed to a volcanic eruption can have various physical consequences, such as injuries caused by contact with volcanic materials as well as respiratory symptoms caused by breathing gases and fumes (Carlsen et al., 2012; Pan American Health Organization, 2000). A study conducted after the 2010 volcanic eruption in Eyjafjallajökull in Iceland, found that people living close to the volcano were more likely to have various physical symptoms such as tightness in the chest, cough, phlegm and eye irritation compared to those living further away from the volcano (Carlsen et al., 2012). A study conducted on residents living close to the Kilauea volcano in Hawaii found an association between exposure to sulphurous volcanic air pollution and self-reported adverse health effects e.g. cough, phlegm, sore and dry throat, wheezing, eye irritation and diagnosed bronchitis (Longo, 2009).

Mental health may also be affected, as shown for example in a study conducted after the Mount St. Helens eruption in Washington in 1980. Psychological morbidity among 935 residents was measured 38 to 42 months after the eruption. Participants were divided into high-exposed, low-exposed and non-exposed groups. Having lost a close relative or suffered great property loss was defined as high exposure (N=121) and others as low exposure (N=375), while those further away from the volcano were defined as non-exposed (N=439). Higher levels of generalized anxiety, major depression and PTSD symptoms (referred to as the MSH-disorders) were found among those highly exposed. Previous research has shown that exposure level is predictive of psychological morbidity. There were clear gender differences, the prevalence of MSH-disorders in males was 11.1% among high-exposed, 2.5% among low-exposed and 0.9% among non-exposed. The prevalence of MSH-disorders in females was 20.9% among high-exposed, 5.6% among low-exposed and 1.9% among non-exposed (Shore et al., 1986). A study on the Mount Merapi volcanic eruption in Indonesia took advantage of the fact that while one village was seriously damaged by pyroclastic flow (high-exposed), another village was not seriously affected (low-exposed). PTSD symptoms were significantly higher among the high-exposed than low-exposed participants (Warsini et al., 2014).

The effects of a volcanic eruption on society may last far beyond the eruption itself. For example, people may have evacuated their homes for several weeks, months or even years, their homes may have been damaged and their livelihoods destroyed (Witham, 2005). Araki et al. (1998)
conducted a study assessing mental distress (measured by GHQ-30) among evacuees following the eruption of Mt Unzen-Fugan in Japan. Participants were 4,115 residents that had been forced to evacuate their homes due to the volcano and 1,098 non-exposed residents of a nearby town that escaped the disaster. Of the evacuees 66.9% showed symptoms of mental distress six months after the eruption started, compared to 9.8% of the non-exposed group. In a follow-up 44 months after the eruption started, mental distress among the exposed had decreased to 45.6% (Ohta et al., 2003).

Predictive factors for psychological morbidity following natural disasters

Studies have shown that a variety of factors predict mental health problems in the aftermath of disasters. People who experience the same event may respond differently and studies indicate that the outcomes vary with regard to severity of exposure as well as personal characteristics of survivors (Chen et al., 2001; Neria et al., 2008; Norris et al., 2002a; Norris et al., 2002b; Ohta et al., 2003; Shore et al., 1986; Yang et al., 2003). Findings from a review of studies investigating health consequences following natural disasters showed that more severe exposure, female gender, ethnic minority status, secondary stressors such as financial stress and prior psychiatric problems were factors that increased the likelihood of psychological morbidity, especially PTSD symptoms, depression and anxiety (Norris et al., 2002a). These findings are comparable to the findings of various studies assessing psychological morbidity following a natural disaster (Goto et al., 2006; Neria et al., 2008; Yang et al., 2003).

Severity of exposure

Several studies have examined the effects of exposure on mental health following a natural disaster. These seem to be consistent in showing that the severity of exposure is one of the most predictive factors contributing to disaster-related psychological morbidity (Araki et al., 1998; Galea et al., 2005; Goenjian et al., 1994; Goenjian et al., 2005; Neria et al., 2008; Shore et al., 1986; Wang et al., 2000). Those who are close to the epicentre of a natural event or are otherwise heavily affected show higher levels of psychological morbidity, such as PTSD symptoms, depression and stress than those less affected (Araki et al., 1998; Goenjian et al., 1994; Goenjian et al., 2005; Neria et al., 2008). A study measuring the impact of exposure level on adolescents (N=125) following an earthquake in Armenia 1.5 years and 5 years post-disaster found that depressive and PTSD symptoms were highest in adolescents residing in the city nearest to the earthquake epicentre compared to those residing in cities further away (Goenjian et al., 2005). Another study conducted after the Mount St. Helens eruption in 1980, comparing psychological morbidity in high-exposed, low-exposed and non-exposed groups, found higher levels of generalized anxiety, major depression and PTSD symptoms among those living closest to the volcano (Shore et al., 1986). Similarly, when comparing two villages affected by a volcanic
eruption, Warsini et al. (2014) found that PTSD symptoms were higher among high-exposed participants.

However, contrary to previous findings in a study from the year 2000 where PTSD rates were compared nine months post-earthquake in two differently affected villages, lower rate of PTSD symptoms were found among those living closer to the epicentre compared to those living further away (Wang et al., 2000). A likely explanation is that inhabitants in the village closest to the epicentre got immediate relief and support in rebuilding their homes while inhabitants in the village further away did not receive such immediate assistance. These findings demonstrate the importance of psychological support and assisting in rebuilding homes to those suffering after natural disasters.

**Damage**
Another predictive factor for psychological morbidity following natural disasters is experiencing damage to one’s property. Studies show that those experiencing damage to property or property loss are more likely to show symptoms of psychological morbidity (Carr et al., 1995; Ohta et al., 2003; Seplaki et al., 2006).

Bland et al. (1996) assessed psychological morbidity (measured by the Symptom Checklist-90-Revised (SCL-90-R)) in 772 male factory workers in Italy seven years after an earthquake. Those who experienced property damage caused by the earthquake, reported higher levels of psychological distress, compared to those who did not report such damage. For those experiencing damage the mean self-reported distress symptomatology was higher for all indices of the SCL-90-R, i.e. somatization, obsessive compulsiveness, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, psychoticism and sleep disturbance compared to those who did not suffer damage to their property. Similarly, a study on 3,007 Australian adults following an earthquake in Newcastle in 1989, found that persons living in a moderately damaged area and experiencing damage to their property due to the earthquake were more likely to experience psychological morbidity six months after the earthquake than those not experiencing damage (Carr et al., 1995; Carr et al., 1997). Also, in a study by Goto et al. (2006) 231 Japanese evacuees responded to a questionnaire 10 months after a volcanic eruption in Miyake Island. The aim was to assess whether the amount of material loss or damage caused by the eruption would predict symptoms of psychological morbidity. Those who experienced property loss, damage to property or uncertainty of losses had higher levels of PTSD symptoms and depression than other survivors.

The studies above are consistent with each other, i.e. those experiencing damage due to a natural disaster are more prone to experiencing psychological morbidity (e.g. PTSD symptoms, depression and anxiety).
Gender

According to the World Health Organization (WHO) there appears to be a gender difference in negative health consequences of natural disasters (World Health Organization, 2002). Studies indicate that females suffer more frequently from emotional disorders, such as PTSD symptoms, depression and anxiety, following disasters than males (Goto et al., 2006; Norris et al., 2002a; World Health Organization, 2002; Yang et al., 2003). Higher levels of depressive symptoms were found among females than males following the Chi-Chi earthquake in Taiwan in 1999 (Seplaki et al., 2006; Yang et al., 2003). Females were also found to be more likely to develop PTSD symptoms following the Mount Merapi volcanic eruption in Indonesia (Warsini et al., 2014). A study conducted after the Mount St. Helens eruption, found higher levels of psychological morbidity among females within all exposure groups (Shore et al., 1986). Also, in the study by Goto et al. (2006) females were more likely than males to develop depression. Norris et al. (2002a) compiled a disaster literature review that showed that in 94% of the studies that found a gender difference with regard to psychological morbidity, females proved to be more negatively affected after disasters than males, particularly with regard to PTSD. It is not known whether this gender difference is due to biological differences between the sexes, or socially determined differences between women’s and men’s roles, or a mixture of both (World Health Organization, 2002).

Age

Studies on the relationship between age and psychological morbidity following disasters report contrary findings (Norris et al., 2002a). Most studies show more psychological morbidity among older adults (Goto et al., 2006; Ohta et al., 2003; Ticehurst et al., 1996) and middle-aged adults (Seplaki et al., 2006; Shore et al., 1986) than younger adults. However some studies report more psychological morbidity among younger and middle aged adults than older adults (Acierno et al., 2006; Warsini et al., 2014). Yet other studies report equal levels of PTSD symptoms in young and old adults (Goenjian et al., 1994). Although Goenjian et al. (1994) found no significant difference in total PTSD scores among older and younger adults there was a significant difference in symptomology on the PTSD subclusters. Older adults scored higher on the hyperarousal subcluster and lower on the intrusion subcluster than the younger adults. In a study on 3,007 adults following an earthquake in Newcastle in Australia in 1989, where 13 people died, older adults (>65 years old) reported higher PTSD symptomology, measured by the Impact of Event Scale (IES), and higher levels of psychiatric morbidity than younger adults (<65 years old). Older adults, who showed high levels of PTSD symptoms, were more likely to be female, report higher levels of exposure and use behavioural and avoidance coping styles (Ticehurst et al., 1996). In a study following the Chi-Chi earthquake Yang et al. (2003) showed that older participants (>65 years) were at highest-risk of experiencing psychological morbidity compared with middle aged (44-64 years old) and younger (<44 years old) participants. Ohta et al. (2003) found that recovery from psychological distress, following a volcanic eruption in Japan, proved more difficult for the middle-aged and elderly (≥50 years old) than younger evacuees (<50 years old). Also, Carr et al.
(1995) showed that the middle-aged and elderly (≥45 years old) scored higher on GHQ-12 compared to younger adults (<45 years old). However, Seplaki et al. (2006) study after the 1999 Chi-Chi earthquake showed that psychological morbidity was higher among the middle-aged (54-70 years old) compared to the elderly (>70 years old).

These studies show contradicting age-specific results of psychological morbidity following natural disasters. However, as noted above, more studies show higher levels of psychological morbidity among older than younger adults.

**Natural disasters in Iceland**

Iceland is a country that is relatively prone to natural disasters, especially volcanic eruptions, avalanches and earthquakes. For that reason, and because Iceland has a strong infrastructure, a literate population motivated to take part in surveys and access to a variety of population-based registries, Iceland provides good opportunities for studies on the effects of natural disasters (Carlsen et al., 2012).

In the period 1900-2008, at least 68 natural events with serious consequences occurred in Iceland. Among those were nine earthquakes, 13 avalanches and 35 volcanic eruptions. At least 80 people lost their lives in these disasters, mostly due to avalanches (Gylfason, 2008).

In the past century, earthquakes have claimed one life in Iceland and caused a great deal of economic damage (Gylfason, 2008). Studies on the effects of earthquakes in Iceland have implied psychological morbidity in those exposed to them. In the year 2000 two earthquakes occurred with a few days interval in Iceland. Symptoms of PTSD among 52 exposed and 29 non-exposed adults were found in 24% of the exposed versus none in the non-exposed group (Bodvarsdottir et al., 2004).

As mentioned above, avalanches have the highest mortality rate of natural disasters in Iceland, resulting in the deaths of more than 200 people in 1885-1995 (Ásmundsson et al., 2000). Twenty-four people died in an avalanche in Seyðisfjörður in 1885, 20 in an avalanche in Hnifsdalur in 1910, 18 in Siglufjörður in 1919, 12 in Neskaupstaður in 1974, 14 in Súðavik in 1995 and 20 in Flateyri in 1995 (Ásmundsson et al., 2000). A survey of written records indicates that avalanches have claimed about 680 lives since 1118. However, these figures are not accurate and it is expected that several hundred fatalities may be unaccounted for (Jóhannesson et al., 2001). Avalanches can also cause great economic damage and it is assumed that direct economic loss due to avalanches and landslides in the years 1974-2000 is around 3.3 billion IKR (Jóhannesson et al., 2001).

Volcanic eruptions are fairly frequent in Iceland with an average of 20-25 eruptions per century (Thordarson et al., 2007). Over the past 1100 years, 205 eruptive events have been recorded in Iceland. Of these, about 70 eruptions are attributed to the Grímsvötn volcanic system in Vatnajökull in southeast Iceland, making it the most active volcanic system in Iceland in historical times. Bárðarbunga in Vatnajökull glacier is the second most active volcanic system followed by Katla in South Iceland (Thordarson et al., 2007).
Nowadays, the greatest volcanic threats are due to eruptions beneath glaciers due to glacier floods that they may entail. The most dangerous volcanoes of that kind are Eyjafjallajökull, Katla, Öræfajökull and other volcanic system beneath Vatnajökull (Gylfason, 2008). However, Katla is the most dangerous volcanic system in Iceland with approximately two volcanic eruptions every century, which result in glacier bursts that are estimated to reach the closest township within three hours (Gylfason, 2008).

Volcanic eruptions in Iceland have claimed two lives in the last century (Jóhannesson, 2001), as well as causing major economic damage (Gylfason, 2008). In 1996, there was a glacier burst following a volcanic eruption in Vatnajökull, resulting in the destruction of bridges, telephone lines and roads (Gylfason, 2008). The eruption in Heimaey, a small island south of Iceland, which lasted for 155 days in 1973, had a great impact on the lives of the inhabitants and on the Icelandic society as a whole. The eruption caused vast economic damage with more than 400 houses buried under ash and other 400 damaged. All the 5,000 residents of the island had to be evacuated to the mainland and were not able to return until many months later (Gylfason, 2008).

The volcanic eruption in Eyjafjallajökull in 2010

In April 2010, the Eyjafjallajökull volcano in Southern Iceland erupted, directly affecting more than 2,000 residents of the area closest to the volcano, most notably through vast amounts of finely grained ash emitted for more than five weeks during the eruption, and repeatedly re-suspended for months after that. The ash affected both people and animals, reduced visibility, delayed transportation, and damaged property (Briem, 2010; Carlsen et al., 2012; Karlsdóttir et al., 2012). In a cross sectional study on 207 individuals living close to the volcano conducted a few weeks after the onset of the eruption, 39% showed symptoms of mental distress (Carlsen et al., 2012). In addition, a population based study of self-reported symptoms conducted six months later (N=1,615) showed that mental distress was marginally more common among those exposed to the eruption (Carlsen et al., 2012). However, further analyses are needed to elucidate how the eruption affected the mental health of the exposed population, what factors predicted adverse mental health and which subgroups within the exposed group had the highest risk of morbidity.
Aims of the study

The aim of this study was to investigate:

1. The mental health effects of the Eyjafjallajökull volcano eruption on nearby residents, six to nine months after the eruption ended.

2. Whether there is increased likelihood of symptoms of mental distress, PTSD and stress among those living closest to the volcano (high-exposed) compared to those living further away from the volcano (low-exposed) and a non-exposed group in a different part of the country six to nine months after the eruption ended.

3. Explore whether being directly affected by the volcanic eruption, through material damage, insecurity due to the volcano, needing to use protective equipment while working outside, having to stay outdoors in ash fall and viewing the eruption from home is associated with increased risk of psychological morbidity six to nine months after the eruption ended.
References


Article

Mental health following the eruption in Eyjafjallajökull volcano
– A population-based study

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Abstract

Introduction The aim of this study was to examine the mental health effects of the Eyjafjallajökull volcanic eruption on nearby residents, six to nine months after the eruption ended. A further aim was to examine whether potential mental health effects differentiated by level of exposure and having experienced the volcanic eruption directly.

Methods This cross sectional study included 1,615 residents living in an area close to the Eyjafjallajökull volcano at the time of the eruption (further divided into low exposure and high exposure residents) and a sample of 697 residents from a non-exposed area. In fall of 2010, all consenting participants received a questionnaire, containing questions on physical and mental well-being. The exposed group received additional questions related to how they experienced the eruption.

Results Questionnaires were received from 1,146 participants in the exposed group (71%) and 510 participants in the non-exposed group (73%). Compared to the non-exposed group, participants living in the high-exposed area were at increased risk of experiencing mental distress (GHQ-12 score ≥3) 6-9 months following the eruption (OR 1.39%; 95% CI 1.06 to 1.83). High-exposed participants were furthermore at increased risk of experiencing symptoms of post-traumatic stress disorder (PTSD) compared to those living in the low-exposed area (OR 3.74; 95% CI 1.16 to 12.11). For the exposed group as a whole, we found that those who directly experienced the eruption, e.g. those whose property was damaged, felt insecure during the eruption, had to stay outdoors in ash fall due to work or other duties, or had a view of the volcanic eruption from their home, were more likely to suffer from symptoms of mental distress, PTSD symptoms and perceived stress, compared to others exposed.

Conclusion These findings of increased psychological morbidity following the volcanic eruption claims that future studies and interventions should aim at further identifying vulnerable groups following volcanic eruptions.
Introduction

Volcanic eruptions and other natural disasters are common events that affect people throughout the world every year. During the years 2002-2011, some major natural catastrophes occurred such as the Haiti earthquake in 2010 and the Indian Ocean tsunami in 2004, which rendered the decade’s average annual mortality number due to natural disasters as high as 107,000 and 268 million victims annually otherwise affected (Guha-Sapir, 2012; Noji, 1996). These high numbers emphasize the importance of understanding the potential effects disasters have on the people exposed, not only the physical health effects (e.g. respiratory health, injuries and diseases) but also the mental health effects.

Previous studies assessing psychological effects of natural disasters have shown that survivors are prone to experience symptoms of psychological morbidity, such as post-traumatic stress disorder (PTSD), depression and anxiety (Kokai et al., 2004; Neria et al., 2008; Norris et al., 2002a).

In April 2010, the Eyjafjallajökull volcano in Southern Iceland erupted, directly affecting more than 2,000 residents of the area closest to the volcano, most notably through vast amounts of finely grained ash emitted for more than five weeks during the eruption, and repeatedly re-suspended for months after that. The ash affected both people and animals, reduced visibility, delayed transportation, and damaged property (Briem, 2010; Carlsen et al., 2012; Karlsdóttir et al., 2012). In a cross sectional study on 207 individuals living close to the volcano, 39% showed symptoms of mental distress, seven weeks after the onset of the eruption (Carlsen et al., 2012). In addition, a population based study conducted six months after the onset of the eruption (N=1615) showed that mental distress was marginally more common among those exposed to the eruption compared to those not exposed (Carlsen et al., 2012).

A variety of risk factors have been found to be associated with mental health problems in the aftermath of disasters, such as higher exposure, female gender and having prior psychiatric problems (Chen et al., 2001; Neria et al., 2008; Norris et al., 2002a; Norris et al., 2002b; Yang et al., 2003). However, further studies are needed to assess the impact of volcanic eruptions on the mental health of exposed populations; what factors may predict adverse mental health effects and which subgroups within exposed groups have the highest risk of morbidity.

In many ways, Iceland offers good opportunities for studies on the effects of natural disasters, due to strong infrastructures with ideal access to population-based registries, a literate population motivated to take part in surveys and relatively frequent natural hazards.

The general aim of this study was to examine the mental health effects of the Eyjafjallajökull volcano eruption on nearby residents, six to nine months after the eruption ended. Specifically, to study whether there is increased likelihood of symptoms of mental distress and stress among those living closest to the volcano (high-exposed) compared to those living further away (low-exposed) and those non-exposed, i.e. living in a different part of the country. PTSD symptoms were assessed in the exposed group with regard to degree of exposure. In addition, the aim was to study whether direct experience and effects of the volcanic eruption, such as; experiencing
material damage, having to use protective equipment while working outside, staying outdoors during ash fall, viewing the eruption from home and experiencing feelings of insecurity during the volcanic eruption increased the risk of psychological morbidity.

**Methods**

**Study population**

This cross-sectional study included a population of residents 18-80 years old living in an area close to the Eyjafjallajökull volcano at the time of the eruption (N=1,615), who were located in the area at the time of the eruption, spoke Icelandic fluently and could be reached at the time of the study. A sample from a population of residents living in a non-exposed area in Northern Iceland (N=697), matched to the exposed group with regard to age, gender and urban/rural habitation was further included (see Figures 1-2).

**Procedure**

Six to nine months after the eruption ended, a letter describing the purpose of the study was sent to the exposed group, followed by a telephone call a few days later asking for the participants consent and their preference for a paper or online questionnaire. Subsequently, questionnaires were sent via email or postal mail to those who agreed to participate. The comparison group was contacted in a similar way, except that the introductory letter stated that a questionnaire would be sent a few days later, unless participation was declined (Carlsen et al., 2012). A week later, participants received a combined thank-you/reminder card. If the questionnaire was not answered within a week after receiving the card, participants were reminded again by phone (Carlsen et al., 2012).

**Measures**

**Questionnaire**

The overall questionnaire contained 68 questions concerning demographic background factors, physical and psychological well-being and questions regarding the physical and psychological well-being of children. In addition, the exposed group received questions regarding direct experience to and effects of the volcanic eruption. The current study focuses on the psychological consequences of the volcanic eruption and their predictors.

**Exposure**

Exposure to the volcanic eruption was classified into two categories: high exposure (participants living in the area most exposed to the volcano) and low exposure (participants living in a less
exposed area). In addition, a comparison group was used, consisting of residents living in a part of the country that was not exposed to the eruption or ash-fall (Figure 1).

The questionnaire for the exposed group included questions on direct experience to the volcanic eruption and the effects of the volcanic eruption, including: “How often were you required to stay outdoors in ash fall or drift due to work or other duties?” with response alternatives categorized into (1) no (never) and (2) yes (1-2 hours per day, 2-4 hours per day, 4-6 hours per day or more than 6 hours per day). We also asked: “Have you experienced damages as a result of the volcanic eruption to the following? (a) farm/domestic animals, (b) residence (c) barns/sheds (d) other nearby constructions (e.g. garage or fences), (e) yard and (f) farmland.” The response alternatives were categorized into (1) no (no, not relevant, does not apply) and (2) yes (a little or a lot).

**Mental health**

The questionnaire administered to all participants measured mental health with the following tools:

*General Health Questionnaire - 12-item version (GHQ-12)*

The General Health Questionnaire (GHQ-12) is a screening tool for current mental distress within three domains: social dysfunction, anxiety and loss of confidence (Hankins, 2008). The list is a 12 item self-report measure assessing mood states, six of which are positively phrased and six negatively phrased, including questions such as “Have you been able to concentrate on what you are doing?” and “Have you thought of yourself as worthless?”. Each item of the GHQ-12 has four response options. Scores are coded on a bimodal scale (0-0-1-1) resulting in a possible score range from 0 to 12. A standard cut-off of ≥3 was used, which is indicative of experiencing more mental distress than usual (Goldberg et al., 2000). GHQ-12 is a widely validated instrument and has been found to be a reliable tool to measure current mental distress (Goldberg et al., 1997). The Icelandic version of the questionnaire was used (Tomasson et al., 2009).

*Perceived stress scale (PSS-4)*

The Perceived stress scale (PSS-4) is used to measure the degree to which situations in one’s life during the past month are appraised as stressful (Cohen et al., 1983). The four-item version of the PSS list used in this study has proven to be a good tool to measure perceived stress, with a coefficient alpha reliability of 0.72 (Cohen et al., 1983). The scale includes questions such as “In the last month, how often have you felt confident about your ability to handle your personal problems?” Answers are coded on a five point Likert scale (never = 0; almost never = 1; sometimes = 2; fairly often = 3; very often = 4) resulting in a score from 0-16. To be able to identify those highly stressed, a cut-off point at the 90th percentile of the total PSS-4 scores was defined (Hauksdottir et al., 2013), giving a score of 7 and above as a cut-off score to identify the highly stressed group. The Icelandic version of the questionnaire was used (Jónsson et al., 2011).
The questionnaire administered to only the exposed participants measured mental health with the following tool:

*Primary care PTSD (PC-PTSD)*

The Primary Care PTSD (PC-PTSD) is a four-item screening tool for PTSD in the primary care setting assessing symptoms in the past month. The list includes an introductory sentence to cue respondents to answer questions with the Eyjafjallajökull volcanic eruption in mind. Items reflect the four factors that are specific to the DSM-IV criterion of PTSD: re-experiencing, numbing, avoidance and hyperarousal (Prins et al., 2003). An example is “Have you had nightmares about it or thought about it when you did not want to?” Scores are coded into binary response format (yes/no) and a cut-off score of ≥3 was used. The list has been translated into Icelandic (Reykjavíkurborg, n.d).

**Covariates**

The questionnaire assessed several demographic factors, e.g. gender, age, education, marital status and occupation. Age was categorized into (1) 18-50 years old and (2) 51-80 years old. Education was categorized as (1) professional or university education, (2) secondary education and (3) primary education or less or other education. Marital status was categorized as (1) married or in a relationship and (2) single, divorced or widowed. Occupation was categorized as (1) full or part-time job or student and (2) unemployed, homemaker, maternity leave, retired, on disability or sick leave.

**Statistical analysis**

Statistical analysis was conducted using SPSS statistical program, version 22. First, descriptive statistics were calculated for gender, age, education, marital status, occupation, direct experiences and effects of the volcanic eruption. P-values were calculated using chi-square test for contingency tables. Secondly, logistic regression was conducted to evaluate odds ratios (ORs) and 95% confidence intervals (CIs) of current mental distress (measured by GHQ-12), PTSD symptoms (measured by PC-PTSD) and perceived stress (measured by PSS-4). We compared the exposed group with regard to degree of exposure as well as the exposed vs. control groups with regard to gender, age, education, marital status and occupation. Models were adjusted for age, gender and education.

**Ethical issues**

This study was approved by the Icelandic Data Protection Authority (no. S4878/2010) and the National Bioethics Committee (no. VSNb2010080002/03.7). All participants included in the study gave informed consent.
Results

Responses were received from 1,146 participants in the exposed group (71%) and 510 participants in the control group (73%) (Figure 2). There were no statistically significant differences between the exposed and the control groups with regard to gender, age, occupation and marital status. However, the level of education was slightly lower in the exposed group compared to the control group (p-value < 0.05) (Table 1). When exposed participants were classified with regard to degree of exposure (low exposure (N=152) vs. high exposure group (N=994)) a slightly higher proportion of younger residents was found in the latter (p-value < 0.05). The high exposure group was more likely to have experienced damage due to the volcanic eruption, had to use protective equipment while working outside during or after the eruption, required to stay outdoors in ash fall or drift due to work or other duties and had the eruption in plain view from their home (all p-values < 0.001) (Table 1).

Mental distress

Table 2 shows the proportion among different groups (non-, low- and high exposed) reporting current mental distress, as measured with GHQ-12. Odds ratios are presented within groups of gender, age, education level, marital status and employment status. ORs are adjusted for age, gender and education (Table 2).

High-exposed participants were at an overall increased risk of experiencing mental distress six to nine months following the eruption (OR 1.39; 95% CI 1.06 to 1.83) compared to non-exposed participants. No significant difference in mental distress was found between non- and low exposed participants (OR 1.05; 95% CI 0.66 to 1.67). A similar trend was observed for both genders, although not statistically significant (females OR 1.35; 95% CI 0.94 to 1.96 and males OR 1.39; 95% CI 0.94 to 2.06). With regard to age, younger participants (18-50) in the high exposure group were at increased risk of mental distress compared to non-exposed participants in the same age group (OR 1.43; 95% CI 1.02 to 2.01). Similar results, although not significant, were found when comparing the high and low exposure groups of this age (OR 1.47; 95% CI 0.81 to 2.64) (Table 2). Participants with a university degree in both exposure groups were at increased risk of mental distress compared to non-exposed group (OR 3.35; 95% CI 1.36 to 8.27 for the low-exposed group and OR 2.37; 95% CI 1.28 to 4.38 for the high exposed-group) (Table 2). No significant difference was found among different exposure groups with less education. With regard to marital status, high exposed residents who were married or in a relationship were at increased risk of mental distress compared to non-exposed participants (OR 1.41; 95% CI 1.04 to 1.92). However, this did not apply to the single, divorced or widowed (Table 2). Participants in the high exposure area who were employed or studying were at increased risk (marginally significant) of mental distress compared to the non-exposed (OR 1.36; 95% CI 1.003 to 1.86). This did not apply to those who were unemployed, homemakers, on maternity leave, retired, on disability or on sick leave (Table 2).
PTSD symptoms and stress symptoms

With regard to PTSD symptoms, the high exposed group was at increased risk compared to the low exposed group (OR 3.74; 95% CI 1.16 to 12.11). For gender specific results, females in the high exposure group were at increased risk of PTSD symptoms compared to females in the low exposure group (OR 8.01; 95% CI 1.09 to 58.96). Regarding occupational status, a similar trend was observed for those who were employed or studying compared to the non-exposed (OR 4.74; 95% CI 1.13 to 19.83). However, this did not apply when perceived stress symptoms were assessed (Appendix A).

Direct experience of the volcanic eruption and psychological morbidity.

Table 3 shows results from a multiple logistic regression model analysing experience related risk factors for experiencing symptoms of mental distress, PTSD symptoms and perceived stress following the volcanic eruption. All ORs are adjusted for age, gender and education (Table 3). Those who suffered material damages due to the volcanic eruption were at increased risk of mental distress (OR 2.70; 95% CI 2.02 to 3.60), PTSD symptoms (OR 5.21; 95% CI 2.98 to 9.11) and perceived stress (OR 1.37; 95% CI 1.02 to 1.85), compared to those who did not suffer such damages. Similarly, those who felt insecure during the eruption were more likely to experience mental distress (OR 3.56; 95% CI 2.40 to 5.26), PTSD symptoms (OR 11.35; 95% CI 6.67 to 19.31) and perceived stress symptoms (OR 2.33; 95% CI 1.55 to 3.49), than those who did not experience insecurity. Residents who had to use protective equipment outside during the eruption were at increased risk of developing mental distress (OR 1.53; 95% CI 1.11 to 2.11) and PTSD symptoms (OR 2.39; 95% CI 1.23 to 4.62), compared to those who did not have to use protective equipment while outside. In addition, those who were required to stay outdoors in ash fall or drift due to work or other duties were more likely to experience mental distress (OR 1.59; 95% CI 1.17 to 2.15), as well as PTSD symptoms (OR 4.77; 95% CI 2.39 to 9.52) and perceived stress symptoms (OR 1.54; 95% CI 1.12 to 2.12), compared to others. Having had a view of the eruption from ones home also increased the risk of mental distress (OR 3.08; 95% CI 1.89 to 5.04), PTSD symptoms (OR 14.22; 95% CI 1.96 to 103.27) and perceived stress symptoms (OR 1.78; 95% CI 1.13 to 2.80).

Discussion

In our 6-9 month follow-up of residents exposed to the Eyjafjallajökull volcanic eruption, being highly exposed to the volcano was strongly associated with an increase in mental distress compared to the non-exposed participants living in a different part of the country. Further, our findings indicated that younger participants, those with a university degree and who are married or in a relationship were more vulnerable to mental distress following the eruption.
Highly exposed participants were at greater risk of experiencing PTSD symptoms compared to low-exposed participants. Risk factors for PTSD symptoms were being female, employed and student. Finally, we found increased risk of mental distress, PTSD symptoms and stress among those who had had directly experienced the volcanic eruption (e.g. experienced property damage, stayed outside in ash fall, had view of the volcano from one’s home or felt insecure during the eruption).

**Psychological morbidity**

Existing studies that have examined mental health effects in relation to volcanic eruptions and other types of natural disasters, e.g. earthquakes, avalanches and tsunamis, have established similar findings to ours, i.e. that psychological morbidity increases following such disasters (Carlsen et al., 2012; Chen et al., 2001; Goto et al., 2006; Kokai et al., 2004; Norris et al., 2002a; Ohta et al., 2003; Ticehurst et al., 1996; Yang et al., 2003).

In our study, 25.4% of high-exposed residents experienced mental distress compared to 19.1% of the control group. Our findings indicate less mental distress than the findings of Carlsen et al. (2012) where 39% of 207 individuals living close to the Eyjafjallajökull volcanic eruption showed symptoms of mental distress a few weeks after the onset of the eruption. Our study was conducted 6-9 months after the onset of the eruption but the study of Carlsen et al. (2012) only few weeks after the onset. The difference in mental distress in our study and Carlsen’s et al. (2012) is probably due to normal decline in symptoms of mental distress over time. Neither are our findings as severe as those of a study on mental distress in evacuees following a volcanic eruption of Mt Unzen-Fugen in Japan, where 67% of evacuees showed symptoms of mental distress one month after the onset of the eruption but only 10% of a control group of residents that were not evacuated (Araki et al., 1998). A possible explanation is the difference in severity of these two disasters. The volcanic eruption of Mt Unzen-Fugen had dramatic consequences and entailed injuries, deaths and evacuation for a long time, none of which were the case in the eruption in the current study.

Some studies have examined the effects of exposure on mental health following a natural disaster (Araki et al., 1998; Goenjian et al., 1994; Goenjian et al., 2005; Neria et al., 2008; Shore et al., 1986; Wang et al., 2000). A study on adolescents following an earthquake in Armenia showed higher levels of depression and PTSD symptoms among those living in a highly exposed area compared to those living in a less exposed area, both 1.5 years and 5 years post-earthquake (Goenjian et al., 2005). After the Mount St. Helens eruption in 1980, a study found higher levels of generalized anxiety, major depression and PTSD among those living in an area close to the volcano. Our findings are consistent with these studies that indicate a dose-response pattern between psychological morbidity and exposure to the volcano (Shore et al., 1986). In line with previous research, we found higher levels of mental distress among high-exposed residents compared to a non-exposed group and greater PTSD symptomology among high exposed residents compared to low exposed residents.
As for demographic factors and effects on psychological morbidity, previous studies have found females to be more prone to such outcomes following natural disasters than males (Goto et al., 2006; Norris et al., 2002a; Ohta et al., 2003). In Norris et al. (2002a), disaster literature review, 94% of the studies that found a gender difference with regard to psychological morbidity found females to be more negatively affected after disasters than males, particularly with regard to PTSD. In our study, females in the high exposure group are at greater risk of PTSD symptoms compared to females in the low exposure group. However, no such increased risk was found among males. These findings indicate that exposure level during disasters is a risk factor for PTSD symptomology for females but not for males.

Findings on the relationship between age and psychological morbidity following disasters are diverse, whereas some studies report increased risk of psychological morbidity among the elderly (Ohta et al., 2003; Ticehurst et al., 1996) while others report increased risk among middle aged and younger people (Goenjian et al., 1994; Shore et al., 1986). In our study, younger participants (18-50 years old) in the high exposure group were more likely to experience mental distress compared to non-exposed participants in the same age group, a difference not found for older individuals. Our findings indicate that exposure level during disasters is a risk factor for mental distress for younger people, but not for people of older age.

Direct experience and effects of the volcanic eruption

Our findings on the association between property damage and psychological morbidity are consistent with those of Goto et al. (2006) on 231 Japanese evacuees after a volcanic eruption in Miyake Island, which showed that property loss, damage to property or uncertainty of losses was associated with higher levels of PTSD symptoms 10 months post-disaster. Similarly, a study on 3007 Australian adults following an earthquake in Newcastle in 1989, found that living in a moderately damaged area and experiencing property damage was associated with psychological morbidity 6 months after the earthquake (Carr et al., 1995). Similar results were found in a study conducted on Italian males 7 years after an earthquake, showing that experiencing material damage was associated with higher levels of psychological distress (Bland et al., 1996).

To our knowledge, this is the first study to examine the effects of other direct experiences following a natural disaster leading neither to injuries nor fatalities, and only to limited evacuation. We have thus found no other studies that have investigated direct experiences such as insecurity during a volcanic eruption, having to use protective equipment outdoors, spending time outside in ash fall, and having a view of a active volcano from one’s home. These direct experiences could lead to future mental health problems and therefore it is important to examine what impact these factors have on people who experience natural disasters.
**Strength and limitations**

As noted above, Iceland offers opportunities for studies where the whole population is identified through population-based registries. This strengthens the study, as do other factors such as the demographic similarities between different parts of the country that facilitate reliable comparison of the exposed and non-exposed groups, the high response rate in both groups and the fact that we used standardized measurements to assess mental health.

Limitations include lack of information on previous psychological morbidity. It is possible that those with previous psychological morbidity may have experienced the eruption differently (e.g. felt more insecure) than others. However, findings on more objective experiences (e.g. property damages) should be minimally affected by this. Another limitation is that despite the number of participants being relatively large, some sub-analyses are hampered due to limited statistical power. For example, age is only categorized into two groups and although it might be interesting to subdivide age into more categories the total number of participants divided by exposure does not allow that.

**Conclusion**

As many volcanic eruptions are life threatening, residents often have to evacuate their homes for extensive periods of time (Goto et al., 2006; Ohta et al., 2003; Shore et al., 1986). Although evacuation may not be needed nor the eruption result in any casualties, the event may have a severe impact on people’s well-being and everyday life. It is therefore important to understand these impacts and how they may be alleviated.

In conclusion, our findings indicate that high-exposed residents living closest to the Eyjafjallajökull volcano at the time of the eruption are more likely to suffer from symptoms of mental distress than low-exposed and non-exposed residents. Also, that high-exposed residents are more likely of suffering from PTSD symptoms than low-exposed residents. Furthermore, our findings indicate that people who see the eruption from their home and directly experience the eruption (i.e. experienced material damage, had to use protective equipment while working outside, stayed outdoors during ash fall and experienced feelings of insecurity during the volcanic eruption) are at increased risk of suffering from symptoms of psychological morbidity.

The findings call for further studies on underlying mechanisms and long-term health, e.g. whether these effects decline with time and whether increased psychological support should be provided to those directly affected by volcanic eruptions.
References


### Tables

**Table 1:** Demographic characteristics of participants in a study on the health effects of the volcanic eruption in Eyjafjallajökull in Iceland 2010 (classified by exposure).

<table>
<thead>
<tr>
<th></th>
<th>Non-exposed (N=510)</th>
<th>Exposed (N=1146)</th>
<th>Low exposure (N=152)</th>
<th>High exposure (N=994)</th>
<th>(p)-value (^1)</th>
<th>(p)-value (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>262 (51.4)</td>
<td>562 (49.0)</td>
<td>74 (48.7)</td>
<td>488 (49.1)</td>
<td>0.38</td>
<td>0.93</td>
</tr>
<tr>
<td>Female</td>
<td>248 (48.6)</td>
<td>584 (51.0)</td>
<td>78 (51.3)</td>
<td>506 (50.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-50</td>
<td>270 (52.9)</td>
<td>635 (55.4)</td>
<td>71 (46.7)</td>
<td>564 (56.7)</td>
<td>0.35</td>
<td>0.02*</td>
</tr>
<tr>
<td>51-80</td>
<td>240 (47.1)</td>
<td>511 (44.6)</td>
<td>81 (53.3)</td>
<td>430 (43.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional or university education</td>
<td>119 (23.8)</td>
<td>234 (20.7)</td>
<td>32 (21.3)</td>
<td>202 (20.6)</td>
<td>0.02*</td>
<td>0.62</td>
</tr>
<tr>
<td>Secondary education</td>
<td>189 (37.7)</td>
<td>379 (33.5)</td>
<td>45 (30.0)</td>
<td>334 (34.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary education, no education or other education</td>
<td>193 (38.5)</td>
<td>519 (45.8)</td>
<td>73 (48.7)</td>
<td>446 (45.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married or in a relationship</td>
<td>415 (81.4)</td>
<td>907 (79.1)</td>
<td>119 (78.3)</td>
<td>788 (79.3)</td>
<td>0.30</td>
<td>0.78</td>
</tr>
<tr>
<td>Single, divorced or widowed</td>
<td>95 (18.6)</td>
<td>239 (20.9)</td>
<td>33 (21.7)</td>
<td>206 (20.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Occupational status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time job, part-time job or student</td>
<td>397 (78.3)</td>
<td>862 (76.4)</td>
<td>117 (77.0)</td>
<td>745 (76.3)</td>
<td>0.40</td>
<td>0.86</td>
</tr>
<tr>
<td>Unemployed, homemaker, maternity leave, retired, on disability or on sick leave</td>
<td>110 (21.7)</td>
<td>266 (23.6)</td>
<td>35 (23.0)</td>
<td>231 (23.7)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Experiences during the volcano eruption:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experienced damages</td>
<td>447 (40.3)</td>
<td>9 (6.1)</td>
<td>438 (45.6)</td>
<td></td>
<td>0.00**</td>
<td></td>
</tr>
<tr>
<td>Experienced insecurity</td>
<td>126 (11.2)</td>
<td>12 (8.1)</td>
<td>114 (11.7)</td>
<td></td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Used protective equipment while working outside</td>
<td>789 (70.4)</td>
<td>50 (34.2)</td>
<td>739 (75.8)</td>
<td>0.00**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spent time outside in ash fall due to work</td>
<td>697 (62.3)</td>
<td>49 (33.3)</td>
<td>648 (66.7)</td>
<td>0.00**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Had view of the volcano eruption from own home</td>
<td>881 (82.7)</td>
<td>57 (40.1)</td>
<td>824 (89.3)</td>
<td>0.00**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) \(p\)-value < 0.05; \(^2\) \(p\)-value < 0.001

\(^1\) \(p\)-value for difference between control and exposed group

\(^2\) \(p\)-value for difference between low exposure and high exposure groups
Table 2: Mental distress among participants in a study on the health effects of the volcanic eruption in Eyjafjallajökull in Iceland 2010 (classified by exposure).

<table>
<thead>
<tr>
<th></th>
<th>Control (N=510)</th>
<th>Low exposure (N=152)</th>
<th>High exposure (N=994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>97 (19.1)</td>
<td>30 (20.0)</td>
<td>249 (25.4)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.05 (0.66-1.67)</td>
<td>1.39 (1.06-1.83)*</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.28 (0.83-1.96)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>52 (21.1)</td>
<td>15 (19.7)</td>
<td>139 (27.8)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>0.88 (0.46-1.68)</td>
<td>1.35 (0.94-1.96)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.49 (0.82-2.73)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>45 (17.2)</td>
<td>15 (20.3)</td>
<td>110 (22.8)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.34 (0.68-2.60)</td>
<td>1.39 (0.94-2.06)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.07 (0.58-1.98)</td>
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</table>

<table>
<thead>
<tr>
<th>Age</th>
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</tr>
</thead>
<tbody>
<tr>
<td>18-50</td>
<td>61 (22.7)</td>
<td>16 (22.9)</td>
<td>168 (30.3)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.01 (0.60-1.71)</td>
<td>1.43 (1.02-2.01)*</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.47 (0.81-2.64)</td>
<td></td>
</tr>
<tr>
<td>51-80</td>
<td>36 (15.1)</td>
<td>14 (17.5)</td>
<td>81 (19.0)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.23 (0.61-2.44)</td>
<td>1.29 (0.83-2.00)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.05 (0.56-1.98)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional or university education</td>
<td>16 (13.6)</td>
<td>11 (34.4)</td>
<td>54 (27.0)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>3.35 (1.36-8.27)*</td>
<td>2.37 (1.28-4.38)*</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>0.70 (0.32-1.55)</td>
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</tr>
<tr>
<td>Primary education, no education or other education</td>
<td>45 (23.4)</td>
<td>12 (16.9)</td>
<td>106 (24.0)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>0.74 (0.36-1.52)</td>
<td>1.01 (0.67-1.51)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.38 (0.71-2.70)</td>
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</tr>
<tr>
<td>Secondary education</td>
<td>36 (19.1)</td>
<td>7 (15.6)</td>
<td>86 (28.1)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>0.77 (0.32-1.87)</td>
<td>1.41 (0.90-2.19)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.95 (0.83-4.53)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marital status</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Married or relationship</td>
<td>72 (17.4)</td>
<td>22 (18.6)</td>
<td>188 (24.1)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.05 (0.61-1.79)</td>
<td>1.41 (1.04-1.92)*</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.31 (0.80-2.15)</td>
<td></td>
</tr>
<tr>
<td>Single, divorced or widowed</td>
<td>25 (26.6)</td>
<td>8 (25.0)</td>
<td>61 (30.3)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>0.91 (0.35-2.34)</td>
<td>1.15 (0.66-2.01)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.26 (0.52-3.02)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupational status</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time job, part-time job or student</td>
<td>73 (18.5)</td>
<td>25 (21.4)</td>
<td>182 (24.8)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>1.19 (0.71-1.99)</td>
<td>1.36 (1.00-1.86)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.12 (0.69-1.81)</td>
<td></td>
</tr>
<tr>
<td>Unemployed, homemaker, maternity leave, retired, on disability or on sick leave</td>
<td>24 (22.0)</td>
<td>5 (15.2)</td>
<td>61 (26.4)</td>
</tr>
<tr>
<td>ORs for control vs. low and high exposure</td>
<td>1.0-Ref</td>
<td>0.60 (0.20-1.78)</td>
<td>1.22 (0.70-2.11)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0-Ref</td>
<td>1.97 (0.72-5.40)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Mental distress was measured with the GHQ-12 (General health questionnaire) referring to “the previous weeks”, using a binary cut-off score of =>3.
* P < 0.05
ORs are adjusted for age, gender and education.
Table 3: Disaster related risk factors and symptoms of mental distress, PTSD symptoms and perceived stress among participants exposed to the eruption in a study on the health effects of the volcanic eruption in Eyjafjallajökull in Iceland 2010.

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>GHQ-12(^1) OR (95% CI)</th>
<th>PC-PTSD(^1) OR (95% CI)</th>
<th>PSS-4(^1) OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced damages due to the volcano (yes)</td>
<td>2.70 (2.02-3.60)**</td>
<td>5.21 (2.98-9.11)**</td>
<td>1.37 (1.02-1.85)*</td>
</tr>
<tr>
<td>Experienced insecurity during the volcano (yes)</td>
<td>3.56 (2.40-5.26)**</td>
<td>11.35 (6.67-19.31)**</td>
<td>2.33 (1.55-3.49)**</td>
</tr>
<tr>
<td>Used protective equipment while working outside during or after the volcanic eruption (yes)</td>
<td>1.53 (1.11-2.11)*</td>
<td>2.39 (1.23-4.62)*</td>
<td>1.15 (0.83-1.76)</td>
</tr>
<tr>
<td>Spent time outside in ash fall due to work (yes)</td>
<td>1.59 (1.17-2.15)*</td>
<td>4.77 (2.39-9.52)**</td>
<td>1.54 (1.12-2.12)*</td>
</tr>
<tr>
<td>Noticed the volcanic eruption from your home (yes)</td>
<td>3.08 (1.89-5.04)**</td>
<td>14.22 (1.96-103.27)*</td>
<td>1.78 (1.13-2.80)</td>
</tr>
</tbody>
</table>

\(^*\) P-value < 0.05; \(^**\) P-value < 0.001; \(^1\) PSS-4 >=90\(^\text{th}\) percentile

Note. Mental distress was measured with the GHQ-12 (General health questionnaire). Post-traumatic stress disorder (PTSD) was measured with the PC-PTSD (Primary care PTSD). Perceived stress was measured with the PSS-4 (Perceived stress scale).

\(^1\) ORs are adjusted for age, gender and education.
Figure 1: Map of Iceland and study areas of the Eyjafjallajökull volcanic study. The map of Iceland shows the study area close to the Eyjafjallajökull volcanic eruption in Southern Iceland and the control area in Skagafjörður in Northern Iceland. The larger map of the exposed areas shows Eyjafjallajökull (marked with x) and the low and high ash exposure areas.
Figure 2: Residents participating in the study on health effects of the volcanic eruption in Eyjafjallajökull in Iceland 2010.
Appendix

Appendix A – Perceived stress and PTSD symptoms among those exposed to the volcanic eruption and the control group.

<table>
<thead>
<tr>
<th></th>
<th>Control (N=510) OR (95% CI)</th>
<th>Low exposure (N=152) OR (95% CI)</th>
<th>High exposure (N=994) OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSS-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR for control vs. low and high exposure</td>
<td>1.0 – Ref</td>
<td>0.8 (0.49 – 1.29)</td>
<td>1.03 (0.78 – 1.34)</td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0 – Ref</td>
<td>1.28 (0.82 – 2.02)</td>
<td></td>
</tr>
<tr>
<td>PTSD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR for low exposure vs. high exposure</td>
<td>1.0 – Ref</td>
<td>3.74 (1.16 – 12.11)*</td>
<td></td>
</tr>
</tbody>
</table>

Note: Perceived stress was measured with the PSS-4 (Perceived stress scale) referring to "the past month", using a binary cut-off point at the 90th percentile and post-traumatic stress disorder symptoms was measured with the PC-PTSD (Primary care PTSD) referring to "the past month, using a binary cut-off score of =>3.

* P < 0.05

1 ORs are adjusted for age, gender and education.