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Spatiotemporal Analysis of Health Care Service Utilization for Post-Traumatic Stress Disorder Before and After the Sewol Ferry Disaster in Ansan City, Korea

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Abstract

Use of Health Care Services for Post-Traumatic Stress Disorder Before and After the Sewol Ferry Disaster in Ansan City, Korea

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Background: Disasters are traumatic events that may result in physical and mental health problems. Following exposure to disasters, individuals often suffer from depression, anxiety disorder, and/or suicidal ideation. Above all, post-traumatic stress disorder (PTSD) is the most common mental health disorder that affected individuals can experience; therefore, many studies have been conducted to investigate the effect of disasters on PTSD. However, few studies consider spatial and temporal variation in the analysis.

We first investigated changes in post-traumatic symptoms after Sewol ferry disaster on April 16, 2014 in Ansan-si compared to Gyeonggi-do. Then, we performed spatiotemporal analysis by using small area units to capture any effects of the disaster.

Methods: Data were collected using National Health Insurance Service database from 2011 to 2016. Inpatients, outpatients, and emergency patients who received health insurance benefits in Gyeonggi-do were included in the analysis. DID estimators and Bayesian spatiotemporal Poisson regression model was used to examine the change in the health service utilization in patients with PTSD after the Sewol ferry disaster, and to compare health service utilizations in high-risk areas to those of low-risk areas.

Results: After the Sewol ferry disaster, inpatients living in high-risk areas showed significant increase in the PTSD health service utilization (RERI, 0.40; 95% CI, 0.25, 0.79). Outpatients and emergency care visits for PTSD showed no significant association with the time of the event and the area (outpatients: RERI, -0.02, 95% CI, -0.03, 0.00; emergency patients: RERI, 0.20, 95% CI, -0.02, 1.15).

Conclusion: Increased risk for hospitalization due to PTSD was found in the high-risk areas after the Sewol incidence. Detrimental effects of the traumatic event observed in the study imply the need of mental health surveillance systems and proper interventions.

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Keywords: Post-traumatic stress disorder, Disaster, Mental health, Spatiotemporal analysis, Sewol ferry disaster,
Medical use

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I. INTRODUCTION

1.1 Disaster and mental health

Disasters are collectively experienced mass traumatic events that may result in physical and mental health problems. Scale and outcome need to be considered when defining an event to be a disaster (Neria, Nandi, & Galea, 2008). If the scale of an event is large and its consequences are significant, it can be classified as a disaster (Neria et al., 2008). All forms of disaster share some key characteristics in that they harm and cause death of a large population. Primary consequences of a disaster are disruptions of services, social networks, and communal resources. A significant number of affected individuals suffer secondary consequences after a disaster. Secondary consequences are identifiable by mental and physical health outcomes (Goldmann & Galea, 2014).

Following exposure to disasters, individuals often suffer from major depressive disorder, general anxiety disorder, substance use disorder, suicidal ideation, and/or post-traumatic stress disorder as psychological symptoms and asthma, chronic pain syndromes, and hypertension as somatic symptoms (Boscarino, 1996; Goldmann & Galea, 2014; Krysinska & Lester, 2010; Yehuda, 2002; Zatzick et al., 1997). The aftereffects rarely occur in isolation. Comorbidity with one or more psychological disorders are common; for instance, about 80% of patients with PTSD have some other disorders (Helzer, Robins, & McEvoy, 1987; Kessler et al., 1995). Above all, post-traumatic stress disorder (PTSD) is one of the most common mental health disorder that affected individuals can experience. Because PTSD is the only disorder whose diagnosis is based on the experience of a traumatic event, it is most commonly occurring and widely studied psychopathology in the aftermath of disasters (Galea, Nandi, & Vlahov, 2005; Goldmann & Galea, 2014; Neria et al., 2008; Norris, Friedman, Watson, et al., 2002).

1.2 Definition of PTSD

A traumatic event is characterized by actual or threatened death or injury that induce the feeling of fear, helplessness, or horror (Bisson, 2007; Yehuda, 2002). When a person who experienced a traumatic event present symptoms from three diagnostic criteria together for at least one month and present distress, impairments in social, occupational, or other significant functions, she or he can be diagnosed with PTSD (Bisson, 2007). The three distinct diagnostic criteria for PTSD are re-experiencing of the traumatic event, avoidance and numbing, and hyperarousal (APA, 2000; Krysinska & Lester, 2010). Lifetime prevalence of PTSD is 6.8% in the United States (Kessler et al., 2005) while an estimated lifetime prevalence of full PTSD in Korea was 1.7%, and 2.7% for partial PTSD (Jeon et al., 2007).

The prevalence of PTSD is 30-40% among direct victims and 5-10% in the general population (Galea et al., 2005; Neria et al., 2008), These estimates vary depending on types of disaster and degree of exposure (Goldmann & Galea, 2014). In one systematic review that reviewed PTSD prevalence and trajectories in trauma-exposed populations, the mean prevalence of PTSD at 1 month after disasters was 28.8% and gradually decreased to 17.0% at 12 months (Santiago et al., 2013). Classifying traumatic events into intentional and non-intentional events increased the median PTSD prevalence, from 11.8% to 23.3%, of intentional events only (Santiago et al., 2013).

1.3 Biological aspects of PTSD

As PTSD symptoms prolong and become chronic, some patients present somatic symptoms as well as psychological symptoms. Physiological changes such as an increase in circulating levels of norepinephrine, thyroid hormone, and reactivity of beta-adrenergic receptor may help us understand physical representation of PTSD (Mason et al., 1994; Southwick et al., 1993). Brain

structures that are involved in the fear responses and memory processes, the limbic regions of the brain including amygdala and hippocampus, were altered in the patients with PTSD (Liberzon et al., 1999; Schuff et al., 2001; Yehuda, 2002). Trauma-related stimuli produced the exaggerated amygdala response and decreased blood flow in orbitofrontal cortex and anterior cingulate (Bremner, 2006; Rauch et al., 2000). In a brain imaging study, the volume of the hippocampus of PTSD patients were similar to those of control subjects without PTSD, but there was a functional problem that led to hippocampal abnormality in patients with PTSD (Schuff et al., 2001).

The biological changes observed in PTSD show a somewhat different pattern than other mental disorders, specifically with major depression (Yehuda, 2002). Patients with major depression have increased levels of corticotropin-releasing factor and cortisol in cerebrospinal fluid while patients with PTSD have increased levels of a corticotropin-releasing factor but have lower than normal cortisol levels (Mason et al., 1986; Yehuda et al., 1995). Hypothalamic–pituitary–adrenal axis sensitivity increases in patients with PTSD unlike those with major depression (Yehuda, 2002). A memory associated with emotional experience improves by beta-adrenergic system activation (Cahill, Prins, Weber, & McGaugh, 1994). Decreased cortisol levels during the time of trauma also enhances adrenergic activation. More norepinephrine available in the synapses consolidate the memory of events (Pacak, Palkovits, Kopin, & Goldstein, 1995). If traumatized individuals experience these biological changes, the traumatic event will be strongly encoded in the memory as well as associating the event with an intense feeling of torment, grief, and distress (Yehuda, 2002).

1.4 Prognosis and course of disaster-induced PTSD

According to a review article that summarized results from longitudinal

studies that investigated the relationship between disaster and PTSD, PTSD effects or symptoms reach their peak in the first year of a disaster exposure. Most people show improvement over time. Relatively small proportions of people have lingering symptoms that remain stable for months and years (Norris, Friedman, & Watson, 2002). In rarer cases, delayed dysfunction—PTSD symptoms emerge after a reasonable amount of time (at least 6 months) has passed from the event—can be observed (Bisson, 2007; Norris, Tracy, & Galea, 2009). PTSD recovery differs from resilience. Trauma-exposed people who have high resilience have successful adaptability following intense stressors or traumatic events (Norris et al., 2009). They have a capability to quickly return to pre-disaster levels of functioning (Goldmann & Galea, 2014).

Many researchers found a number of risk factors for PTSD to identify high-risk population (Brewin, Andrews, & Valentine, 2000; Ozer, Best, Lipsey, & Weiss, 2003). To assess disaster exposure, the number and intensity of traumatic event exposure, death toll, disaster type, duration of exposure, and proximity to the event site are commonly measured (Goldmann & Galea, 2014). Pre-disaster risk factors are prior mental illness, female, and a young age (Galea et al., 2005; Neria et al., 2008). The most predictive factor of mental illness after the disaster is one of the peri-disaster risk factor; the severity or degree of exposure to the event whether the exposure was direct or not (Goldmann & Galea, 2014). Post-disaster life stressors and social support are two major predictors that determine the course of disaster-related mental illness (Galea et al., 2005; Goldmann & Galea, 2014).

Peri-disaster factors strongly influence PTSD symptoms such as intrusion and arousal symptoms, but post-disaster factors influence depression and avoidance symptoms more strongly (Norris, Perilla, Riad, Kaniasty, & Lavizzo, 1999). Rather than pre-disaster characteristics, peri-disaster

psychological processes are the strongest PTSD predictors (Ozer et al., 2003). Nonetheless, post-disaster factors surpass the importance of peri-disaster factors in understanding the long-term effects of disasters (Norris et al., 1999).

1.5 PTSD after human-made disasters

Disasters can be divided into three broad categories: natural, human-made intentional technological, and human-made non-intentional technological disasters (Goldmann & Galea, 2014). The burden of mental health consequences in the affected population is determined by the type of disaster influences. Neria and his colleagues (2008) conducted a systematic review on articles published from 1980, when PTSD first appeared on Diagnostic and Statistical Manual of Mental Disorders, Third Edition (DSM-III), to February 2007. 284 articles had documented PTSD following disasters. Natural disasters were the most studied (n=116), 65 articles on technological disasters, and 90 articles on human-made disasters. For human-made disasters, a large body of literature, about 65%, focused on the September 11 terrorist attacks and Oklahoma bombing.

Often human-made technological disasters have a more marked effect on disaster-affected population's mental health than natural disasters have (Galea et al., 2005; Norris et al., 2002). Specific groups of victims are generally studied when it comes to human-made disasters: direct victims such as survivors from disasters or indirect victims such as rescue workers, people who lost family members, or people who witnessed disaster events directly or indirectly through media (Galea et al., 2005). Even when the disasters are similar, variation in exposures among victims complicates extrapolation from one context to another. Most studies have focused on adults who were direct victims of the disaster in human-made disasters (Galea et al., 2005). The prevalence of PTSD after human-made

technological disasters is between 25 and 75 percent in the first year according to one systematic review (Galea et al., 2005). In specific, the prevalence range between 30-60 percent in survivors, approximately 5-40 percent in rescue workers, 1-11 percent in the general population (Galea et al., 2005). These results indicate that populations directly affected by disasters are the more vulnerable group to PTSD than the rest.

1.6 Sewol Ferry disaster in South Korea

On April 16, 2014, Sewol ferry capsized and sank near Jindo County, South Jeolla-do. The Sewol ferry disaster has killed a total of 304 victims. 250 victims, approximately two-thirds of entire victims, were students at Danwon High School in Ansan-si. The sinking of the Sewol was broadcast live throughout the country for several days, bringing trauma to the people who watched the situation. Overall interest in PTSD has also increased after the disaster. As of 2014, there has been a sharp increase in disaster research, particularly on safety culture and the victims' mental health (Lee & Kim, 2016). Twelve papers on disasters were published in 2004, 72 in 2013, 131 in 2014, 149 in 2015, and 122 in 2016 (Lee & Kim, 2016)

The process of the Sewol ferry disaster was continuously reported through the media. The negative impact of media exposure, particularly television viewing, on PTSD was well-established in previous literature (Ahern et al., 2002; Pfefferbaum et al., 2000; Schlenger et al., 2002). Community residents both directly involved in the trauma event as well as those indirectly exposed suffer from psychological stress by watching the events through the media (Holman et al., 2014). However, the results show that residents in areas exposed to traumatic events watch more news, suggesting that the live footage of the Sewol disaster could have become a bigger trauma to residents living near Danwon High School. Residents living near the school is more likely to know the victims directly or indirectly. In

the case of the September 11 terrorist attacks, PTSD prevalence of people living near the terror site (high-risk group) was higher than those living far away (low-risk group) (Bonanno et al., 2006; Galea et al., 2003). In the face of adversity, the ability to go back to the normal functioning and take a leap forward called "resilience" was lower among the high-risk group compared to the low-risk group as well. This can be understood in the same context as the fact that social factors such as knowing the victims, have a significant impact on PTSD (DiGangi et al., 2013; Kim & Jang, 2017).

Precedent studies with regards to the Sewol ferry disaster and PTSD predominantly dealt with a characteristics of the certain population (e.g., survivors, parents of victims, etc). The disasters' effect on direct victims are beyond question, but community residents who can be both direct or indirect victims are rarely brought up and is therefore a long-pending question in a human-made technological disaster research. The same thing applies to the Sewol ferry disaster. Of all the research for PTSD, only three articles focused on the entire Ansan-si community residents. Because of this gap in the research, we tried to conduct a research to provide comprehensive information of the community residents mental health status. The objective of the present study was to identify any changes after the disaster in the Ansan-si community as well as variation within the community. To do so, we first looked at the pattern of Ansan-si and Gyeonggi-do region where Ansan-si belongs to. Second, epidemiological characteristics among two different population groups within the Ansan-si were compared to see whether there is notable differences in the community. People living in three mainly affected areas of Ansan-si are classified as high-risk areas and those living in the remaining areas were classified as low-risk areas. Medical use of mental disorders including PTSD and depression were used for the investigation. Two main hypotheses were made in the study. We first

hypothesized that the prevalence of PTSD will increase after the disaster. Lastly, the high-risk areas will have higher prevalence of PTSD than the lower-risk areas after the Sewol accident.

II. SYSTEMATIC REVIEW

2.1 Epidemiologic study of PTSD in community after human-made technological disasters

In this article, we are particularly interested in PTSD prevalence of highly affected community after human-made technological disasters. A systematic literature search of Pubmed and Embase database was conducted on October 31, 2018, by using keywords and corresponding medical subject headings (MeSH) “post-traumatic stress disorder”, “disaster”, “community”, “public health”, and “epidemiology”. The aim of the review was to understand and review current trends in disaster mental health research. 650 articles were identified through database searching, and 130 duplicate articles were screened.

We only included original studies and excluded abstract, comment, letter, review, editorial, and discussion articles. Selection criteria included articles that investigated human-made technological disasters’ effect in a community setting. Populations of our interest were community members and those research that divided exposure group based on exposure levels. Eligible studies had to report post-traumatic stress as outcomes. Relevant articles were compiled in Endnote through a screening process. The final list of 6 studies which met our criteria is listed in Table 2.

Table 1. Search strategy used in Pubmed and Embase

Database	Search terms
Pubmed	("Stress Disorders, Post-Traumatic"[Mesh] OR “Stress Disorders, Post-Traumatic” OR “PTSD”) AND (“Disasters” OR "Disasters"[Mesh]) AND “community” AND ("Public Health"[Mesh] OR “Public Health” OR "Epidemiology"[Mesh] OR “Epidemiology”)
Embase	('posttraumatic stress disorder'/exp OR ‘posttraumatic stress disorder’ OR ‘ptsd’) AND ('disaster'/exp OR 'disaster') AND ('community'/exp OR ‘community’) AND ('public health'/exp OR ‘public health’ OR ‘epidemiology’/exp OR ‘epidemiology’)

Figure 1. Flow diagram of studies included in the literature review of post-disaster PTSD in a community setting

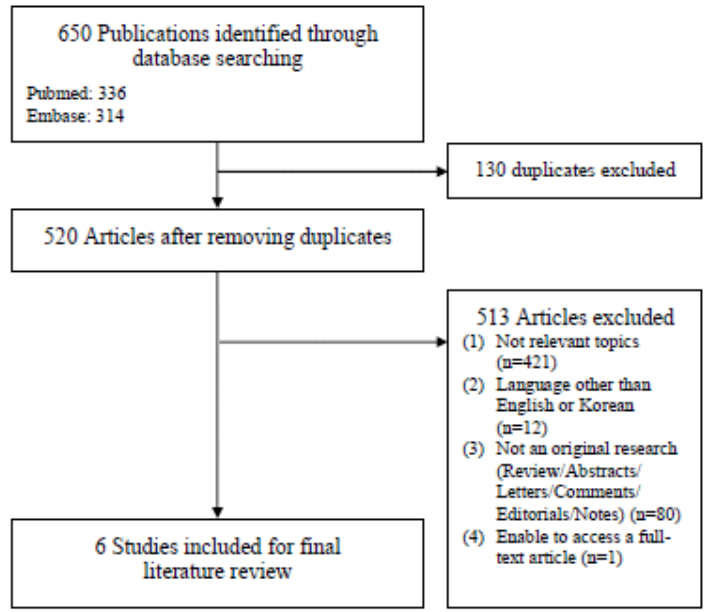


Table 2. Summary of human-made technological disaster exposed population study using different exposure levels for PTSD assessment in a community

Study	Country	Study design	Study period	Subjects	Disaster	Exposure measurement	Outcome	Outcome measurement	Effect Size
Palinkas et al. (1993)	Alaska, United States	Cross-sectional (community survey)	Approximately 1 year after the spill occurred,	699 men and women	Exxon Valdez oil spill	No, low, high exposure	General anxiety disorder, PTSD, depression	Logistic regression analysis (odds ratio)	[PTSD] Unexposed (OR: 1.00, 95% CI: 1.0-1.0) Low exposure (OR: 1.91, 95% CI: 1.13-3.19) High exposure (OR: 3.73, 95% CI: 1.99-6.97)
Chung et al. (2003)	Rickerscote, Stafford, UK.	Cross-sectional (community survey)	7 months after the train disaster	993 residents of Taean District	Railway disaster	Nearer, further away from the crash site	Intrusion, avoidance, somatic, anxiety, social dysfunction, depression, extroversion, psychoticism, neuroticism	Mean score	Stafford residents nearer • Intrusion (mean: 13.16, SD: 10.58) • Avoidance (mean: 11.52, SD: 10.22) Stafford residents further away • Intrusion (mean: 10.33, SD: 12.07 • Avoidance (mean: 9.66, SD: 10.96)
Hoven et al. (2005)	New York, United States	Cross-sectional (community survey)	6 months after September 11, 2001	The sampling plan targeted the universe (excluding special education schools) of New York City public school students enrolled in grades 4-12 (approximately 716 189 youth when the sampling plan was carried out)	September 11, 2001, World Trade Center attack	A citywide, random, representative sample of 8236 students in grades 4 through 12, including oversampling in closest proximity to the World Trade Center site (ground zero) and other high-risk areas.	PTSD, major depression, generalized anxiety, separation anxiety, panic disorder agoraphobia, any anxiety/depressive disorder, conduct disorder, alcohol abuse/dependence	Prevalence, logistic regression models(adjusted odds ratio)	[PTSD Prevalence] Mild exposure: 3.6 % (1.1) Moderate: 10.0 % (1.7) Severe: 18.4 % (2.3) US community studies pre-sepctember 11: 3.3% [Logistic Regression models precting any probable anxious/depressive disorder] Attendance in ground zero area school (AOR: 0.66, 95% CI: 1.24-2.11) Direct exposure (AOR: 1.62, 95% CI: 1.24-2.11) Any family exposure: (AOR: 1.80, 95% CI: 1.28-2.55) High media exposure (AOR: 1.58, 1.23-2.03)

Study	Country	Study design	Study period	Subjects	Disaster	Exposure measurement	Outcome	Outcome measurement	Effect Size
Kim et al. (2013)	Taean, South Korea	Cross-sectional (community survey)	1.5 years after the spill	Total of 10 171 residents living in the study area were surveyed including 9246 adults (male: 3849; female: 5397) and 925 students (male: 505; female: 420 persons).	The Hebei Spirit oil spill	Area 1: < 1.1 km away from the contaminated coastline Area 2: 1.1–4.2 km Area 3: 4.2–23 km Area 4: < 23 km	Asthma, allergy (rhinitis, dematitis, conjunctivitis), mental disease (PTSD, depression)	The excess incidence of disease, estimated from the available prevalence data	[Excess Incidence caused by the oil spill (unit: number of persons)] PTSD Area 1: 1092 (male), 1054 (female) Area 2: 133 (male), 222 (female) Area 3: 0 (male), 0 (female) Area 4: reference
Yang et al. (2015)	Ansan, South Korea	Cross-sectional (community survey)	4 to 6 months after the accident	7,076 adults (≥19 years) living in two victimized communities in Ansan, four control communities from Gyeonggido, Jindo and Haenam near the accident site.	The disaster of the Sewol ferry that sank at sea off Korea's southern coast of the Yellow Sea on April 16, 2014	Proximity to the disaster site	Depression (CES-D), Stress (BEPSI), Somatic symptoms (PHQ-15), Anxiety (GAD-7), Suicidal ideation	Logistic regression (adjusted odds ratio)	[Stress] Ansan (OR: 1.37; 95% CI, 1.10-1.71) Gyeonggi (OR: 1.00, reference) Jindo & Haenam (OR: 0.62, 95% CI: 0.48-0.82)
Choi et al. (2016)	Taean, South Korea	Cross-sectional (community survey)	7 months after the spill occurred	Residents who lived in the Taean District from July 7, 2008, to August 1, 2008.	The Hebei Spirit oil spill (occurred on December 7, 2007)	Distance to the oil band (km); quartiles Q1: 0.17-3.94km distance away from the oil band Q2: 3.84-11.10 Q3: 11.10-14.50 Q4: 14.50-45.20	Post-traumatic stress, Depression, Suicidal ideation, Anxiety	Logistic regression (mutually adjusted odds ratio)	[Post-traumatic stress] Q1 (OR:3.77, 95% CI: 2.30-6.16) Q2 (OR: 1.91, 95% CI: 1.15-3.20) Q3 (OR: 0.73, 95% CI: 0.38-1.38) Q4 (OR: 1.00, 95% CI: 1.00-1.00)

2.2 Mental health research after the Sewol Ferry disaster

A literature search was conducted from October 31, 2018, to November 4, 2018, to identify current mental health research regarding the Sewol Ferry disaster. Pubmed, Embase, DBPIA, RISS, and KoreaMed database were used for searches. The search of the different databases yielded a total of 137 articles after duplicates removal. All types of mental health outcomes in public health research were deemed eligible. In total, 32 studies met our inclusion criteria in total.

A large body of research on the Sewol ferry disaster was done, but only three studies focused on Ansan community. After the incident, 14 papers on post-traumatic stress or PTSD were published in Korean journals and were published in foreign journals after literature search. 15 out of the 32 papers discussed the traumatic experiences of survivors, bereaved families, and friends directly related to the victim. 13 others conducted a study on the population indirectly affected by the Sewol ferry disaster (7 indirect exposures, 2 general public, 2 reporters, 1 teacher, 1 psychiatrist).

Table 3. Search strategy used in Pubmed, Embase, DBPIA, RISS, and KoreaMed

Database	Search terms
Pubmed	("Stress Disorders, Post-Traumatic"[Mesh] OR “Post-Traumatic Stress Disorder*” OR “PTSD” OR "mental illness" OR "Mental Disorders"[Mesh] OR "mental disorder" OR "mental health") AND “Sewol”
Embase	('posttraumatic stress disorder'/exp OR ‘posttraumatic stress disorder’ OR ‘ptsd’) AND ('disaster'/exp OR 'disaster') AND ('community'/exp OR ‘community’) AND ('public health'/exp OR ‘public health’ OR ‘epidemiology’/exp OR ‘epidemiology’)
DBPIA	(1) Sewol AND post-traumatic (2) Sewol AND mental
RISS	(1) Sewol AND post-traumatic (2) Sewol AND mental
KoreaMed	Sewol

Fig. 2. Flow diagram of studies included in the literature review

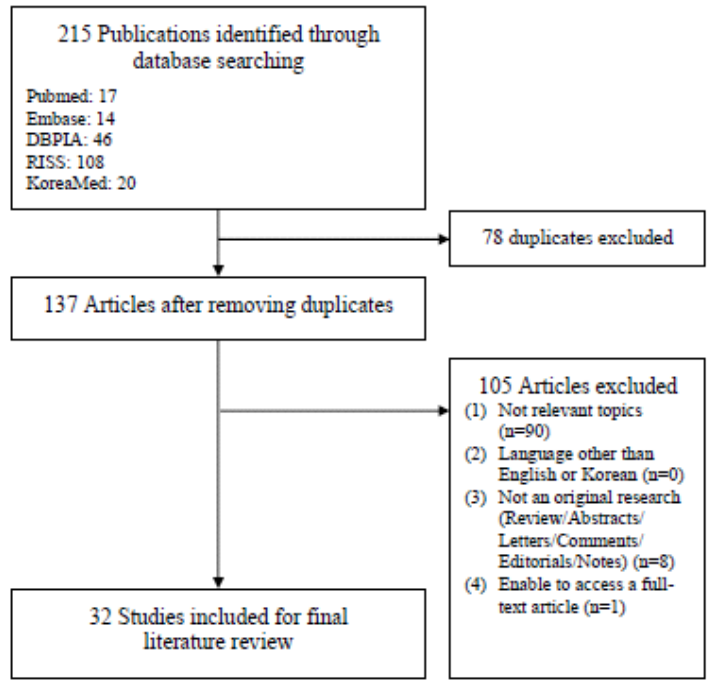


Table 4. Systematic review of the mental health research in public health after the Sewol ferry disaster

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Pae JK et al. (2014)	Cross-sectional	1 month after the event	Reporters of the Sewol Ferry disaster (n=270)	Psychological trauma	The degree of trauma was measured using the event impact scale (IES-R-K)	Mean, correlation analysis	45.9 percent of reporters who covered the Sewol disaster suffered severe trauma. However, no significant difference in the level of experience and trauma covered by different types of reporters, photographers and video reporters were observed.
Sohn SH (2014)	Cross-sectional	3 months after the incidence: from July 10, 2014 to July 22, 2014	346 middle and high school students living in Gyeonggi province (12 cities) who do not have any acquaintances directly related to the Sewol accident	Post-traumatic stress disorder	Risk factors for indirect trauma	One-way ANOVA, hierarchical regression (correlation, frequency)	57.5 percent of the teenagers in the study was in the complete PTSD group, and they experienced the highest level of sadness and anger.
Lee JE et al. (2014)	Cross-sectional	3 months after the event	People living in the metropolitan area	Public's subjective perception of the Sewol ferry disaster and the resulting post-traumatic stress disorder	Post-traumatic stress symptoms (statements)	Q methodology	"Empathy type" was the type of people who empathize with the disaster victims. They had highest prevalence of PTSD and it continued to occur three months after the ferry disaster.
Park GM (2015)	Cross-sectional	1 year after the event: collected from March 19, 2015 to April 5, 2014	Communicate directly with the bereaved for about two months and identify the status of the bereaved families in Ansan (63 men and 68 women)	Post-traumatic stress disorder	Impact of Event Scale (IES)	Frequency	The bereaved families of the ferry victims are suffering from severe post-traumatic stress disorder. PTSD after the disaster caused or worsened various physical ailments. More than half of the bereaved families of the Sewol ferry disaster did suffer from gastritis, stomach ulcers and indigestion, and musculoskeletal pain such as arthritis, disc and back pain.

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Lee MN et al. (2015)	Longitudinal	A follow-up study of psychological trauma on the reporters 6 months after the Sewol disaster.	Reporters of the Sewol Ferry disaster	Psychological trauma	IES-R-K	Frequency, correlation, difference, analysis of variance (ANOVA), additional interview	There was a possibility that macho work ethic may affect symptoms at the first time(a month after the disaster) and indirectly affect the duration of symptoms at the second time.
Woo HK et al. (2015)	Contents analysis	Data were collected from daily Twitter posts from 1 January 2011 to 31 December 2013 and from 1 March 2014 to 30 June 2014	Public mood	Mood (anger, anxiety, sadness, shock, stress, suffering, tragedy, despair, pain/hurt, etc)	Daily Twitter posts	Natural language-processing and text-mining technologies.	This disaster elicited immediate emotional reactions from the public, including anger directed at various social and political events occurring in the aftermath of the disaster. Although the frequency of Twitter keywords fluctuated greatly during the month after the Sewol disaster, keywords associated with suicide were common in the general population.
Yang HJ et al. (2015)	Cross-sectional	4 to 6 months after the accident	Subjects were 7,076 adults (≥19 years) living in two victimized communities in Ansan, four control communities from Gyeonggido, Jindo and Haenam near the accident site.	Depression, stress, somatic symptoms, anxiety, and suicidal ideation were measured	Center for Epidemiologic Studies-Depression Scale(CES-D), Brief Encounter Psychosocial Instrument, Patient Health Questionnaire-15 (PHQ-15), and Generalized Anxiety Disorder 7-Item Scale (GAD-7), respectively.	Multiple logistic regression analysis	The depression rate among the respondents from Ansan was 11.8%, and 18.4% reported suicidal ideation. Depression (OR: 1.66, 95% CI 1.36-2.04) Stress (OR: 1.37, 95% CI: 1.10-1.71), Somatic symptoms (OR: 1.31, 95% CI: 1.08-1.58) Anxiety (OR: 1.82, 95% CI: 1.39-2.39) Suicidal ideation (OR: 1.33, 95% CI: 1.13 -1.56) The accident areas of Jindo and Haenam showed the lowest prevalence and ORs.
Sim KS et al. (2016)	Cross-sectional	From March 13 to May 25, 2015	Mental Health Professionals (n=262)	Secondary traumatic stress (Trauma History Checklist:)	Professional Quality of Life Scale: ProQOL-5	Correlation, independent t-test, ultivariate Analysis of Variance (MANOVA)	It has been revealed that mental health professionals engaged in disaster-supporting activities are at high risk of exhaustion and indirect trauma.

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Lee HP et al. (2016)	Cross-sectional	Approximately 2 months after the event	Among 481 adults aged 18 and over, 439 (male 147 and female 292) were eligible for the survey, with the exception of 42 people who responded insincerely to the survey.	Post-traumatic stress	Posttraumatic Risk Checklist (PRC), IES-R-K, Multidimensional Fear of Death Scale (MFODS)	Correlation, mediation, structural equation model	The death anxiety, post-traumatic and post-traumatic crises significantly related to the relationship between early news exposure and post-traumatic stress symptoms. News exposure immediately after a disaster affects death anxiety, which leads to trauma and post-traumatic stress. These risk factors can increase post-traumatic stress symptoms.
Han HS et al. (2017)	Cross-sectional	1 month after the disaster	93 bereaved family members of the Sewol ferry accident were recruited.	Severity of complicated grief, post-traumatic stress disorder (PTSD) and depressive disorder	Inventory of complicated grief (ICG), PTSD Check List-5 (PCL-5) and Patient Health Questionnaire-9 (PHQ-9).	Univariate analysis, multiple linear regression	Mental health support significantly reduced the severity of grief only in those participants who had not received any psychotherapy or psychiatry clinic service before the accident.
Han KM et al. (2017)	Ecological	Between January 2013 and June 2016.	Investigated whether the time-series pattern of monthly prescriptions per 100,000 people was different in Ansan Danwon (outpatients) compared to that in Cheonan city after the Sewol Ferry disaster through.	Depression	The monthly prescription rates of psychotropic medications (antidepressants, anxiolytics, and sedatives/hypnotics)	Difference-in-differences regression analysis	Ansan Danwon showed a significantly greater increase (5.6%) in the prescription rate of antidepressants compared to Cheonan city following the Sewol Ferry disaster. There were no significant differences in changes in the prescription rates of anxiolytics or sedatives/hypnotics. In the secondary analysis, a significantly greater increase in the prescription rate of antipsychotics was observed in Ansan Danwon compared to a control community after the disaster.
Huh HJ et al. (2017)	Cross-sectional	18 months following the accident	Eighty-four bereaved parents	Prevalence, severity, and correlates of psychiatric symptoms	PHQ-9, PCL-5, ICG	Univariate descriptive statistics, regression analyses	94% of the participants appeared to suffer from complicated grief based on scores on the ICG. Half of the participants were categorized as having severe depression and 70.2% reported clinically significant post-traumatic symptoms

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Jang KI et al. (2017)	A two-channel electroencephalography study	Not mentioned	Eighty-four family members of the Sewol ferry victims (32 men and 52 women) were recruited and their EEG was compared with that of 25 (13 men and 12 women) healthy controls.	Measured cortical activity in the frontal lobe. Symptom severity of insomnia, post-traumatic stress disorder, complicated grief, and anxiety were evaluated.	A two-channel EEG device, PCL-5, ICG, Insomnia Severity Index, GAD Checklist	Pearson's correlations, independent t-tests and the χ^2-test, multivariate analysis of covariance	The bereaved families showed a higher frontal beta power than healthy controls. Subgroup analysis showed that frontal beta power was lower in the individuals with severe insomnia than in those with normal sleep. There was a significant inverse correlation between frontal beta power and insomnia symptom in the bereaved families.
Lee JY et al. (2017)	Cross-sectional	1-2.5 months after the Sewol ferry accident (May 25 and June 3, 2014)	A total of 1101 students attending secondary and high schools in Jindo, the location of the Sewol ferry disaster, were enrolled in a cross-sectional survey	Post-traumatic stress symptoms	The Child Report of Post-traumatic Symptoms (CROPS), CES-D, and the State Anxiety Inventory for Children (SAIC)	Between-group comparisons (chi-square test, independent t-tests), stepwise regression analysis	The regression analysis revealed that directly witnessing the rescue scene was significantly associated with post-traumatic stress symptoms after adjusting for other variables.
Lee JY et al. (2017)	Cross-sectional	Approximately 1 month after the Sewol disaster (May 25th to June 3rd, 2014)	A total of 2,773 parents of students in grades 1 through 12 from 20 of the 21 schools on Jindo Island participated in this study. Participants were asked whether they had participated in rescue work in Paengmok Harbor following the Sewol ferry disaster, and participants were divided into two groups based on their responses.	Post-traumatic stress disorder, depression, anxiety	IES-R-K, CES-D, The Korean version ofthe Beck Anxiety Inventory (BAI)	Between-group comparisons (chi-square test, independent t-tests), logistic regression forward selection	Clinically relevant PTSD symptoms were observed in 151 (19.7%) community volunteers. Logistic regression analysis revealed that volunteering was a significant risk factor for the development of PTSD symptoms in this sample.

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Lee JY et al. (2017)	Cross-sectional	1-2.5 months after the Sewol ferry disaster	1,744 students (813 boys, 931 girls) aged 7–18 years in grades 1–12 from 20 of the 21 schools on Jindo island.	Post-traumatic stress disorder	Post-traumatic Stress Disorder Reaction Index (UCLA PTSD-RI), Young's Internet Addiction Test, CES-D, SAIC	Logistic regression analysis	PIU was significantly and independently associated with a high level of PTSD symptoms.
Lee MS et al. (2017)	Cross-sectional	3 months after the sinking of the Motor Vessel Sewol	32 teachers who underwent psychiatric interventions by 16 volunteer psychiatrists	Psychiatric symptoms (acute stress disorder, adjustment disorder, anxiety, depressed mood and sleep disturbances	Clinical diagnosis	Frequency of psychiatric symptoms	The most commonly diagnosed clinical diagnosis in the teachers were normal reaction, acute stress disorder and adjustment disorder. Psychiatric symptoms including anxiety, depressed mood and sleep disturbances were also observed.
Lee SH et al. (2017)	Cross-sectional	28 months after the disaster	75 Sewol ferry disaster survivors were eligible for participation, 48 (64%) survivors (24 males, 24 females) completed questionnaires	Post-traumatic embitterment disorder	The Post-traumatic Embitterment Disorder (PTED) scale, the Functional Social Support Questionnaire (FSSQ), and the Meaning in Life Questionnaire (MLQ).	Correlation, hierarchical regression analysis	PTED scores were negatively correlated with scores on the FSSQ and the Presence of Meaning (MLQ-P). FSSQ scores may fully mediate the effects of PTED scores on MLQ-P scores, given that the indirect effect was significant whereas the direct effect was not.
Chae JH et al. (2018)	Longitudinal	18 and 30 months after the accident	The mental status of the 111 bereaved families including 84 bereaved parents	Complicated grief, PTED, posttraumatic stress disorder (PTSD), depression, and other trauma-related factors	ICG, PHQ-9, PCL-5	The change in all scales over a 1-year period was measured	Embitterment was related to other mental health problems including depression, anxiety, and complicated grief. Social support and positive individual resource including optimism and wisdom can be helpful for recovery from posttraumatic embitterment.

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Kim EJ et al. (2018)	Longitudinal	The following time points (T): 9 months (T1), 12 months (T2), and 15 months (T3) after the disaster. Additionally, we performed a follow-up review at 27 months (T4).	A group of students from Danwon High School who survived the Sewol ferry disaster for 27 months	Psychological symptoms	The State-Trait Anxiety Inventory for Children (STAIC-State), CES-D, CROPS, ICG	One-way repeated-measures analysis of variance (ANOVA).	Scores of psychological variables tended to increase until T2 and then slowly decreased until T4. The severity of anxiety and complicated grief symptoms changed significantly over time, but the severity of depression and posttraumatic stress symptoms did not.
Lee MS et al. (2018)	Qualitative study	In-depth qualitative research using individual interviews from January to February 2017	Twenty-one of 75 Danwon high school students survived by the MV Sewol disaster were studied. 20 years old, where 10 were male (47.62%), and 11 were female (52.38%)	Psychiatric symptoms (depression and insomnia, anxiety, nightmares and phobias, and difficulties regarding concentration, aggression, and game addiction	In-depth interview	The consolidated criteria for reporting qualitative research (COREQ)	More than 75% of the interviewed students felt that mental health services were needed, and more than 85% required mental health assessments. Regarding psychiatric symptoms, the students reported that they suffered depression and insomnia (19.05%), anxiety (14.29%), nightmares and phobias (9.52%), and difficulties regarding concentration, aggression, and game addiction (4.76%).
Lee SH et al. (2018)	Cross-sectional	20 months after the Sewol ferry disaster (December, 2015)	A sample of 57 students (29 boys and 28 girls) who survived the Sewol ferry disaster	Post-traumatic stress disorder	The Strengths and Difficulties Questionnaire (SDQ), Peritraumatic Dissociation–Post-traumatic Negative Beliefs–Post-traumatic Social Support (PTDPTNB-PTSS) scale, Lifetime Incidence of Traumatic Events-Child (LITE-C), KIDSCREEN-27, CROPS, and the Family Adaptability and Cohesion Evaluation Scale (FACES)-III	Generalized linear model using a log link, Poisson distribution to identify factors associated with PTSD symptoms	26.3% of participants were classified in the clinical group by the Child Report of Post-traumatic Symptoms score. Based on a generalized linear model, Poisson distribution, and log link analyses, PTSD symptoms were positively correlated with the number of exposed traumatic events, peers and social support, peri-traumatic dissociation and post-traumatic negative beliefs, and emotional difficulties. On the other hand, PTSD symptoms were negatively correlated with psychological well-being, family cohesion, post-traumatic social support, receiving care at a psychiatry clinic, and female gender

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Lee SH et al. (2018)	Cross -sectional	20 months after the Sewol ferry disaster (December, 2015)	a sample of 57 students who survived the Sewol ferry disaster	Complicated grief (CG)	ICG, LITE-C, CROPS, KIDSCREEN-27, (FACES)-III, PTDPTNB-PTSS, SDQ	A generalized linear model using a log link and Poisson distribution was performed to identify factors associated with symptoms of CG	The mean score on the ICG was 15.57 (standard deviation: 12.72). Being born in 1999, a higher score on the CROPS and a lower score in autonomy and relationship with parents on the KIDSCREEN-27 were related to higher levels of CG.
Lee SM et al (2018)	Longitudinal	Sixty-seven participants were revisited at the 30 months postdisaster time point.	All family members of the victims of the Sewol disaster were invited to participate in this study (n=67)	Heart rate variability and psychiatric symptoms (PTSD, depression, anxiety)	PCL-5, PHQ-9, GAD-7, the Life Events Checklist (LEC)	Logistic regression analysis	Participants with PTSD had a higher low frequency to high frequency ratio (LF:HF ratio) than those without PTSD. The LF:HF ratio at 18 months postdisaster was associated with a PTSD diagnosis at 30 months postdisaster.
Tae HJ et al. (2018)	Cohort study	The first baseline survey and biochemical measurements: 18 months (SD=1 month) after the accident. 12 months of follow-up (30 months after the accident)	After 12 months of follow-up (30 months after the accident), a total of 64 individuals completed the survey and participated in biochemical analysis (bereaved).	Post-traumatic stress disorder, alcohol use disorder	PCL-5, the Alcohol Use Disorders Identification Test-Alcohol Consumption questionnaire (AUDIT-C)	Two-tailed tests, multiple linear regression model, an independent samples t-test, the Pearson correlation coefficient	Participants reporting clinically significant PTSD symptoms exhibited lower serum HDL-C levels than those without PTSD symptoms. In addition, we found that the severity of PTSD symptoms and sex could explain the changes in lipid profiles independently of other possible risk factors of changes.
Wong AK et al. (2018)	Cross-sectional	Approximately six weeks after the Sewol ferry disaster	A nationwide survey (n=811) who were exposed to the Sewol ferry disaster through the media	PTSD symptom, post-traumatic Growth	IES-R-K, Korean-Stress-related Growth Scale-Revised	Correlation analysis, and one-way ANOVA	30.4% of the sampled participants reported stress symptoms equivalent to

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Yang HJ et al. (2018)	Cross-sectional	Two cross-sectional surveys: survey 1, after 4–6 months and survey 2, after 16–18 months of disaster	Surveyed approximately 1800 adults aged≥19 years in Ansan city, Gyeonggi province in the Korea Community Health Survey (KCHS), The KCHS study participants from Ansan city were 1841 in Survey 1 and 1828 in Survey 2.	Depression, anxiety	CES-D and GAD-7.	Multiple logistic regression	Survey 1: a significantly higher prevalence of depressive symptoms (19.0%; 95% confidence interval [CI], 16.9–21.1) and anxiety (6.1%; 95% CI, 5.0–7.5) among Ansan city, compared to participants from adjacent cities (depressive symptoms: 14.3%; 95% CI, 12.7–16.1; anxiety: 3.6%; 95% CI, 2.9–4.5). Survey 2 showed a decreased prevalence of depression (15.8%; 95% CI, 14.0–17.9) and anxiety (5.0%; 95% CI, 4.0–6.4) among Ansan city residents. Depressive symptoms and anxiety adjusted odds ratio in survey 2 compared with survey 1 were 0.74 (95% CI 0.62–0.89) and 0.81 (0.60–1.08) among Ansan city, respectively.
Yun JA et al. (2018)	Longitudinal	18 months and 30 months after the disaster.	Bereaved family members	Depression, anxiety, posttraumatic stress disorder, complicated grief, and embitterment	PTED scale, PHQ-9, GAD-7, ICG, PCL-5	Independent sample t-tests, chi-square test, paired samples t-tests, a repeated measures analysis of variance (rmANOVA)	Bereaved families showed substantial embitterment at Time 1 (64.3%), which increased at Time 2 (76.8%, t = 1.761, p = 0.084). The participants who displayed increased embitterment at Time 2 also increased in anxiety, post-traumatic stress symptoms, and complicated grief (but not depression). Furthermore, participants who displayed decreased embitterment at Time 2 also decreased in all other psychiatric symptoms. (time × group interaction in depression (F 0.644, p = 0.426), anxiety (F 4.970, p = 0.030), PTSD (F 10.699, p = 0.002), and complicated grief (F 8.389, p = 0.005)).
Kim YA et al. (2018)	Cross-sectional	1 year after the accident	2,009 respondents (552 men, 1,457 women); bereaved families	Indirect trauma and collective emotion	Basic emotions scale	Structural equation modeling (SEM), Pearson correlation, path estimate	Peri-disaster period (T1) and appraisals at the 1st anniversary of the disaster (T2). The proximity, amounts of media exposure (T1 and T2) and initial reactions (T1) influenced collective emotions through the appraisals at T2.

Study	Study design	Study period	Subjects	Outcome	Outcome measurement	Methods	Main outcome
Park NI et al. (2018)	Cross-sectional	For 12 days from the April 28, 2014 right after the accident	The responses of 417 people consisted of college, middle and high school students, and adults in a metropolitan area	Post-traumatic stress symptoms	IES-R-K, DSM-5	Post-hoc analyses for mean differences, hierarchical regression	The level of PTSD of social media users were higher than that of traditional media (newspapers or TV news) users on the accident. Also, the amount of use of disaster news information and social media revealed positive correlations with PTSD.
Yoon SH et al. (2018)	Cross-sectional	December 2016 to June 2017	114 parents who lost children in the Sewol ferry disaster	Quality of life, depression, resilience, social support	World Health Organization Quality of Life Assessment Scale abbreviated version (WHOQOL-BREF), CES-D, resilience scale, social support measures developed by Park	Descriptive statistics, independent t-tests, one-way ANOVA, Pearson correlation, and multivariate linear regression	Lower levels of quality of life were reported by parents with no current occupation, who considered emotional support by others as not helpful, not disclosing self as family of a victim, experiencing change in social activities related to the disaster, and not participating in bereavement activities with other families (all p values <.05). Factors associated with quality of life were depression (β=-.53) and resilience (β=.26) and explained 48.0% variance (F=50.37, p<.001), while social support was not a significant factor.

III. METHODS

3.1 Study Design

This is an ecological study in the form of natural experiment. The unit of observation is the populations in the community, Ansan-si and Gyeonggi-do residents. We focused on the comparison between two groups in Ansan-si: residents in high-risk area and low-areas which are defined under 3.2.2. Outcome variables in the analysis are aggregate measures of each dong. Subjects in the study were grouped by place and time. Group-level effects were of particular interest of us and this was achieved by routinely collected health insurance information.

3.2 Data source

To assess health care utilization, we used National Health Insurance database. We collected health information data from the National Health Insurance Service (referred to as NHIS) of Korea. All citizens in Korea are obligated to have National Health Insurance. The NHIS is a single-payer program. It covers all Korean residents and using the data from NHIS can be a representative of the entire Korean population (Song et al., 2014). The NHIS offers customized database for policy and academic research. They share health insurance data without identification of individual information because of the Personal Information Protection Act. We requested the customized database for academic research purpose. The customized database we requested includes information on records of inpatient and outpatient care usage, and diagnosis of diseases based on health insurance claims (Seong et al., 2017). The study population included all residents in Gyeonggi-do and Ansan-si. Medical utilization information of patients who live in Gyeonggi-do and Ansan-si were obtained. The study period was from the year 2011 to 2016 and patients who received medical treatment during this time period were included in the analysis. Health care utilization information of each disease was collected in the form of frequency by age and sex

group. Since NHIS extracted information we requested, there were no missing information.

3.3. Measures

3.3.1 Post-traumatic Stress Disorder

Operational Definition of PTSD

KCD-6 (Korean Standard Classification of Diseases-6) codes were used to identify each disorder. According to Yehuda et al. (2002), considerable overlap between the symptoms of PTSD, depression and other anxiety disorders exist, thus misclassification of the diagnosis can be easily made even if PTSD symptoms are readily detectable by physicians. Because of the innate problem of disease categorization from the beginning, we consulted psychiatrists to know what codes psychiatrists often use in clinics for the PTSD to categorize precisely.

KCD has a large scale classification called “neurotic, stress-related and somatoform disorders” which encompasses a variety of stress-related disorders—KCD codes from F40 to F48—including post-traumatic stress disorder (F43.1). Obsessive-compulsive disorder (F42) was excluded in the classification for the analysis. Because these disorders under the “neurotic, stress-related and somatoform disorders” category can be seen as symptoms of post-traumatic stress, an operational definition of PTSD was made. We will refer to codes from Table 5 as PTSD from here.

3.3.2 High-risk areas and low-risk area

The three administrative districts of Ansan-si (Gojan 1-dong, Wa-dong, Seonbu 3-dong) are classified as high-risk areas and the remainder is defined as low-risk areas. Ansan-si is made up of 25 administrative districts in total; hence the low-risk areas are 22 administrative districts. Due to the policy on the equalization of high schools, students get allocated to the

nearest school after graduating from middle school. Danwon high school is located in Gojan 1-dong. Living in the above-mentioned high-risk areas means that all students living in these areas get allocated to Danwon high school after their graduation.

The statistics of victims from Ansan city hall provides supporting evidence. The residential areas of victims at the time of the accident was 107 in Gojan 1-dong, 97 in Wa-dong, 69 in Seonbu 1-dong, 12 in Seonbu 2-dong and 45 people in other regions ("Status of Victims from," n.d.). According to our hypothesis, Gojan 1-dong, Wa-dong, and Seonbu 1-dong can be defined as high-risk areas because we assumed that majority of victims must live in these areas as most victims from the disaster are Danwon high school students. This supposition has been proven by the statistics by Ansan city hall which indicates 273 victims resided in high-risk areas. Considering 250 victims were Danwon high school students, it is reasonable to define these regions as high-risk areas as it covers more victims than the actual number of the students. Furthermore, it is extremely likely to know victims in any way if one is a resident in these areas that eventually becomes stronger psychological influence than not knowing the direct victims. One news article illustrates that one victim in each row house of Gojan-dong is not an exaggerated statement (Bae, 2014).

Table 5. Categorization of diseases that were used as outcomes in the present study

Categorization	KCD-6	Disease Entry
Depression	F32	Depressive Episode
	F33	Recurrent Depressive Disorder
Post-traumatic Stress Disorder (Neurotic, Stress-related and Somatoform Disorders)	F40	Phobic Anxiety Disorder
	F41	Other Anxiety Disorder
	F43	Reaction to severe stress, and adjustment disorder
	F44	Dissociative[Conversion] Disorders
	F45	Somatoform Disorders
	F48	Other Neurotic Disorders
Heart Disease	I21	Acute Myocardial Infarction
	I22	Subsequent Myocardial Infarction
	I23	Certain current complications following Acute Myocardial Infarction
	I24	Other Acute Ischemic Heart Disease
	I25	Chronic Ischemic Heart Disease

3.4. Statistical analyses

3.4.1 Time-series Analysis

We first standardized health care service utilization and identified time-series trends to find the effect of the Sewol Ferry disaster on PTSD. To standardize three diseases, we first subdivided the actual number of cases of medical treatment and the actual number of patients into outpatients, inpatients, and emergency patients; then divided them into gender and age groups corresponding to the population—age and gender standardized rates. Standardized populations were residents in Ansan-si and in Gyeonggi-do except for Ansan-si. The result was presented on a monthly basis. After the standardization process, Comparison between Ansan-si and Gyeonggi-do's monthly trends in health care utilization was conducted to determine whether there was a notable change in the medical use trends in the Ansan-si area after the disaster.

3.4.1.1 Piecewise regression before and after the disaster in Ansan-si

Piecewise regression was performed to quantify a sudden change of a dependent variable of a varying independent variable. Variations in Ansan-si was of specific interest. Independent variable was time period from January 2011 to December 2016 and dependent variable was each month's standardized prevalence rate. Independent variable, the time, was separated into two interval by a breakpoint. In the analysis, the breakpoint was the time of the Sewol accident, March 2014; hence, we have two time periods: time A is before the disaster and time B is after the disaster. Changes in the regression results between time A and time B will be discussed.

3.4.2 Cluster detection and Bayesian hierarchical regression of spatiotemporal association

Scan statistics were first obtained by using SaTScan v.9.6 to identify any spatial or temporal clusters of medical use in Ansan-si. To detect clusters

with high prevalence rates, retrospective space-time analysis scanning were carried out. Discrete Poisson model was applied in the analysis.

Followed by the cluster detection process, Bayesian spatiotemporal Poisson regression model was used to examine the change in the health service utilization in patients with PTSD, depression and heart disease after the Sewol Ferry Disaster and to compare high-risk areas and low-risk areas. Age and sex standardized health care service utilization was calculated similar to that of Ansan-si and Gyeonggi-do in 3.3.1. The only difference is that we standardized the population of Ansan-si based on the Gyeonggi-do population for the Bayesian regression analysis and the result was presented on a quarterly basis. This is because the number of occurrences has been reduced by dividing Ansan-si into smaller regions.

Space and time variables were used as independent variables in the form of a dummy variable, a numerical value 0 or 1. The space variables were coded as 1 for high-risk areas and 0 for low-risk areas. The time variables were coded as 1 after Sewol ferry disaster and 0 before the disaster. Frequency of health care utilization caused by depression, post-traumatic disorders, and heart disease was set as the outcome variables. In order to adjust for temporal trends, random-walk smoothing of time was included in the model.

3.4.3 Statistical model of spatiotemporal regression

When modeling the frequency of health care use for the specified area, the conditional autoregressive (CAR) model is often applied to control spatial correlation since it is highly likely that the frequency of medical use in certain areas tends to be similar to that in neighboring areas. The spatial distribution of regional i's character values as u_i, is a statistical model often used in disease mapping proposed by Besag, York and Mollie (1991), which is:

$$u_i|u_{-i} \sim N(\frac{1}{N_i}\sum_k a_{ik}u_k, \frac{\sigma_u^2}{n_i})$$

$$a_{ik} = \begin{cases} 1, if\ area\ i\ and\ k\ are\ neighbors \\ 0, \qquad\qquad otherwise \end{cases}$$

where ($i \in not\ i$) is the weighted average of the effects of the surrounding area excluding the region i. If the frequency of patients with the disease is referred to as O_{it} and E_{it} as the expected frequency, then θ_{it}, relative risk of the region and time t, can be expressed in the form of a Poisson regression model.

$$O_{\mathrm{it}} \sim Poisson(\mu_{\mathrm{it}}),\ \mu_{\mathrm{it}} = E_{it}\theta_{it}$$

$$i = 1,\ldots,n(=25),\ t = 2011qt1,\ldots,2016qt4$$

$$\log(\mu_{\mathrm{it}}) = \log(E_{\mathrm{it}}) + x_i'\beta + \gamma_t + u_i + v_i$$
$$v_i \sim N(0, \sigma_v^2)$$

Here x_i and β are a set of exploratory variables and corresponding coefficients respectively and v_i is in the form which represents the unique variability of the region i, and u_i is a random effect on spatial correlation which results in conditional autoregressive form above and γ_t is a second-order random walk for smoothing temporal trend as:

$$\gamma_t|\gamma_{-\mathrm{t}} \sim N(\frac{\gamma_{t-1} + \gamma_{t+1}}{2}, \frac{\tau_\gamma}{2})$$

The calculation method for Bayesian inference uses a method based on an aggregated named Integrated Nested Laplace Approximation (INLA) developed by Rue et al (2009). The prior distribution is required for

Bayesian analysis. However, because there were no similar cases of studies in Korea, non-informative prior distribution, the normal distribution with the mean of zero and the variance of, was applied as the distribution of the estimated parameters. All statistical analyses were performed using R 3.5.1.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board of Seoul National University (approval No. E1808/001-003).

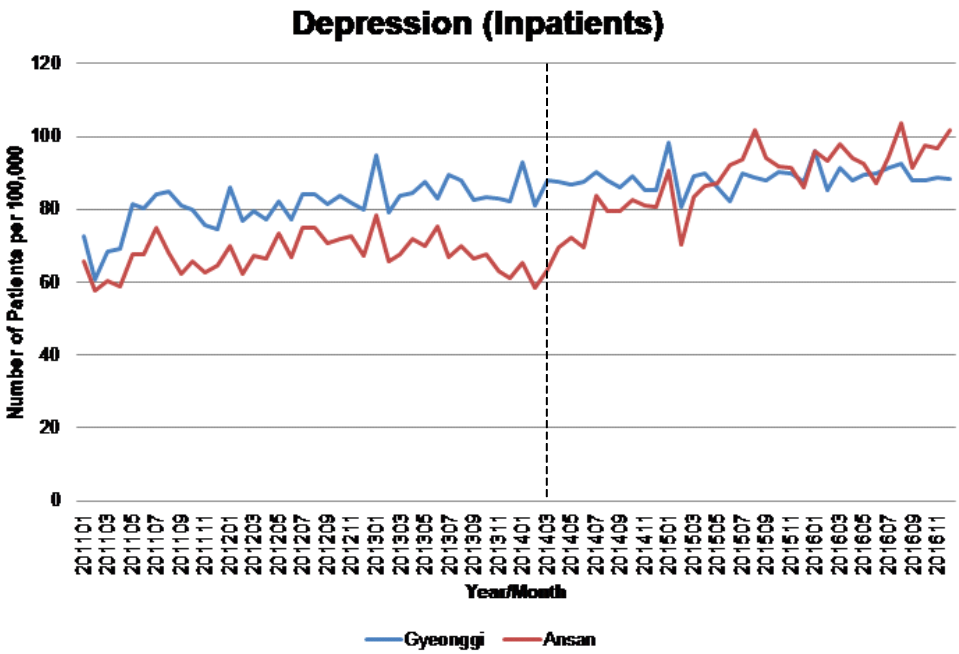
IV. RESULTS

4.1 Standardized Health Care Usage in Ansan-si and Gyeonggi-do

A time series pattern of monthly medical treatment usage was investigated to determine whether there are differences between Ansan-si and Gyeonggi-do. Standardized comparison between two areas indicates that overall medical use in Gyeonggi-do was higher than in Ansan-si. However, inpatients and emergency patients with PTSD showed different results. Health care usage in Ansan-si was higher than in Gyeonggi-do for PTSD inpatients; for emergency patients with PTSD, it was initially higher than Gyeonggi-do until September 2012 and then gradually declined.

The time series patterns in Figure 3, 10, and 11 did not show any notable differences before and after the disaster except inpatients with depression, PTSD, and those with heart disease in Ansan-si. We ruled out Gyeonggi-do for detailed investigation because our primary focus is on the Ansan-si region; in addition, the inpatients and outpatients in Gyeonggi area had relatively stable health care utilization pattern when compared with Ansan-si. We offer results for outpatients and emergency patients in the appendix section. The number of inpatients with depression in Ansan-si were continuously increasing after March 2014, the month of Sewol ferry incidence. The prevalence was initially lower than Gyeonggi-do area before March 2014, but then it surpassed Gyeonggi-do's medical treatment utilization after the incidence. PTSD inpatients did not exhibit an apparent change right after the event as in depression but on a rising trend. This tendency were displayed to the heart disease as well. In all patient categories, excluding outpatients with heart disease and the entire emergency patients, health care utilization went a slightly upward direction as time goes by. In all disease categories, emergency patients displayed highly inconsistent patterns of medical utilization.

Fig. 3. Monthly Secular Trends for Inpatients from 2011 to 2016 (depression, PTSD, and heart disease respectively)



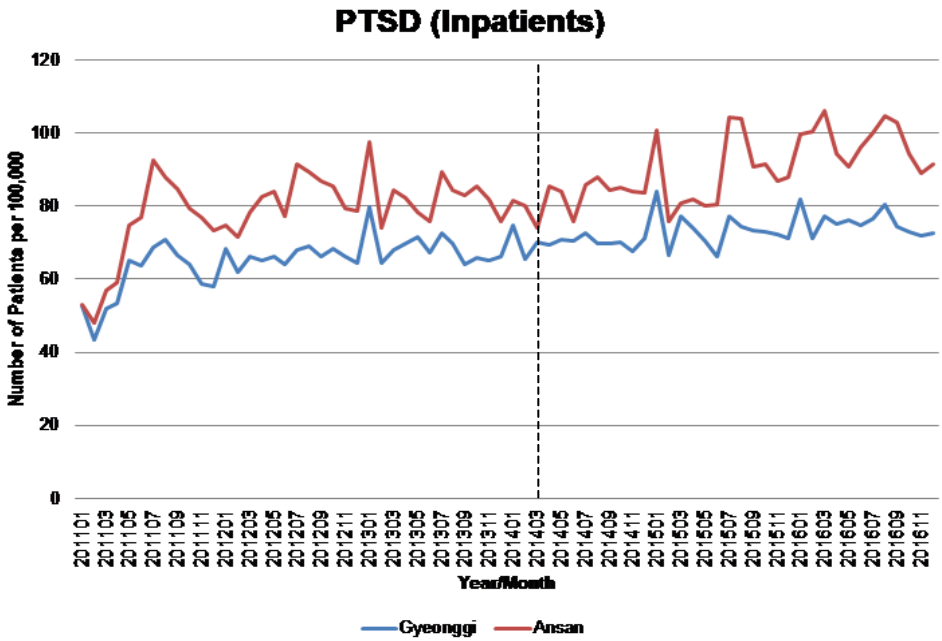
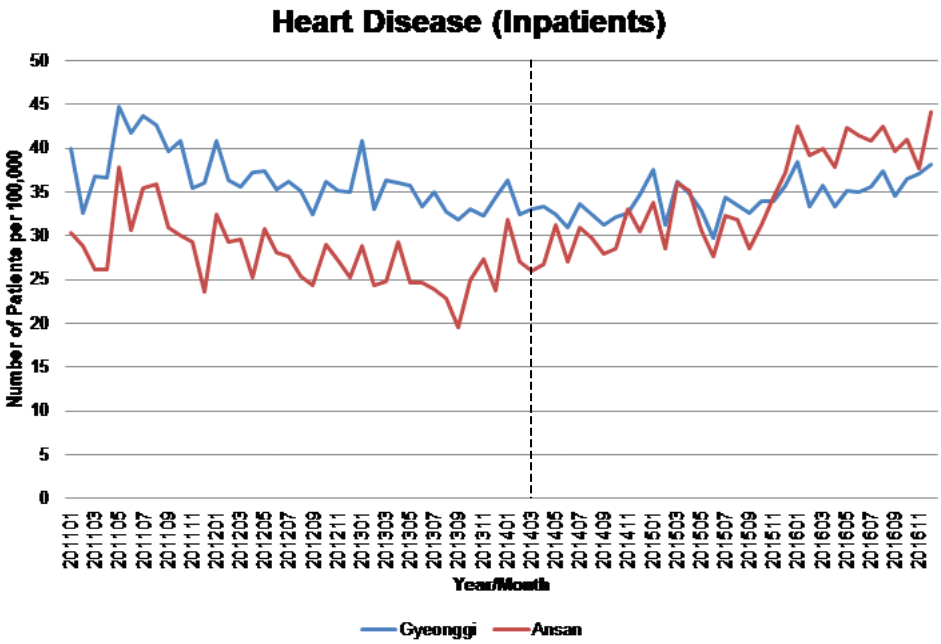


Fig. 3. (cont.) Monthly Secular Trends for Inpatients from 2011 to 2016 (depression, PTSD, and heart disease, respectively)

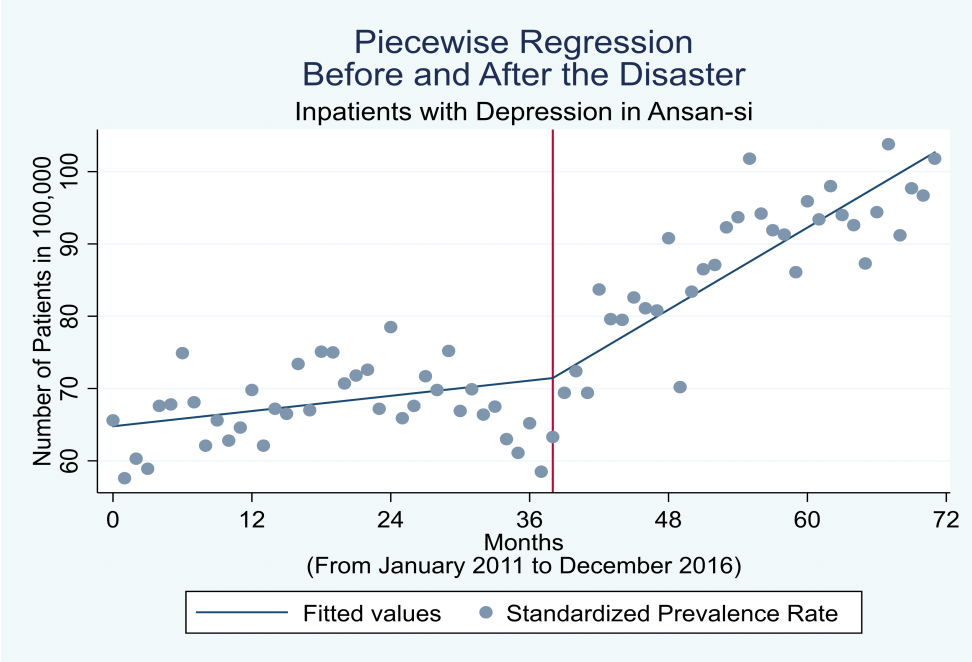


4.1.1 Piecewise regression before and after the disaster in Ansan-si

Piecewise regression analysis was performed to capture any abrupt change after the disaster. The standardized prevalence rate (SPR) of inpatients with depression had 0.167 increase for every additional months before the disaster (time A), but there were significant change after the disaster (time B) in which SPR was 0.953. Inpatients with PTSD showed slightly weaker association than inpatients with depression, but still a positive association: 0.317 in time A and 0.418 in time B. For inpatients with heart disease, -0.141 before and 0.528 after per unit increase of time. All were statistically significant associations. To sum up, partitioning time period by the breakpoint demonstrated stronger increase in the SPR after the disaster.

Every outpatient exhibited the same pattern as the inpatients. Significant increase in SPR after the disaster were observed. 2.93 increase of SPR in time A and 6.68 in time B for depression, 0.220 in time A and 9.41 in time B for PTSD, and -1.57 in time A and 0.427 in time B for heart disease. these were statistically significant except for PTSD in time A. Emergency care showed inconsistent associations. -0.0259 before and –0.00215 after for depression, -0.170 before and -0.105 after for PTSD, -0.00911 before and –0.0145 after for heart disease. Only PTSD emergency patients claim statistical significance. Piecewise regression helped us detect the disease that were influenced by the breakpoint. Predicated on the results, inpatients and outpatients after the disaster resulted in stronger positive associations. On the other hand, emergency patients did not have any association for clear interpretation.

Fig. 4. Standardized Prevalence Rate from a Piecewise Model with OneKnot at the Time of the Disaster (inpatients with depression, PTSD, and heart disease, respectively).



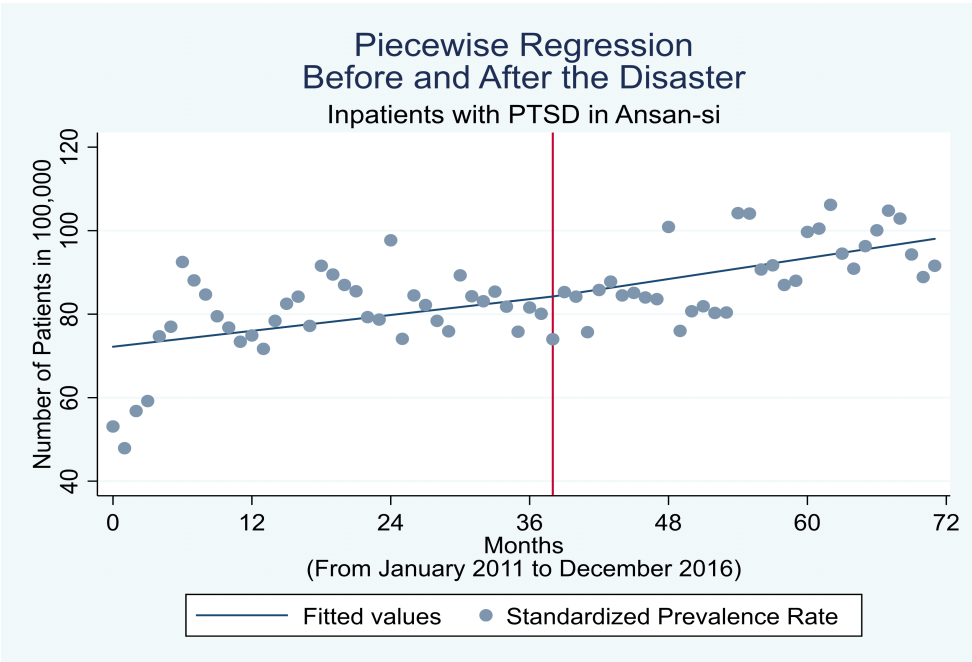
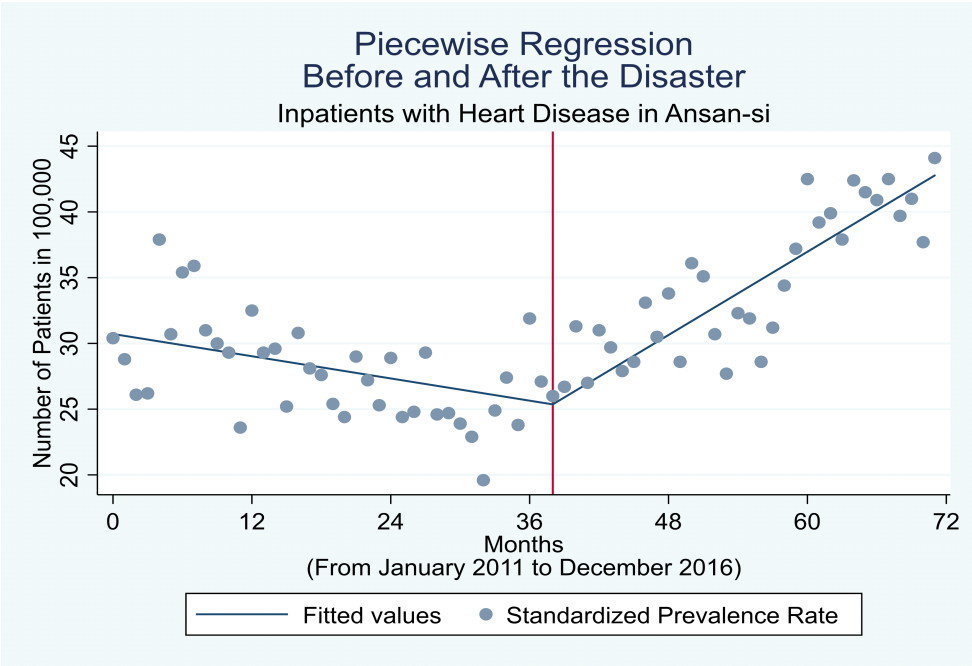


Fig. 4. (cont.) Standardized Prevalence Rate from a Piecewise Model with One Knot at the Time of the Disaster (inpatients with depression, PTSD, and heart disease, respectively).



4.2 Disease mapping of each Dong

4.2.1 Depression

The Sewol ferry disaster occurred in the first quarter of 2014. In outpatients with depression, no apparent changes were made in the second, third and fourth quarters of 2014. From 2015, the number of outpatients continued to increase, resulted in higher relative risks (RR) in 2016. Similar to outpatients, the number of cases of hospitalization increased. Gojan dong and Wongok 1-dong showed the highest number of cases compared to the other regions over any timeframe. Emergency patients with depression were the highest in 2011 and were on the decline over time.

4.2.2 Post-traumatic stress disorder

Although the number of inpatient cases had been increasing since 2015, there were no significant changes observed to be said to be due to the incident. From the beginning of the study period, the number of hospitalization was high in Wa-dong and Ansan-dong, and these two areas exhibited the highest frequency of inpatient clinic use from the year 2015. In case of PTSD emergency, Wolpi-dong was the highest from the outset. In 2011 and 2012, PTSD emergency medical use was high and fell in 2016; however, it made a sudden leap from the first quarter to the fourth quarter of 2014.

4.2.3 Heart disease

According to the map in Fig. 7, heart disease outpatients slightly increased over time. Patients who were hospitalized for heart disease have shown an increase since the second quarter of 2014. The number of emergency patients with heart disease was higher in 2011 and decreased to the first quarter in 2014. There was a sudden rise in the second quarter of 2014 and then decreased back again from the second quarter of 2015.

Fig. 5. Quarterly Secular Trends of Inpatients with Depression in Ansan-si from 2011 to 2016

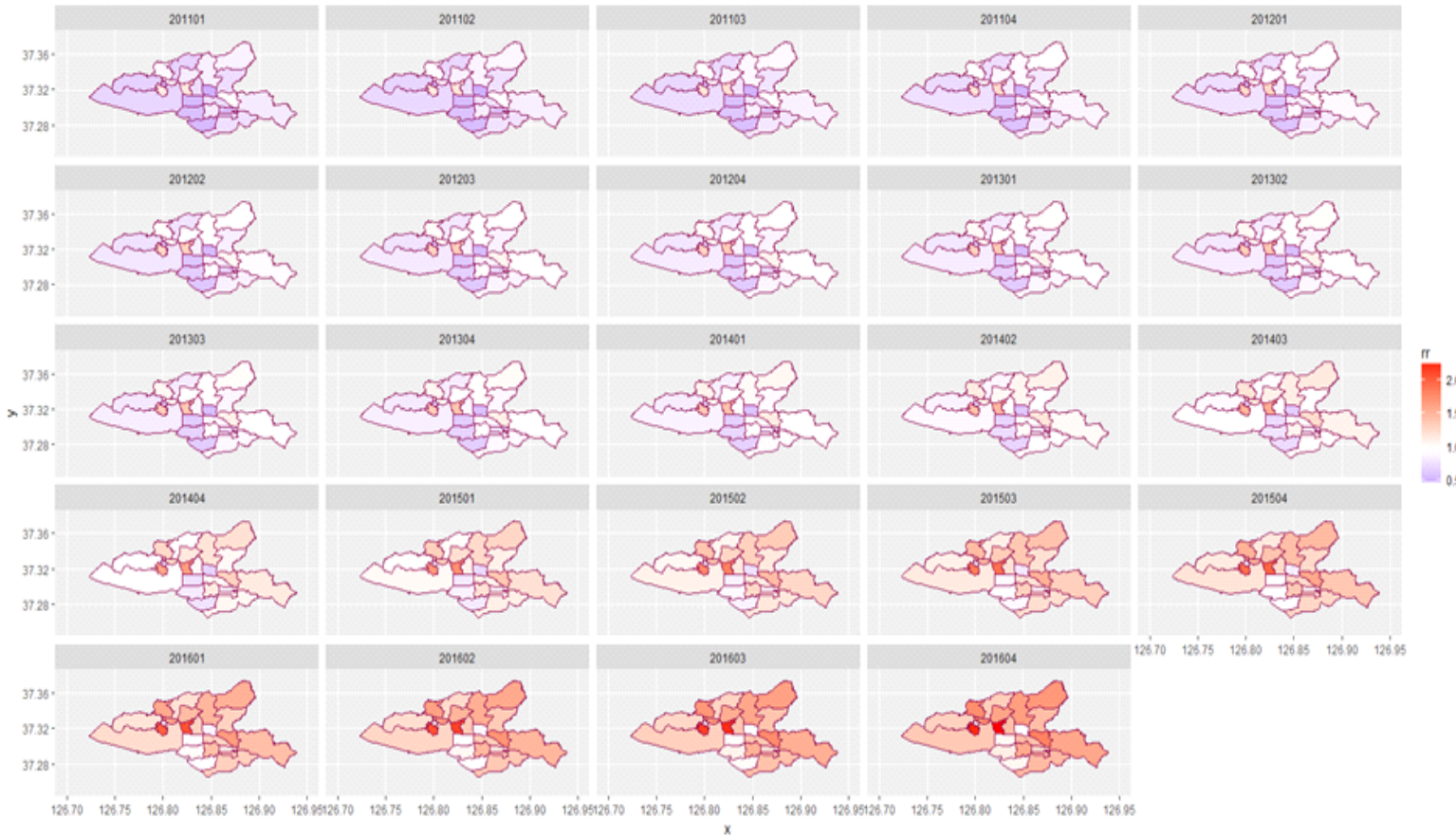


Fig. 6. Quarterly Secular Trends of Inpatients with PTSD in Ansan-si from 2011 to 2016

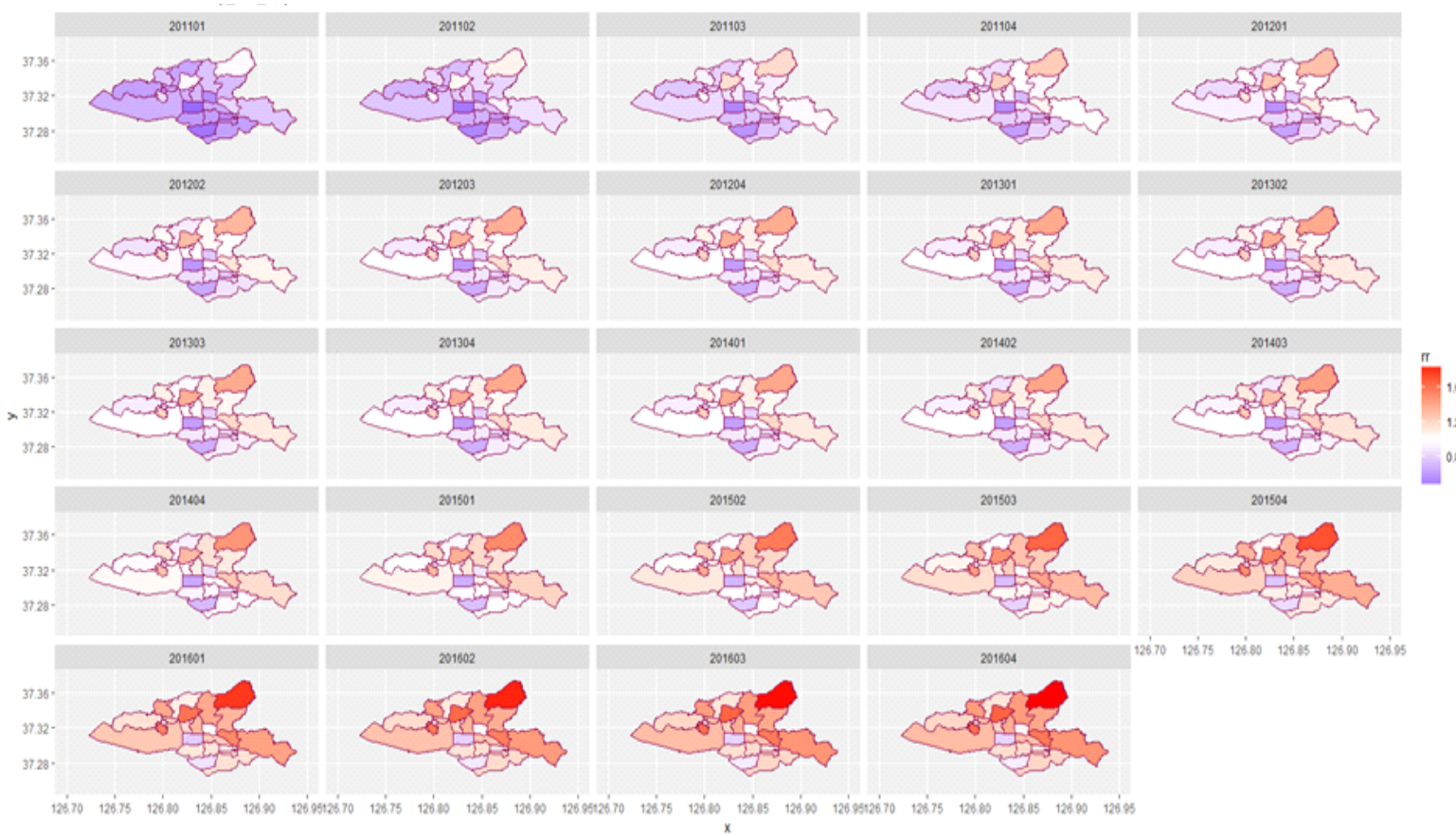
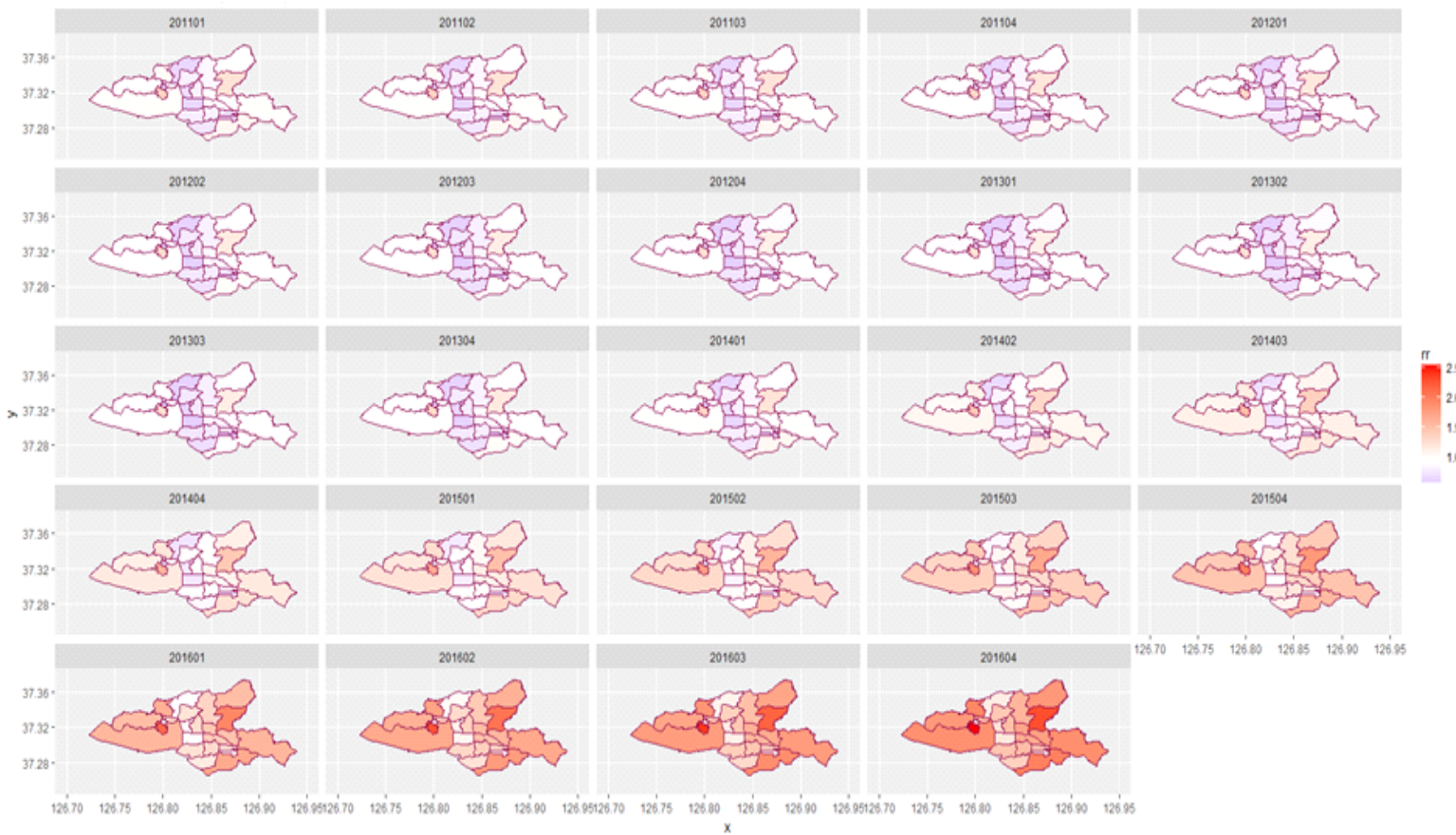


Fig. 7. Quarterly Secular Trends of Inpatients with Heart Disease in Ansan-si from 2011 to 2016



4.3 Cluster detection in Ansan-si

4.3.1 Depression

We performed cluster detection using SaTScan to find purely spatial and temporal clusters. In 2011, clusters of emergency patients with depression were found with relative risk of 5.44 in three areas: Ansan-dong, Bugok-dong, and Wolpy-dong. From January 2015 to December 2016, the inpatients with depression in all parts of Ansan-si was 34% higher (relative risk [RR]: 1.34). In this time period, the hospitalization was high in particular in Seonbu 1, 2, 3-dong, Wa-dong, Wolpi-dong, Gojan 1, 2-dong and Wongok 1, 2-dong regions (RR: 1.39). From June 2015 to December 2016 in all parts of Ansan-si, outpatients for depression increased by 14% (RR 1.14). During this period, the utilization rates in Wongok dong, Seonbu 1, 2-dong, Gojan 1, 2-dong, Wa-dong, and Choji-dong were 21% (RR 1.21) higher than other regions.

4.3.2 Post-traumatic stress disorder

Emergency use due to PTSD-related disorders from January 2011 to December 2012 was higher than that from other time periods (RR 1.83). During this period, the relative risk for the three areas—Ansan-dong, Bugok-dong, and Wolpy-dong—was 2.94. The clusters of hospitalization from PTSD was found from January 2014 to December 2016 in Bugok-dong, Wolpy-dong, Seongpo-dong, Il-dong, I-dong, Ansan-dong, Gojan 2-dong, and Wa-dong (RR 1.36). In addition, the risk of being hospitalized with PTSD-related disorders was 17% higher in the entire Ansan-si from 2011 to 2012. Bono 1, 2 and 3-dong's outpatients number were relatively high throughout the entire study period (RR: 1.39). The risk of using PTSD outpatient service in Gojan 2-dong increased 33% (RR: 1.33) from January 2014 to December 2016.

4.3.3 Heart disease

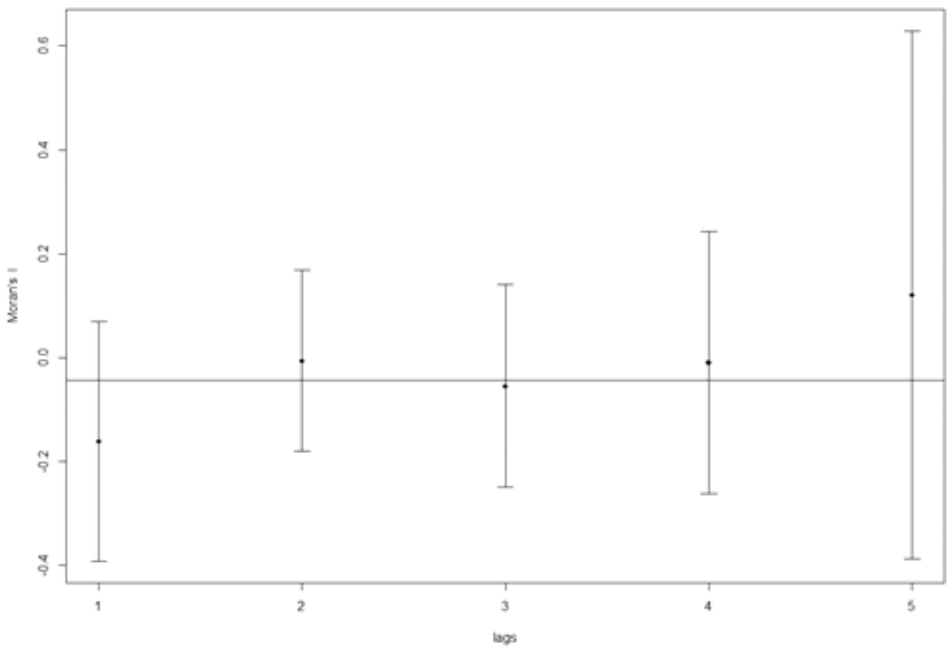
A cluster with the highest relative risk of emergency care use with heart disease was found in Daebu-dong for 2014 (RR: 3.99), subsequently followed by Bono 2, 3-dong and Il-dong in 2015 (RR: 2.11). Heart disease hospitalization was 41% higher in all regions for 2016 in comparison with 2011, 2012, 2013, 2014 and 2015. A cluster with a high relative risk was found in Bono 1-dong (RR: 1.80) from January 2015 to December 2016. Outpatient medical service use due to heart disease for 2011 in Seonbu 1, 2, 3-dong and Wongok 2-dong regions were 2.34 times higher than other areas. For Bugok-dong, this relative risk was 1.13 from January 2014 to December 2015.

4.3.4 Measuring Spatial Autocorrelation using Moran's I

Fig. 9, 20, and 21 illustrated a spatial correlogram, a series of estimates of Moran's *I*. Spatial lag was evaluated at adjacency from the high-risk areas. According to Pfeiffer (2008), the correlogram can be used to decide where spatial autocorrelation is maximized on average. Moran's *I* statistics were calculated from first to fifth-order adjacencies. Inpatients with depression demonstrated negative spatial autocorrelation on lag 1, but positive on lag 5; the others that we will not discuss in detail here had no spatial autocorrelation effect. The plot for inpatients with PTSD illustrated the positive autocorrelation on the lag 1 and lag 5, but not on lag 2. Only one negative spatial autocorrelation, in lag 1, was found in inpatients with heart disease. To conclude, no prominent effect of spatial autocorrelation was observed.

Fig. 8. The Map of Each Administrative District of Ansan-si, Korea

Fig. 9. Spatial Correlogram of Inpatients using Moran's I (depression, PTSD, and heart disease, respectively). Moran's I was plotted on the vertical axis, and spatial lag is plotted on the horizontal axis.



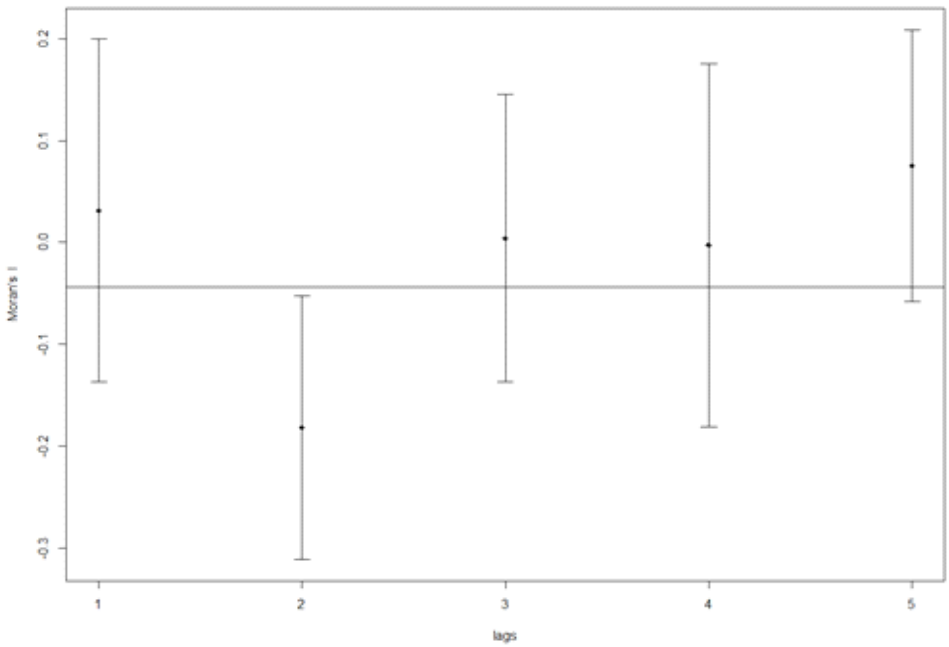
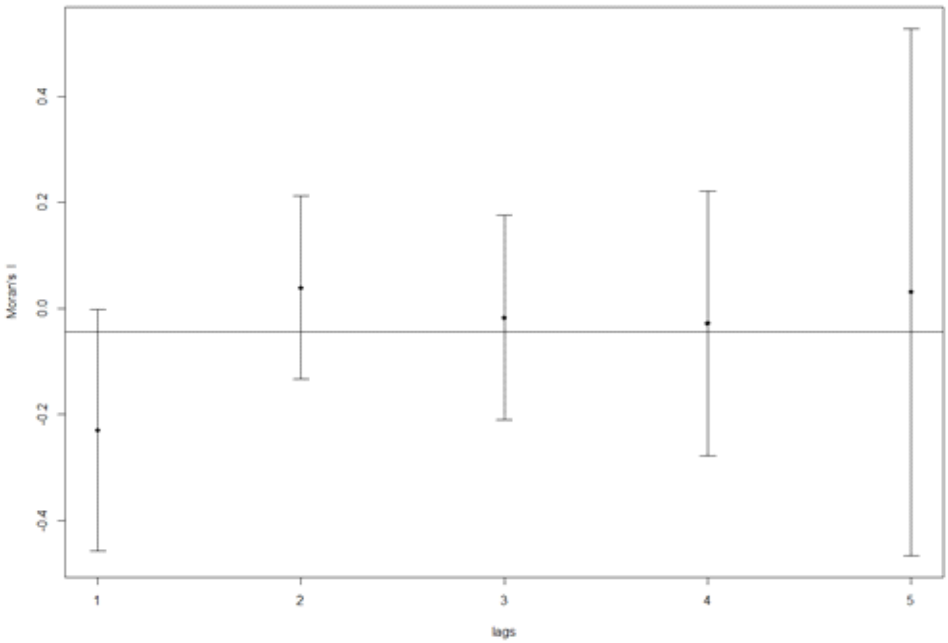


Fig. 9 (cont.) Spatial Correlogram of Inpatients using Moran's I (depression, PTSD, and heart Disease, respectively). Moran's I was plotted on the vertical axis, and spatial lag is plotted on the horizontal axis.



4.4 Spatiotemporal regression to compare high-risk areas and low-risk areas

The effects of the disaster in the study were presented in two forms: using the difference in differences method and analyses of interactions. The difference in differences (DID) method was first applied to detect a change average of quarterly SPR per 100,000 people in the high-risk areas after the disaster (Table 6). To calculate the rough prevalence rate, frequency of visits each month were averaged based on the time period, before and after the incidence, then divided by estimated total population of Ansan-si in a given year. Lastly, the resulting values were multiplied by 100,000. Results for inpatients indicated that only visits for PTSD increased after the Sewol ferry disaster in the high-risk areas (DID estimator = 1.3) while others showed a little less in the high-risk regions after the accident. Outpatients with PTSD showed a great increase of the average SPR (DID estimator = 80) in the high-risk areas after the disaster when outpatients with depression increased 10 out of 100,000 people per each quarters; on the other hand, outpatients with heart disease demonstrated an opposite result that is significant decrease in SPR (DID estimator = -78). Emergency medical care visits showed either small increase or no difference.

Spatiotemporal regression showed somewhat different results than the DID method. The results outlined in Table 7 below are based on estimated relative risks. We interpreted the results from additive scale of interaction to test the hypotheses. According to Richardson & Kaufman (2009), the relative excess risk due to interaction (RERI) is a useful metric that measures deviation from additivity of effects on a relative risk scale. The following equation was used to see the additive scale interaction in terms of the relative excess risk due to interaction (RERI).

$$\text{RERI} = \exp(\beta_1 + \beta_2 + \beta_3) - \exp(\beta_1) - \exp(\beta_2) + 1$$

In the expression, β_1 indicates a spatial factor of the higher-risk areas. β_2 is

a time factor for duration, after the Sewol ferry disaster, and β_3 accounts for both spatial and temporal factors accounting for interaction on multiplicative scale. The RERI is a measure that is often used to see additive interaction. A significant positive interaction in inpatients with PTSD (RERI: 0.40; 95% CI: 0.25, 0.79) and a significant negative interaction in inpatients with depression (REIR: -0.25; 95% CI: -0.26, -0.13) and heart disease (-0.14; -0.10, -0.07). Outpatients with PTSD, depression, and heart disease decreased, but these were not statistically significant interactions. Emergency medical care visits for PTSD and heart disease increased. These were also not significant outcomes; nevertheless, emergency patients with depression increased greatly. In short, using a DID method was analogous to a Bayesian spatiotemporal regression method. Similar findings were produced in general, but the details of it were different. For instance, DID estimator implied that inpatients with PTSD displayed a small increase in the high-risk areas after the accident, but spatiotemporal regression method showed a stronger interaction between the spatial and time factors. In addition, outpatients with PTSD showed the highest DID estimator among all the diseases, but the regression model indicated that there were not significant interactions in the high-risk areas after the disaster.

Table 6. Estimated Difference in Differences Based on Quarterly Standardized Prevalence Rate per 100,000 People of Post-Traumatic Stress Disorder, Depression, and Heart Disease

Outcome	Inpatients			Outpatients			Emergency Patients		
	Pre-disaster	Post-disaster	Difference†	Pre-disaster	Post-disaster	Difference	Pre-disaster	Post-disaster	Difference
PTSD									
Low-risk areas	62.3	78.8	16.5	2,400	2,760	360	11.3	6.88	-4.4
High-risk areas	63.8	81.6	17.8	1,780	2,220	440	8.22	6.82	-1.40
Difference‡	1.5	2.8	1.3	-620	-540	80	-3.1	-0.06	3.0
Depression									
Low-risk areas	51.6	74.0	22.4	1,330	1,590	260	1.20	0.751	-0.45
High-risk areas	60.7	79.9	19.2	1,250	1,520	270	0.870	0.744	-0.126
Difference	9.1	5.9	-3.2	-80	-70	10	-0.33	-0.007	0.32
Heart disease									
Low-risk areas	22.0	31.8	9.8	258	292	34	1.41	1.25	-0.16
High-risk areas	18.1	24.5	6.4	306	262	-44	1.14	0.979	-0.16
Difference	-3.9	-7.3	-3.4	48	-30	-78	-0.27	-0.27	0

†Difference: post-disaster – pre-disaster; ‡Difference: high-risk area – low-risk area

Table 7. Relative risks and Additive Scale Interaction of Space and Time on the Risk of Post-Traumatic Stress Disorder, Depression, and Heart Disease, National Health Insurance Service Database 2011-2016

Outcome	Inpatients		Outpatients		Emergency Patients	
	Pre-disaster (time = 0)	Post-disaster (time = 1)	Pre-disaster (time = 0)	Post-disaster (time = 1)	Pre-disaster (time = 0)	Post-disaster (time = 1)
	RR* (95% CI**)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
PTSD						
Low-risk areas (space = 0)	Reference	0.91 (0.77, 1.07)	Reference	1.03 (1.01, 1.05)	Reference	1.28 (0.99, 1.65)
High-risk areas (space = 1)	1.04 (0.80, 1.36)	1.35 (0.82, 2.23)	0.81 (0.65, 1.00)	0.82 (0.64, 1.05)	0.83 (0.62, 1.12)	1.31 (0.59, 2.93)
Additive scale of interaction (RERI†; 95% CI)	0.40 (0.25, 0.79)		-0.02 (-0.03, 0.00)		0.20 (-0.02, 1.15)	
Depression						
Low-risk areas (space = 0)	Reference	1.10 (1.03, 1.18)	Reference	1.04 (1.02, 1.07)	Reference	0.78 (0.52, 1.12)
High-risk areas (space = 1)	1.23 (0.93, 1.62)	1.08 (0.70, 1.66)	0.95 (0.79, 1.14)	0.98 (0.78, 1.24)	0.79 (0.54, 1.17)	0.97 (0.19, 4.45)
Additive scale of interaction (RERI†; 95% CI)	-0.25 (-0.26, -0.13)		-0.01 (-0.02, 0.03)		0.40 (0.13, 3.17)	

*RR: Relative Risk **95% CI: 95% Confidence Interval
† RERI: the Relative Excess Risk due to Interaction

Table 7. (cont.) Relative risks and Additive Scale Interaction of Space and Time on the Risk of Post-Traumatic Stress Disorder, Depression, and Heart Disease, National Health Insurance Service Database 2011-2016

Outcome	Inpatients		Outpatients		Emergency Patients	
	Pre-disaster (time = 0)	Post-disaster (time = 1)	Pre-disaster (time = 0)	Post-disaster (time = 1)	Pre-disaster (time = 0)	Post-disaster (time = 1)
	RR* (95% CI**)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)	RR (95% CI)
Heart disease						
Low-risk areas (space = 0)	Reference	0.95 (0.82, 1.07)	Reference	1.05 (0.99, 1.12)	Reference	1.00 (0.74, 1.31)
High-risk areas (space = 1)	0.80 (0.62, 1.03)	0.60 (0.34, 1.03)	0.99 (0.77, 1.27)	0.87 (0.61, 1.24)	0.82 (0.63, 1.05)	0.83 (0.22, 2.74)
Additive scale of interaction (RERI†; 95% CI)	-0.14 (-0.10, -0.07)		-0.17 (-0.15, -0.14)		0.01 (-0.15, 1.38)	

*RR: Relative Risk **95% CI: 95% Confidence Interval
† RERI: the Relative Excess Risk due to Interaction

V. DISCUSSION

5.1 Findings from the present study

We first checked the difference between Ansan-si and Gyeonggi-do using a standardized prevalence rate. Given the time series trend, the monthly medical use was higher in Gyeonggi-do than in Ansan-si in general. On the other hand, in the case of PTSD inpatients and emergency patients, Ansan-si is showing a higher frequency of medical use in comparison to Gyeonggi-do from the beginning of 2011. Piecewise regression revealed the evident influence of the incidence in the patients who were hospitalized for PTSD, depression, and heart disease.

Space or time cluster was examined through cluster analyses of Ansan-si. The number of inpatients with depression from January 2015 to December 2016 was 34 percent higher than other times. A cluster that includes the high-risk areas had a particularly high prevalence of hospitalization due to depression. Outpatients with depression increased 14 percent in all regions from June to December 2015; and 21% higher in the regions which include higher-risk areas than the rest. For PTSD, a clusters of hospitalization was observed from January 2014 to December 2016 in Bugok-dong, Wolpy-dong, Seongpo-dong, Il-dong, I-dong, Ansan-dong, Gojan 2-dong and Wadong, 36% increase; PTSD outpatient service utilization in Gojan 2-dong, where Danwon high school is located in was 33% higher than others from January 2014 to December 2016. There were no spatial autocorrelation effects observed.

Disease mapping was also necessary to look at spatial variations within Ansan-si. we were able to see an increasing tendency in the use of mental health care from 2015, a year after the Sewol accident, in outpatients with depression and inpatients and outpatients with PTSD to be specific.

Using the DID methods showed a slight increase in the average of quarterly SPR per 100,000 people in inpatients with PTSD, but not with

depression and heart disease in the high-risk areas after the disaster. In contrast, a great increase in outpatients with PTSD in the high-risk areas after the disaster was shown. By performing spatiotemporal regression analysis, we have observed a significant change in the inpatients' PTSD health care utilization of high-risk areas after the incident.

To sum up, the number of inpatients in Ansan-si showed a significant increase after the disaster. The spatial clusters of inpatients and outpatients with depression in high-risk areas were found. Disease mapping illustrated that outpatients for PTSD and depression increased after the incidence as well as the PTSD emergency use. DID estimators indicate that outpatients with PTSD increased after the disaster in the high-risk areas whilst a small change in outpatients with depression. In contrary, spatiotemporal analysis displayed that living in high-risk areas after the Sewol ferry disaster increased the risk of PTSD hospitalization and decreased the risk of inpatient use for depression. Taking account of pure temporal or spatial factors showed a definite increase in the prevalence of mental disorders after the disaster. Nevertheless, considering both spatial and temporal factors at the same time brought about mixed results. As the spatiotemporal analysis is a more complex and advanced method that takes account of confounders within the model, we assume that the results from the spatiotemporal analysis are more reliable in comparison to DID estimators which used a rough average of the SPRs.

5.2 Strength and Limitation of the present study

The present study has some limitations. We used NHIS' health insurance data which is based on billing information. Defining an outcome variable using the billing data may result in non-differential misclassification which may underestimate the actual effect. A person can be misclassified as having no experience with the disease when they have. We covered a wide range

of psychiatric disorders to compensate for this potential bias. Likewise, a study that surveyed PTSD symptoms of the Sewol ferry victims' parents illustrated that only 13% of the victims' parents undergo psychotherapy (Park, 2015). This result also suggests that the effect we observed may have been underrated the true impact of the Sewol ferry disaster on the community mental health. One may raise a question the change in direct and indirect victims' place of residence to another. If the assumption is correct, it means that there is an underestimation of the result. Nevertheless, the study is an ecological study of the population and is not significantly affected by individual variations. Also, we have been looking at six years in total which is long enough; therefore, it is highly unlikely to omit these patients. At last, the operational definition of PTSD was used instead of extracting exact KCD codes post-traumatic disorder, F43.1. This was largely due to the fact that the total number of cases in each town was too small to perform analyses with sufficient statistical power. Moreover, the review written by Goldmann and Galea (2014) emphasized the necessity of evaluating a broader spectrum of psychopathology than has currently been studied. The authors argue that most disaster research focuses on PTSD symptoms. Not only PTSD but also other mental illness such as generalized anxiety disorder and panic disorder should be investigated. Even if it is not specific to the actual PTSD, there are two benefits of using the operational definition of PTSD in the study: it increased the statistical power of the small-area analyses and extended the scope of the peri-disaster psychopathology as it includes phobic anxiety disorder, other anxiety disorder, and also the most common comorbid mental disorder, depression.

The major strength of the study is that we used the national health data which is a representative of the entire Korean population. Analysis using small-area units are difficult to perform because first, it is hard to obtain data in small-area units and second national insurance program that

covers the entire nations are not common. Collecting individual patients' data was impossible due to the Privacy Policy reasons, yet we were able to get aggregated counts of individual data. Making an inference about the effect of an exposure on individuals with group-level findings make us fall into the ecological fallacy. One should not generalize these results to the individual level to avoid the bias. Furthermore, the spatiotemporal analysis is one of the few methods used in mental health research in Korea. By using this method, we could see the difference in areas that share similar social and physical environments. People living in nearby neighborhoods are geographically close, so we can assume that their characteristics would be similar to each other except for the incident. Potential confounding variables that should explore in the individual level data were not necessary. Because of these strength of the study, we were able to draw meaningful results within the entire community. Results from the study shed light on community mental health research by giving information that the same event has a different effect on the population living in a different area.

5.3 Public Health Implication

Detrimental effects of the traumatic event observed in the study imply the need for mental health surveillance systems and proper interventions. Currently, treatment services tend to focus on direct victims and survivors. Since communities, as well as people directly related to victims, are affected by the disaster, the study revealed the need to provide population-based mental health services to reduce the mental illness. It alludes the need to offer post-disaster mental health guidelines for psychiatrists as well as for primary physicians.

VI. CONCLUSION

We conclude that the impact of the Sewol accident was evident in inpatients use of Ansan-si residents. Spatiotemporal regression analysis revealed that inpatients in high-risk areas were far more affected with PTSD in comparison with those in low-risk areas after the disaster. We did not observe a significant association in other mental health disorder and heart disease.

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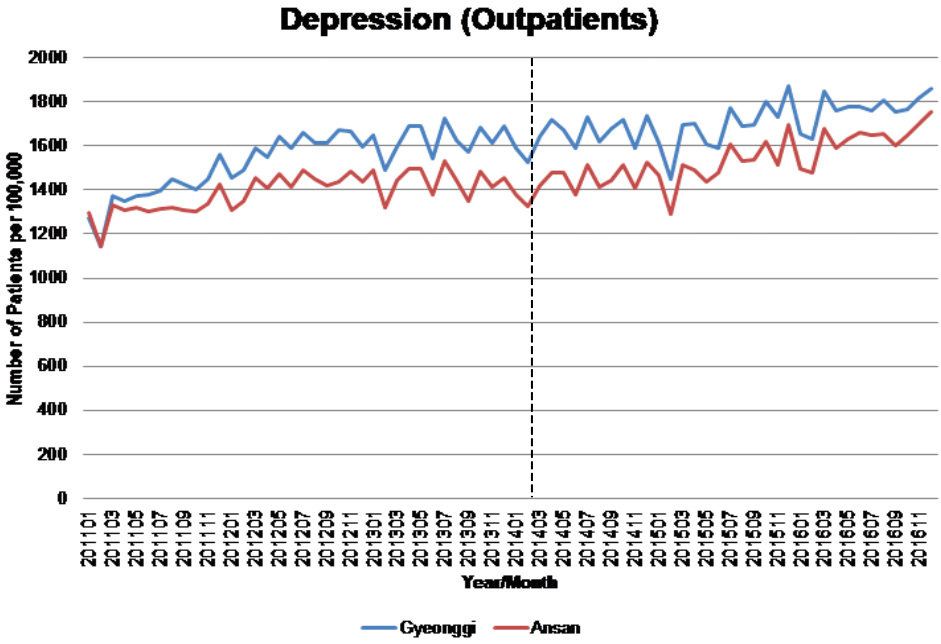
APPENDIX

Fig. 10. Monthly Secular Trends for Outpatients from 2011 to 2016 (depression, PTSD, and heart disease, respectively)



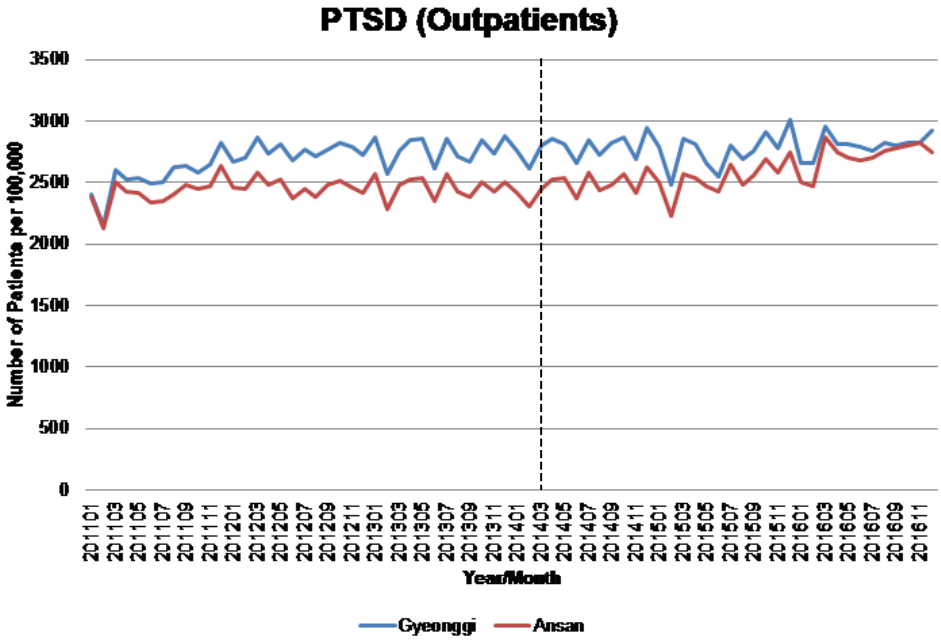


Fig. 10. (cont.) Monthly Secular Trends for Outpatients from 2011 to 2016 (depression, PTSD, and heart disease, respectively)

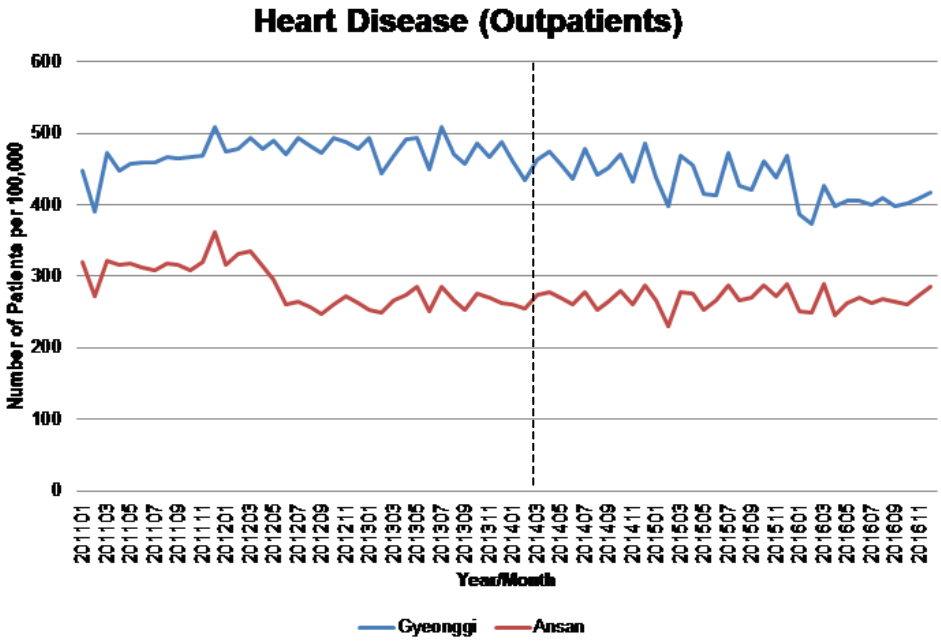
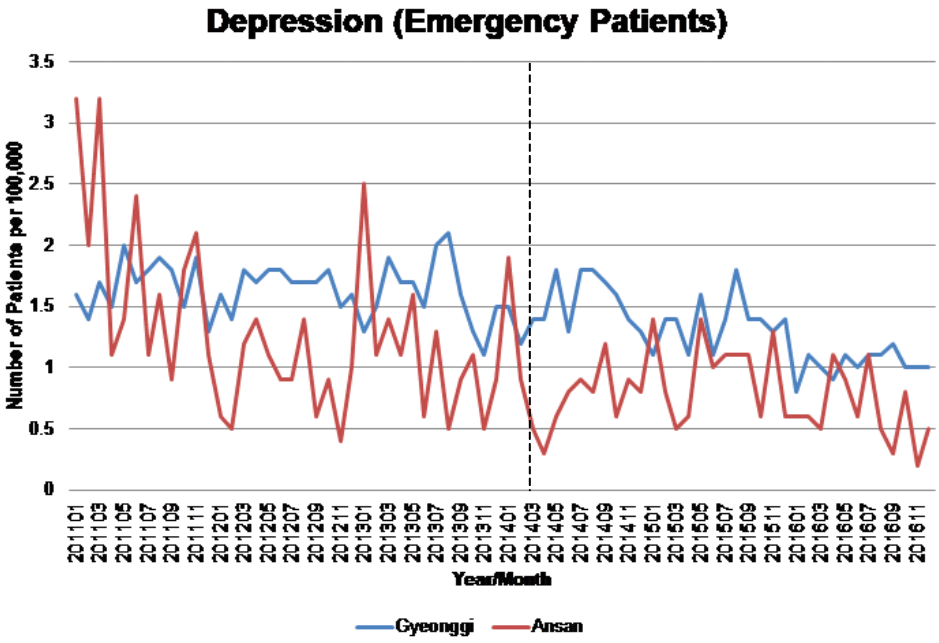


Fig. 11. Monthly Secular Trends for Emergency Patients from 2011 to 2016 (depression, PTSD, and heart disease, respectively)



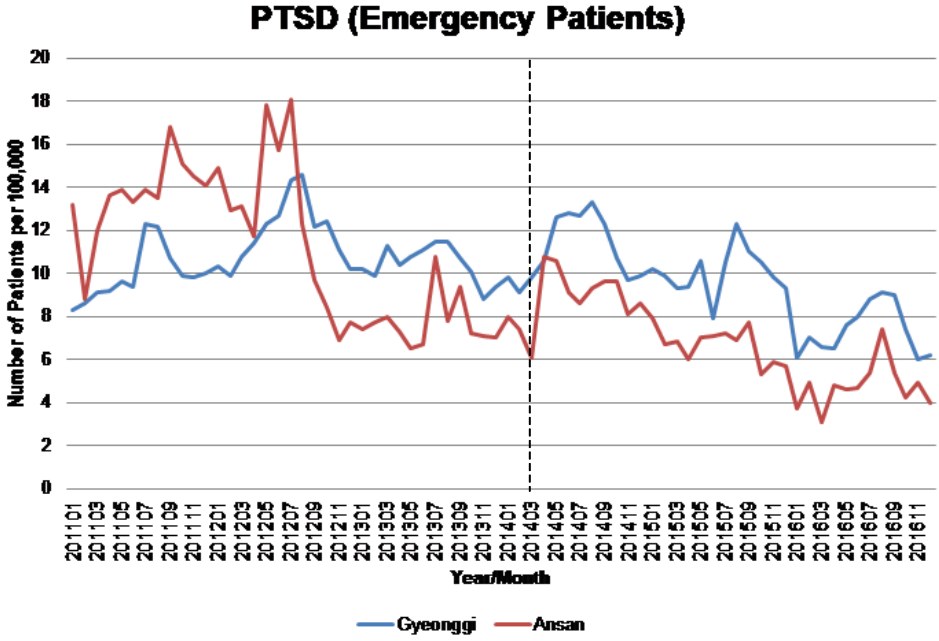


Fig. 11. (cont.) Monthly Secular Trends for Emergency Patients from 2011 to 2016 (depression, PTSD, and heart disease, respectively)

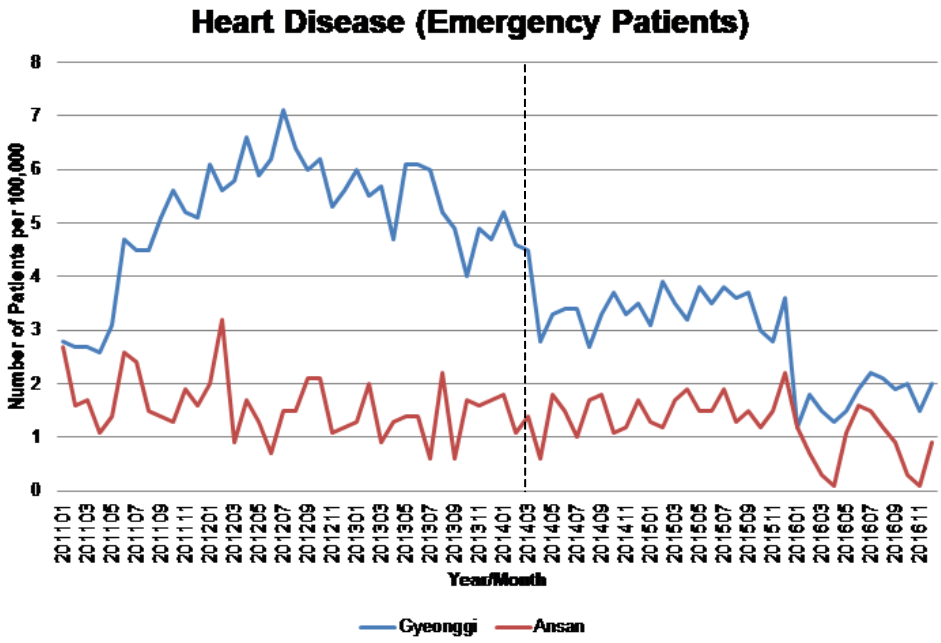
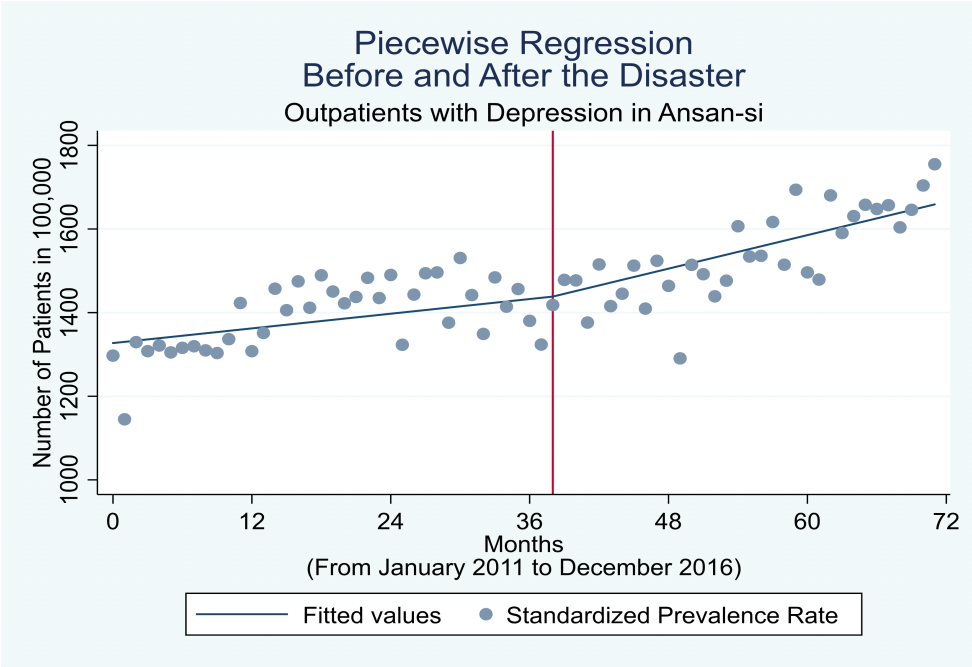


Fig. 12. Standardized Prevalence Rate from a Piecewise Model with One Knot at the Time of the Disaster (outpatients with depression, PTSD, and heart disease, respectively).



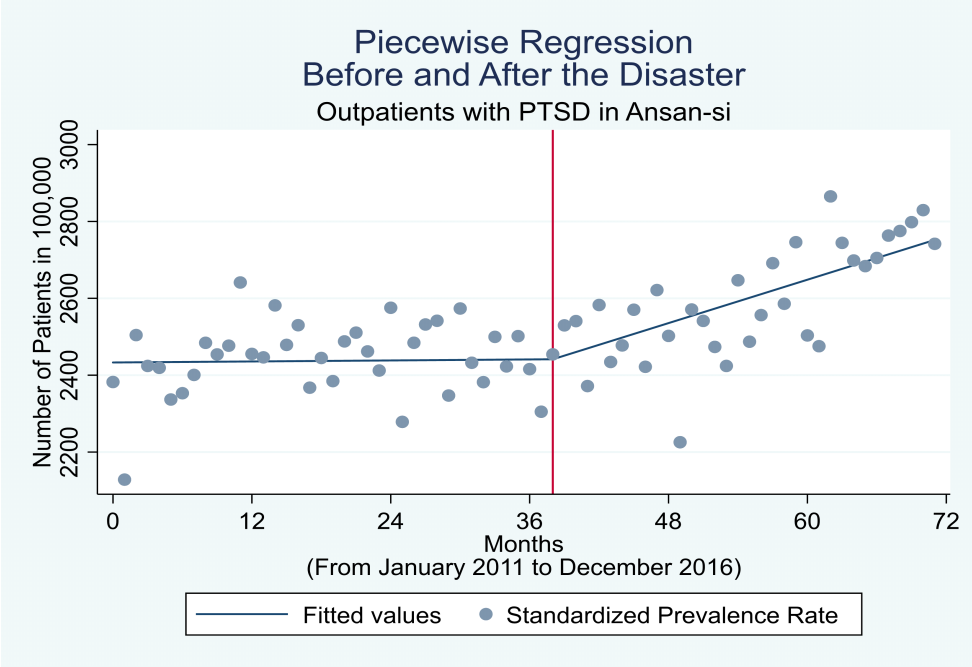


Fig. 12. (cont.). Standardized Prevalence Rate from a Piecewise Model with One Knot at the Time of the Disaster (outpatients with depression, PTSD, and heart disease, respectively).

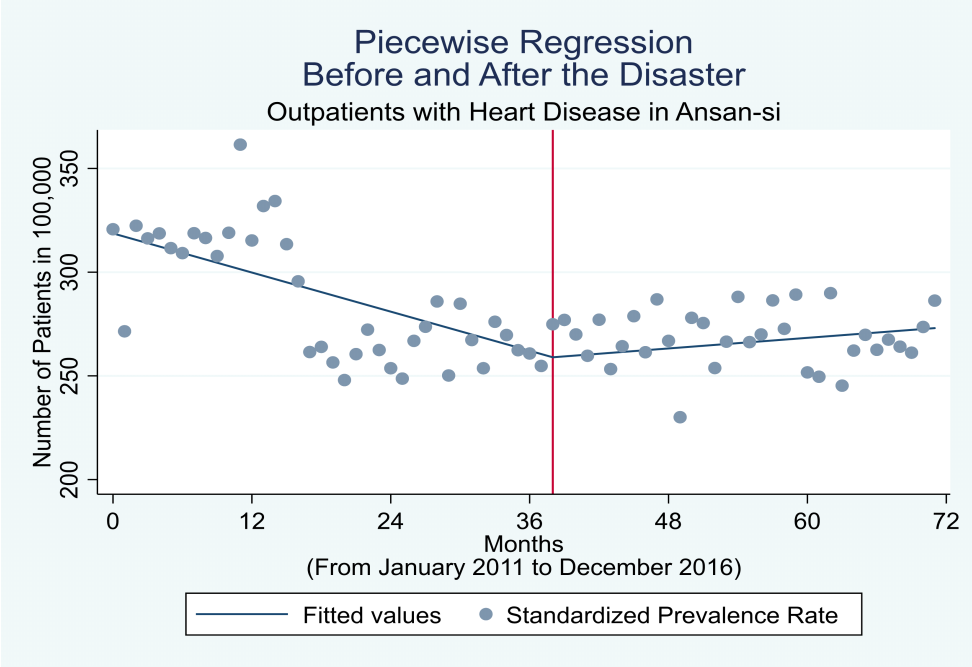
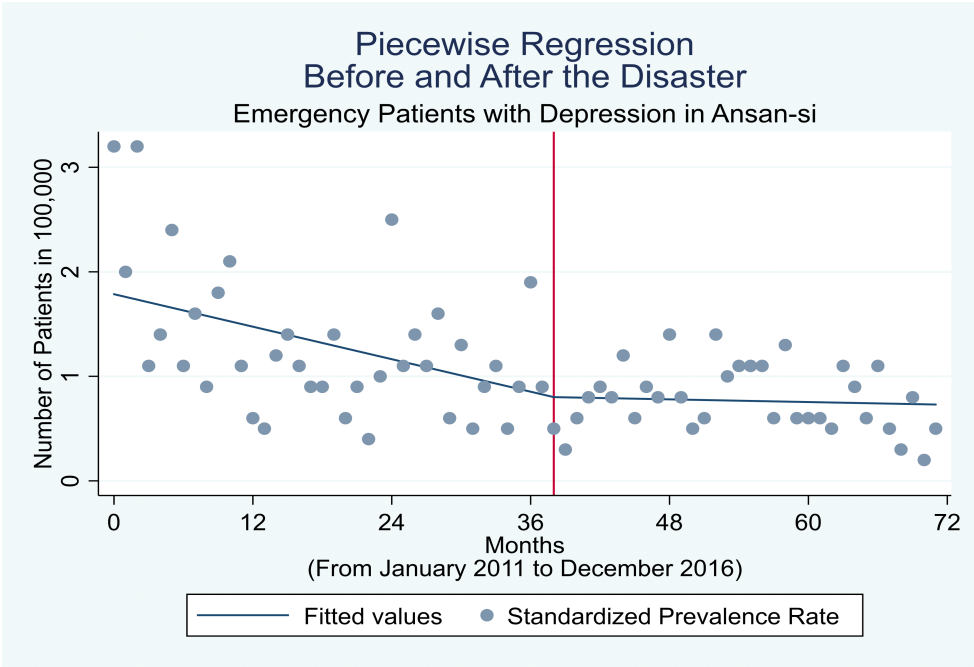


Fig. 13. Standardized Prevalence Rate from a Piecewise Model with One Knot at the Time of the Disaster (emergency patients with depression, PTSD, and heart disease, respectively).



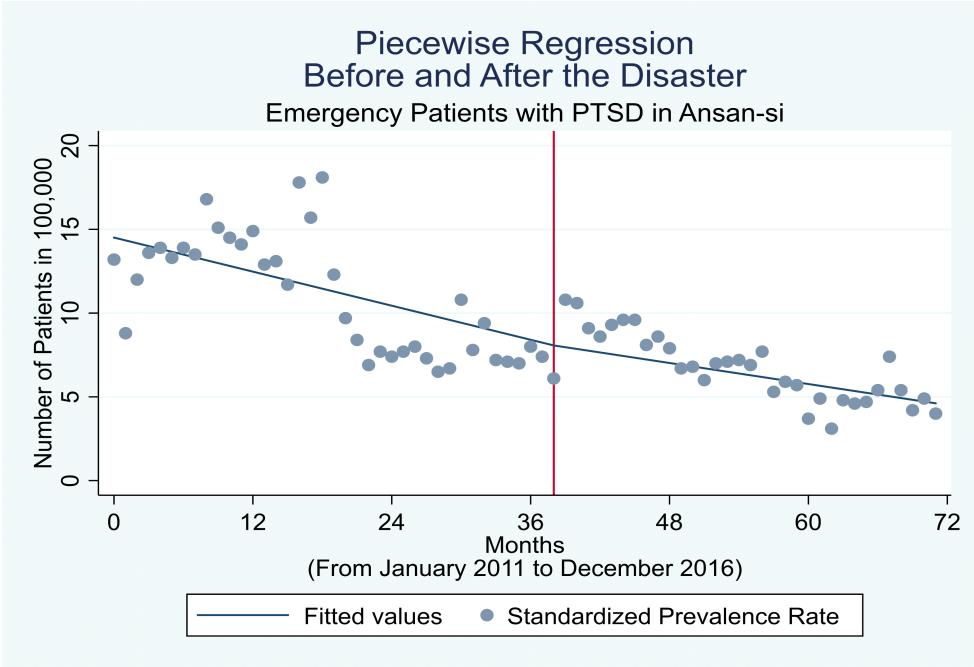


Fig. 13. (cont.) Standardized Prevalence Rate from a Piecewise Model with One Knot at the Time of the Disaster (emergency patients with depression, PTSD, and heart disease, respectively).

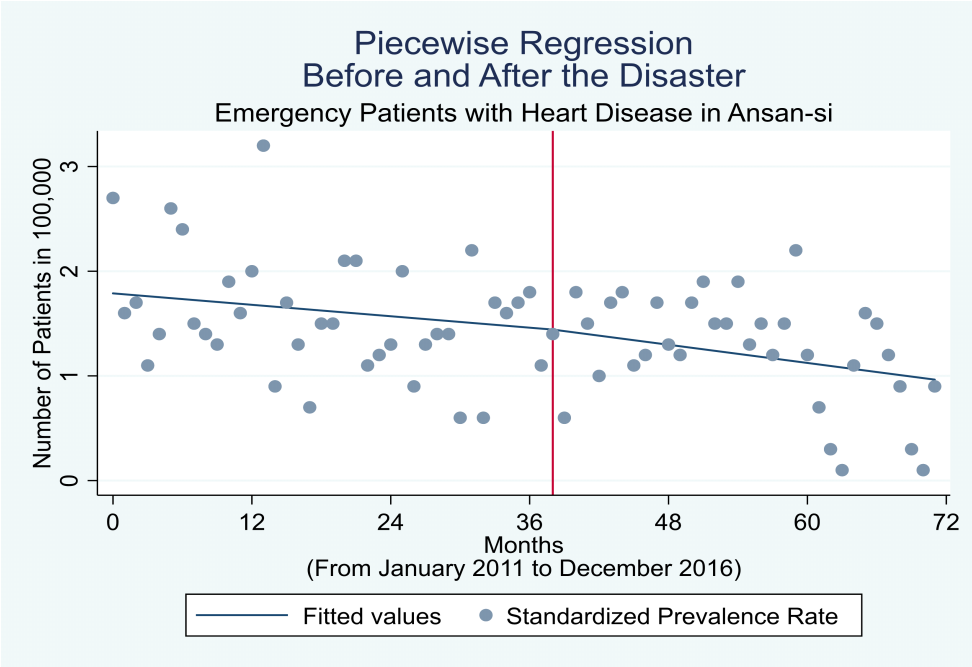


Fig. 14. Quarterly Secular Trends of Outpatients with Depression in Ansan-si from 2011 to 2016

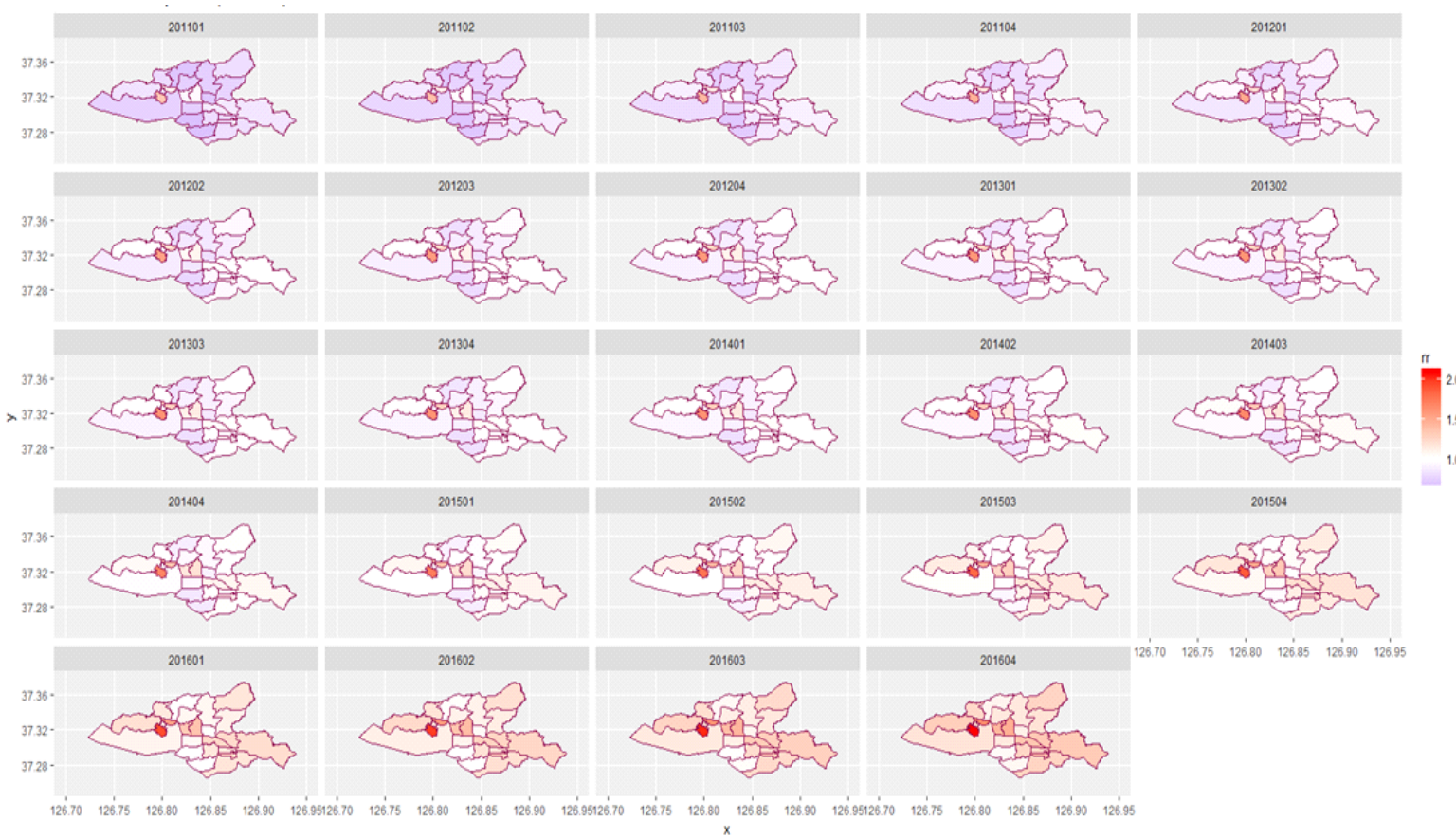


Fig. 15. Quarterly Secular Trends of Emergency Patients with Depression in Ansan-si from 2011 to 2016

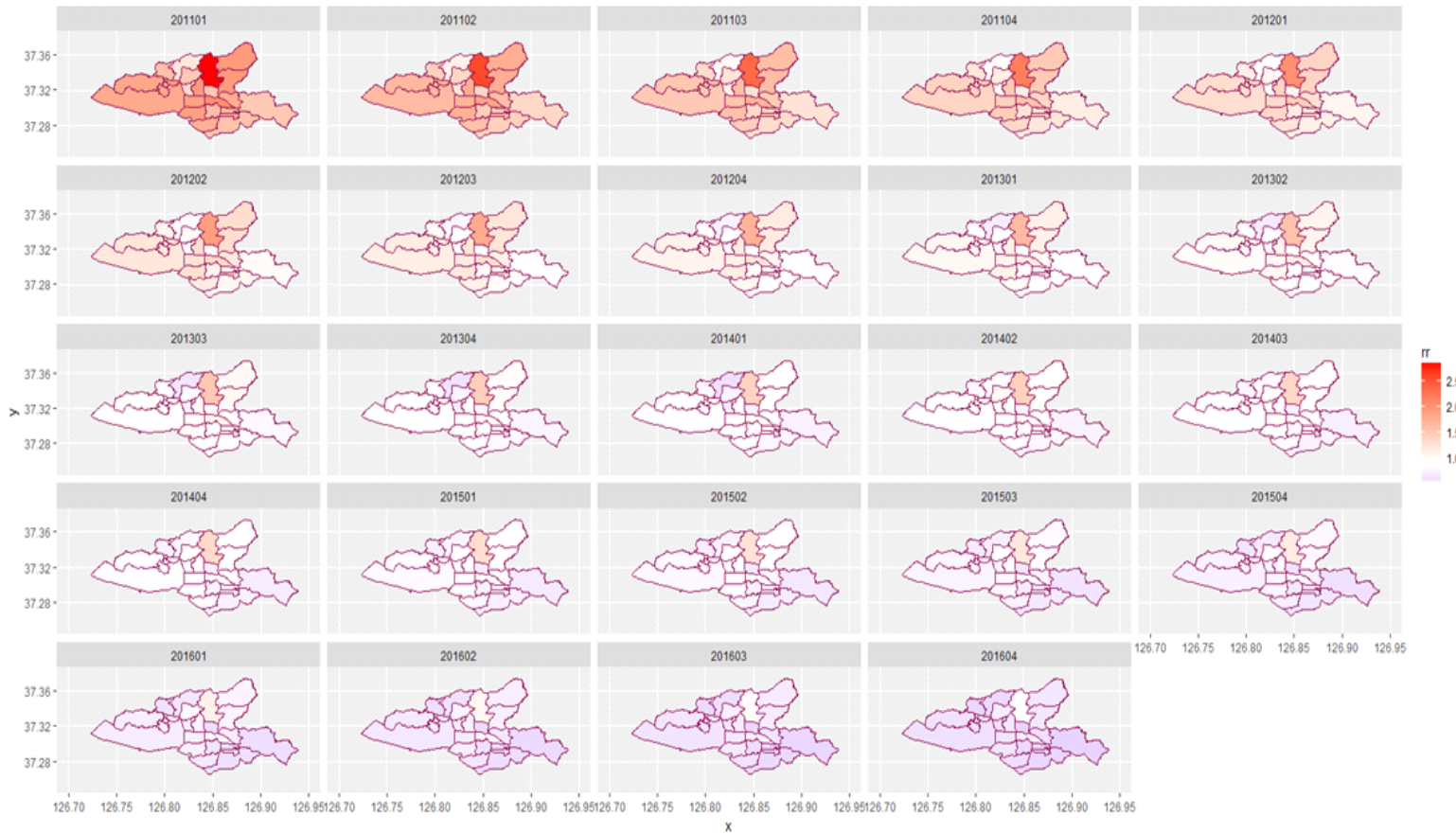


Fig. 16. Quarterly Secular Trends of Outpatients with PTSD in Ansan-si from 2011 to 2016

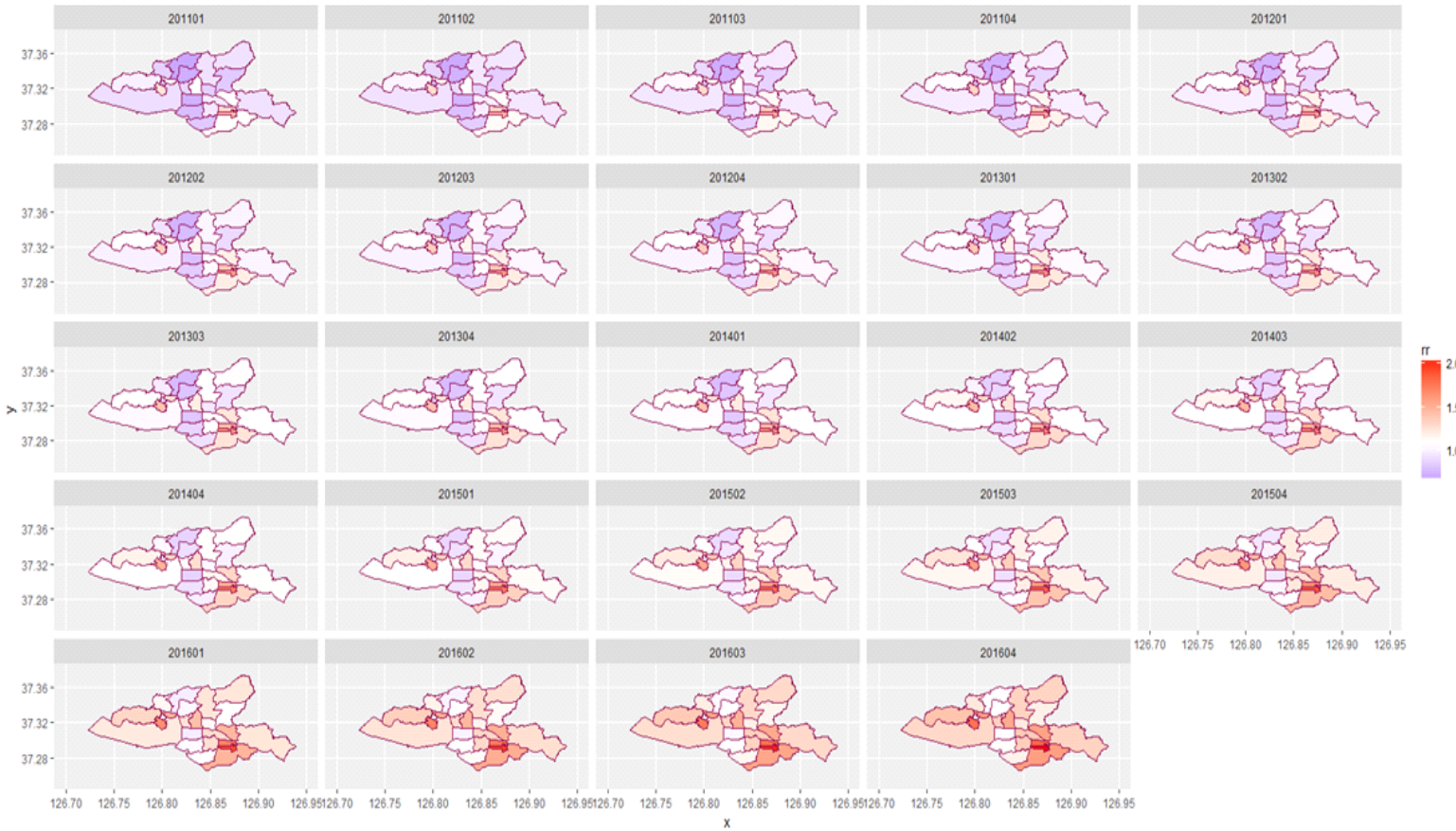


Fig. 17. Quarterly Secular Trends of Emergency Patients with PTSD in Ansan-si from 2011 to 2016

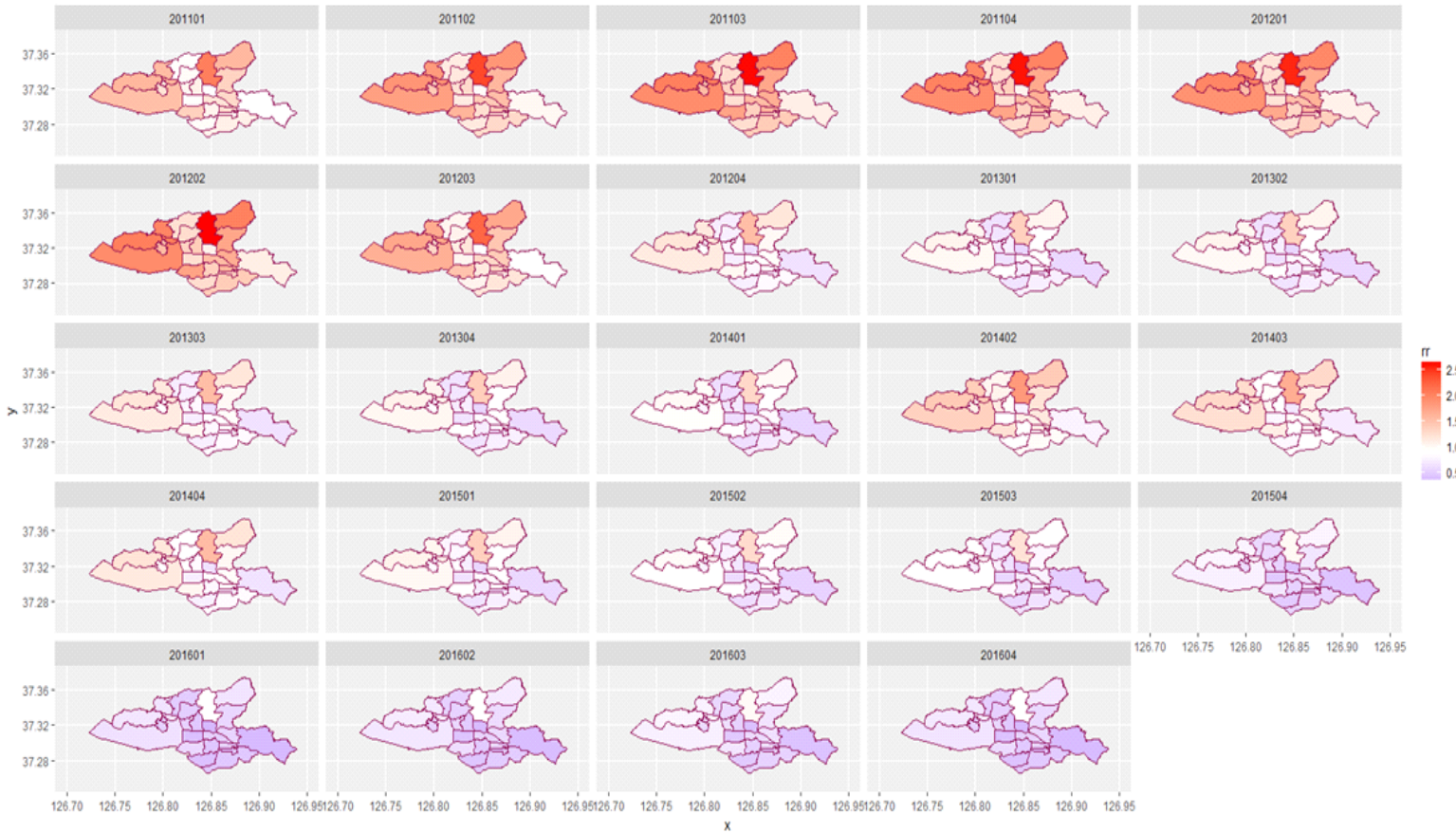


Fig. 18. Quarterly Secular Trends of Outpatients with Heart Disease in Ansan-si from 2011 to 2016

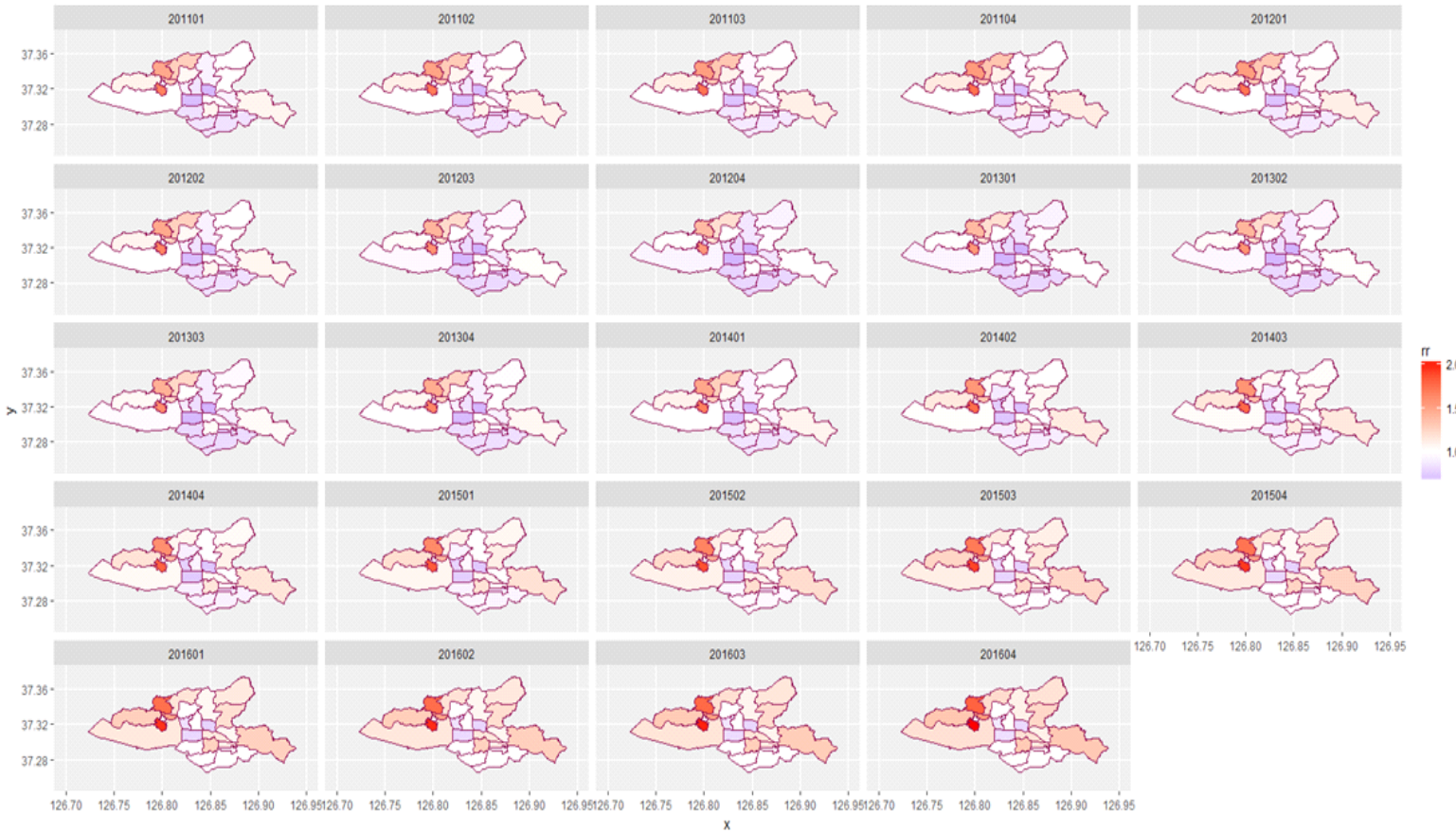


Fig. 19. Quarterly Secular Trends of Emergency Patients with Heart Disease in Ansan-si from 2011 to 2016

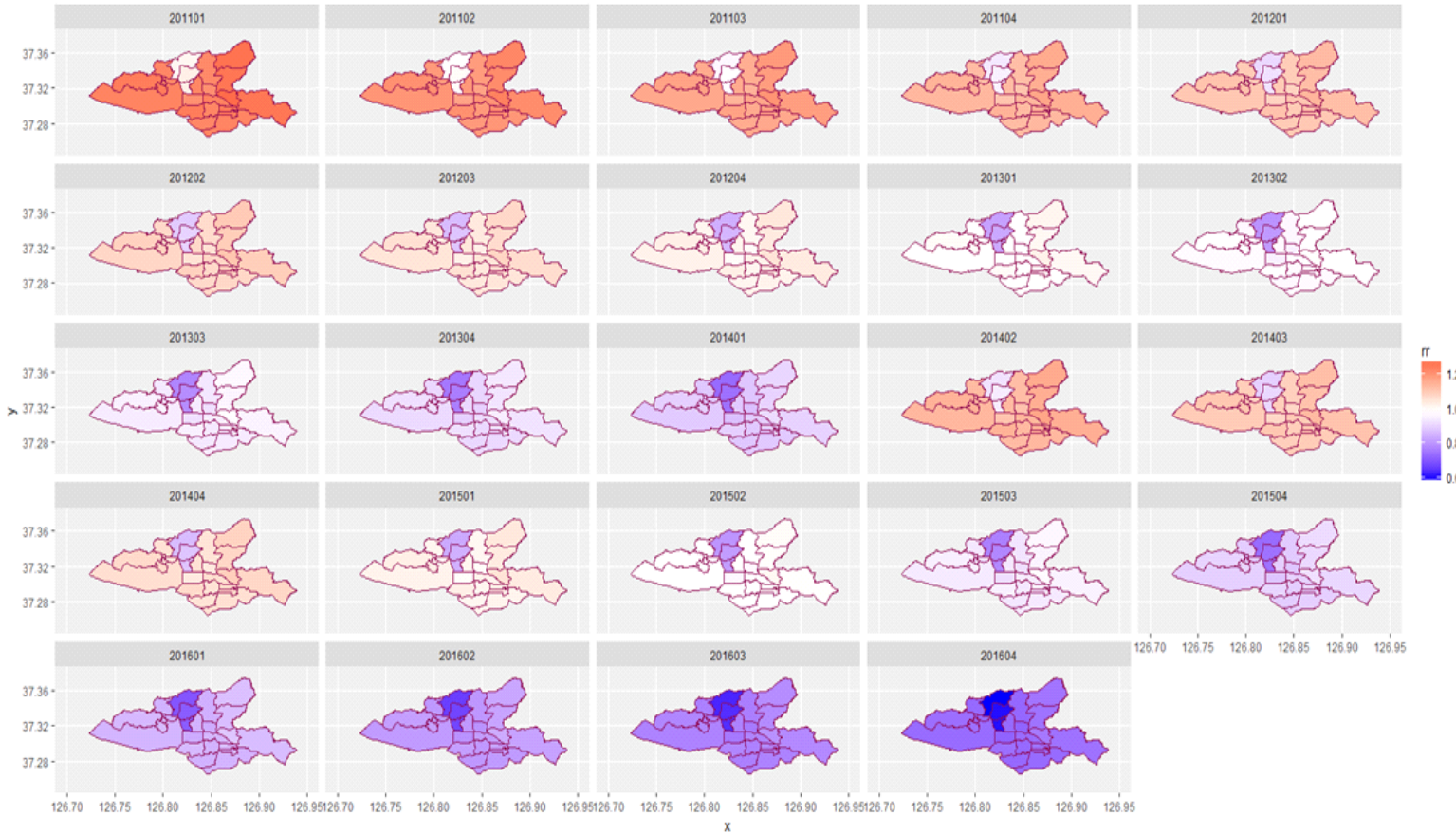
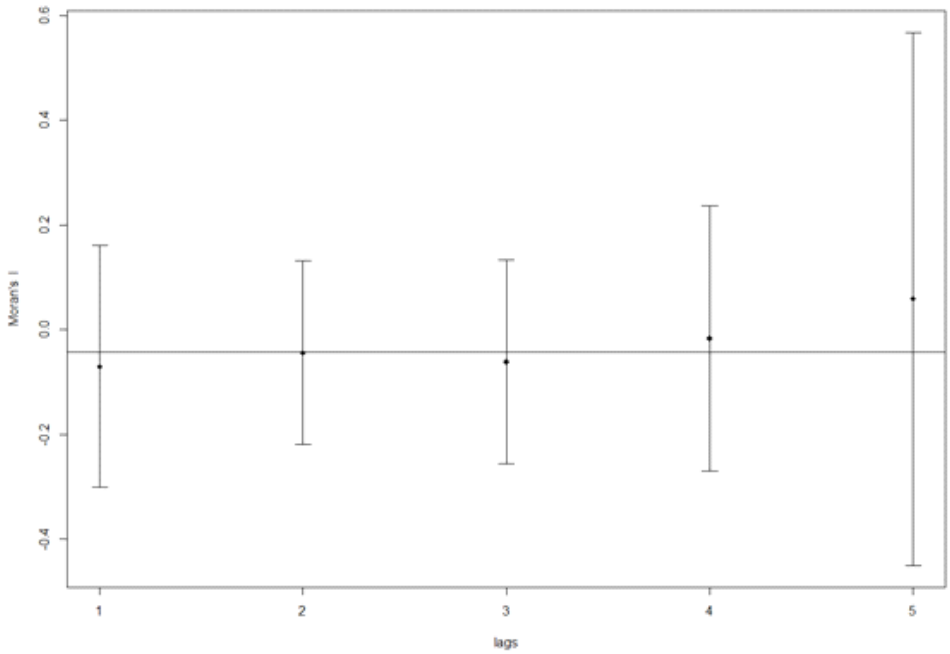


Fig. 20. Spatial Correlogram of Outpatients using Moran's I (depression, PTSD, and heart disease, respectively). Moran's I is plotted on the vertical axis and spatial lag is plotted on the horizontal axis.



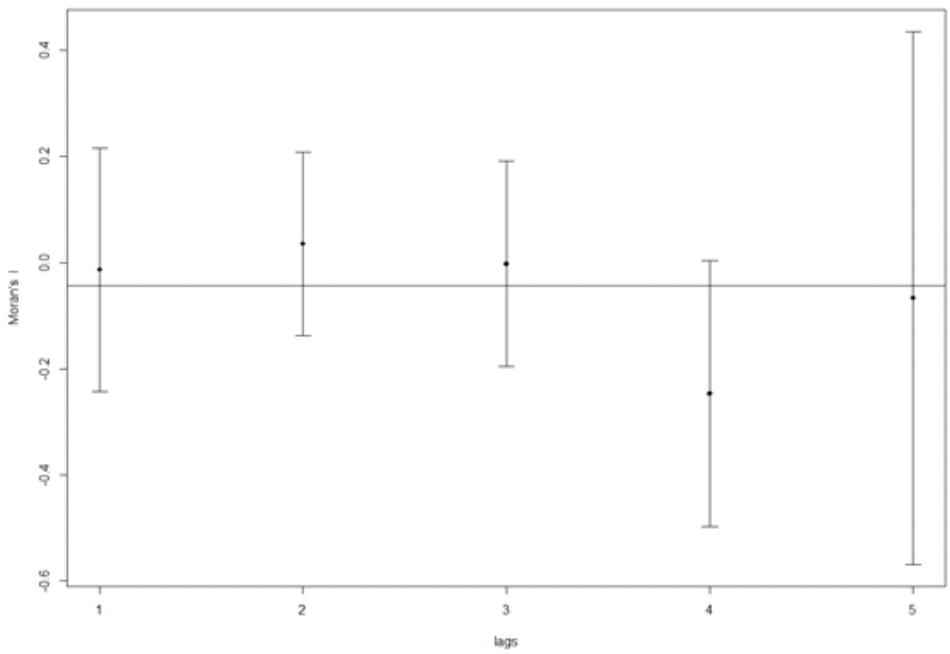


Fig. 20. (cont.) Spatial Correlogram of Outpatients using Moran's I (depression, PTSD, and heart disease, respectively). Moran's I is plotted on the vertical axis and spatial lag is plotted on the horizontal axis.

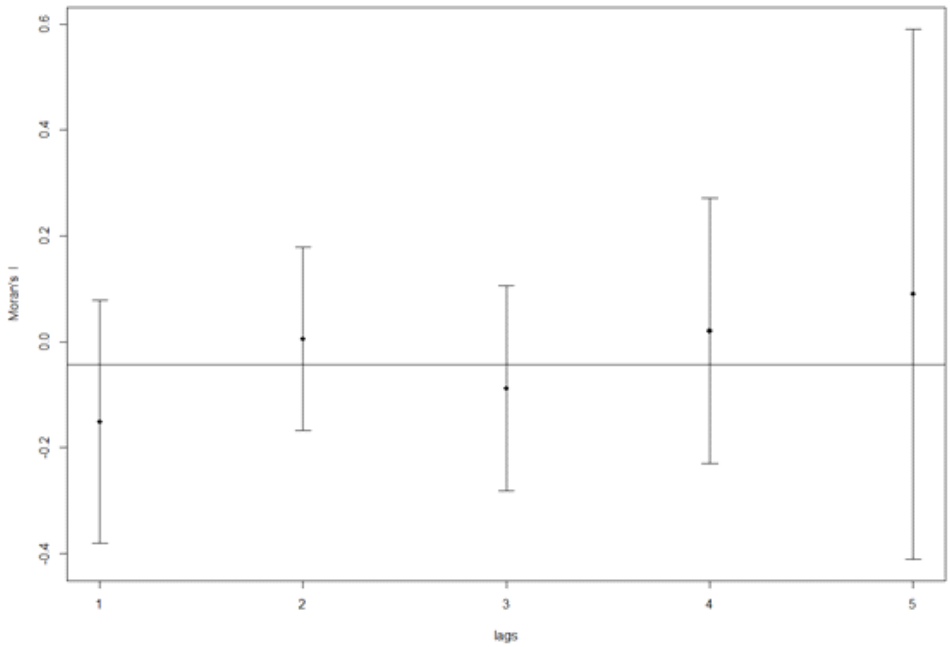
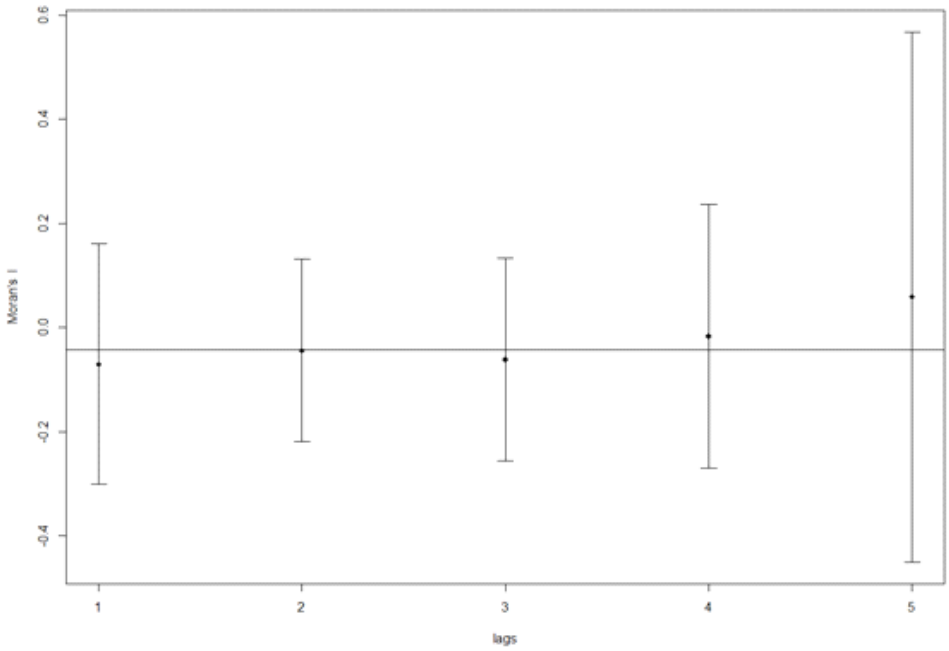


Fig. 21. Spatial Correlogram of Emergency Patients using Moran's I (depression, PTSD, and heart disease, respectively). Moran's I is plotted on the vertical axis and spatial lag is plotted on the horizontal axis.



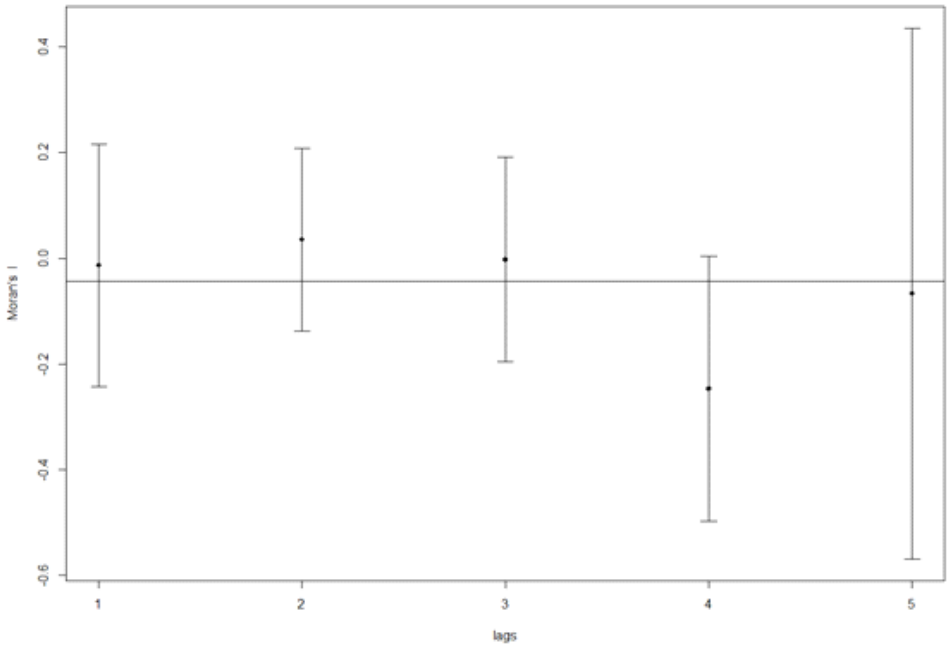


Fig. 21. (cont.) Spatial Correlogram of Emergency Patients using Moran's I (depression, PTSD, and heart disease, respectively). Moran's I is plotted on the vertical axis and spatial lag is plotted on the horizontal axis.

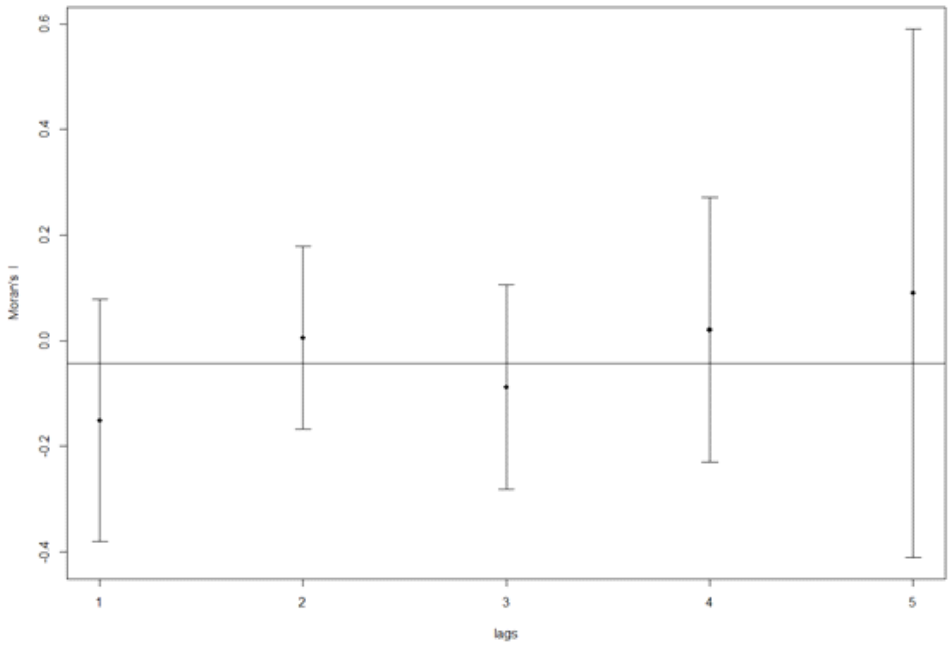


Table 8. The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE + RECORD items (modified)	Location in manuscript where items are reported
Title and abstract			
	1	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included.	Page II
		RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract.	Page II
		RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	N/A
Introduction			
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 6
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 7
Methods			
Study Design	4	Present key elements of study design early in the paper	Page 26
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 26 - 28
Participants	6	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided.	Page 27
		RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided.	N/A
		RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	N/A

	Item No.	STROBE + RECORD items (modified)	Location in manuscript where items are reported
Methods			
Variables	7	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Page 29
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).	Page 27
		Describe comparability of assessment methods if there is more than one group	Page 28
Bias	9	Describe any efforts to address potential sources of bias	N/A
Study size	10	Explain how the study size was arrived at	Page 28
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	Page 27
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Page 30 - 33
		(b) Describe any methods used to examine subgroups and interactions	Page 31 - 33
		(c) Explain how missing data were addressed	N/A
		(d) Describe any sensitivity analyses	N/A
Data access and cleaning methods	13	RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	N/A
		RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	N/A

	Item No.	STROBE + RECORD items (modified)	Location in manuscript where items are reported
Methods			
Linkage	14	RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	Page 26
Results			
Participants	15	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	N/A
Descriptive data	16	(a) Give characteristics of study participants (*e.g.* demographic, clinical, social) and information on exposures and potential confounders	N/A
		(b) Indicate the number of participants with missing data for each variable of interest	N/A
Outcome data	17	*Cross-sectional study* - Report numbers of outcome events or summary measures	Page 51
Main results	18	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	19	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	Page 49 – 50

	Item No.	STROBE + RECORD items (modified)	Location in manuscript where items are reported
Discussion			
Key results	20	Summarize key results with reference to study objectives	Page 55
Limitations	21	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Page 55
Interpretation	22	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 57
Generalisability	23	Discuss the generalisability (external validity) of the study results	Page 57
Other Information			
Funding	24	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A
Accessibility of protocol, raw data, and programming code	25	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	N/A

국문 초록

세월호 참사 전후 안산시 외상 후 스트레스 장애 관련 의료 이용 시공간 분석

변한글
보건학과 보건학전공
서울대학교 보건대학원

연구배경: 재해는 신체적, 정신적 건강 문제를 일으킬 수 있는 충격적인 사건이다. 재난에 노출되면, 노출된 사람들은 종종 우울증, 불안장애 또는 자살충동을 겪는다. 무엇보다도 외상 후 스트레스 장애는 개인이 경험할 수 있는 가장 흔한 정신 건강 장애이다. 따라서, 재난이 PTSD에 미치는 영향을 조사하기 위해 많은 연구가 실시되어 왔다. 그러나 분석의 공간적 및 시간적 변화를 고려한 연구는 거의 없었다. 본 연구는 2014년 4월 16일 발생한 세월호 참사 이후 경기도와 안산시의 외상 후 스트레스로 인한 의료 이용의 변화를 확인한다. 또한 소지역 단위를 사용한 시공간 회귀분석으로 세월호 참사가 안산시에 미친 영향을 파악하고자 한다.

연구방법: 2011년부터 2016년까지 국민건강보험 공단 맞춤형 DB를 사용하여 데이터를 수집했다. 건강 보험 혜택을 받은 경기도와 안산시에 거주하는 외래, 외래, 응급환자가 분석에 포함되었다. 이중차분법과 베이지언 시공간 포아송 회귀 모형을 사용해 세월호 참사 이후 PTSD 의료 이

용 변화를 확인하였다.

연구결과: 세월호 참사 이후 고위험군의 PTSD 입원 이용이 크게 증가했다(RERI, 0.40; 95% CI, 0.25, 0.79). 외래 및 응급 환자는 시간과 공간에 통계적으로 유의하지 않은 연관성을 보였다(외래 환자: RERI, -0.02, 95% CI, -0.03, 0.00; 응급 환자: RERI, 0.20, 95% CI, -0.02, 1.15)

결론: 세월호 사고 이후 고위험지역에서 PTSD로 인한 입원의 위험이 증가했다. 이 연구에서 발견된 외상 사건의 영향은 정신 건강 감시 시스템의 필요성과 적절한 개입을 필요하다는 것을 서사한다.

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주요어: 외상 후 스트레스 장애, 재난, 정신 건강, 시공간분석, 세월호 참사, 의료이용

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