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Shattered ground, shaken minds: Mental health consequences of earthquakes☆

Andika Ridha Ayu Perdana [a,b,*,1], Judit Vall Castelló [c,2]

[a] Department of Economics, University of Barcelona, J.M. Keynes, 1, 11, 08034 Barcelona, Spain
[b] Department of Economics, Universitas Islam Indonesia, Indonesia
[c] Department of Economics, University of Barcelona, IEB and CRES-UPF, J.M. Keynes, 1, 11, 08034 Barcelona, Spain

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ABSTRACT

Despite growing recognition of the importance of mental health status for the achievement of the global development goals, substantial challenges persist in addressing this issue in both developed and developing countries. The literature has pointed to a variety of conditions as triggers for mental health problems, including exposure to unexpected natural disasters. Contributing to the literature, our study quantifies the mental health consequences of the devastating 2006 Yogyakarta earthquake in Indonesia. We combine the Modified Mercalli Intensity from the United States Geological Survey with individual-level data from the Indonesia Family Life Survey to assess the impacts on municipalities with varying earthquake intensities. Employing a difference-in-differences approach, we identify a significant and persistent deterioration in the mental health condition for individuals in municipalities with stronger earthquake severity. To explore the mechanisms underlying this impact, we analyze the roles of family casualties, physical health declines, and socio-economic disruptions, identifying family loss and worsened physical health as particularly influential factors driving the observed mental health outcomes.

1. Introduction

The role of mental health in achieving global development goals is increasingly acknowledged in academic and policy discussions (De Silva, 2015; Jenkins, 2019). However, complex challenges associated with mental health persist in both developed and developing countries. According to the World Health Organization (2022), one in eight people lives with a mental disorder, with anxiety and depressive conditions placing as the most prevalent among both men and women. This sizeable proportion highlights a pressing universal health issue, emphasizing the immediate need for enhanced awareness. Moreover, the recent COVID-19 pandemic has introduced another layer of complexity, which is undoubtedly capable of weakening the mental health situation and creating major changes in people's well-being through many ways (König et al., 2023; Mureşan et al., 2022; Song, 2020). While mental health is influenced by a complex interaction of internal and external factors, it is well-recognized that experiencing unexpected and traumatic events may also contribute to this issue.

In this study, we investigate the impact on individuals' mental health resulting from unexpected incidents, particularly catastrophic natural disasters. Over the past two decades, the destructive impact of natural disasters has increased worldwide, resulting in the loss of approximately 1.23 million lives and an estimated economic toll of around US$ 2.97 trillion (United Nations Office for Disaster Risk Reduction, 2020). These disasters have influenced a broad range of outcomes, including health (Bertinelli et al., 2023; Khanal, 2022; Raker et al., 2019), education (Caruso and Miller, 2015; Deuchert and Felfe, 2015; Herrera-Almanza and Cas, 2021; Paudel and Ryu, 2018; Rosales-Rueda, 2018; Shidiqi et al., 2023), labor market (Di Pietro and Mora, 2015; Kirchberger, 2017), social capital (Bai and Li, 2021; Cipollone and Rosolia, 2007),

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* Corresponding author at: Department of Economics, University of Barcelona, J.M. Keynes, 1, 11, 08034 Barcelona, Spain.
E-mail addresses: andika.ayu@uii.ac.id (A.R.A. Perdana), judit.vall@ub.edu (J. Vall Castelló).
[1] Orchid ID: 0000-0002-4527-0093
[2] Orchid ID: 0000-0002-1925-1657

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well-being (De and Thamarapani, 2022; Goebel et al., 2015; Rehdanz et al., 2015; Wang and Wang, 2023), demographic (Nandi et al., 2018), migration (Gröger and Zylberberg, 2016), finance (Deryugina, 2017; Gallagher and Hartley, 2017), crime rates (García Hombrados, 2020), and even electoral outcomes (Masiero and Santarossa, 2020).

Research consistently demonstrates that the impact of natural disasters extends far beyond physical destruction and financial loss, pointing out complex consequences for quality of life, including well-being and mental health. For instance, Rehdanz et al. (2015), De and Thamarapani (2022), and Wang and Wang (2023) highlight that natural disasters tend to have adverse impact in aspects of well-being, such as standard of living and happiness. In terms of mental health, interdisciplinary studies have shed light on the broader effects of disasters on this issue, exposing how survivors may experience a range of responses, both adverse and positive, from a clinical perspective. Research such as Norris et al. (2009), Galea et al. (2005), and Raker et al. (2019) illustrate that psychological responses can vary from immediate stress reactions to long-term disorders like post-traumatic stress disorder (PTSD) and depression, indicating that the psychological aftermath of disasters can affect mental health for years. The resilience of individuals and communities, as discussed by Bonanno et al. (2011) and Hobfoll et al. (2007) plays a critical role in recovery, indicating that mental health interventions should be designed to reinforce these inherent strengths. The impact on vulnerable groups such as children and the elderly is also substantial, as noted by Peek (2008) and Joseph and Jaswal (2021). This strand of literature indicates a complex relationship of factors that influence mental health outcomes post-disaster and points to the importance of comprehensive and varied approaches in disaster response and recovery strategies. Within this framework, we hypothesize three outcomes. First, greater exposure to the earthquake will be significantly correlated with heightened psychological distress. Second, these effects are expected to diminish over the long term due to potential resilience among individuals. Third, the elderly, being a vulnerable group, are more likely to experience adverse effects from the earthquake.

We analyze the changes in individuals' mental health following the 2006 earthquake in Yogyakarta Province, Indonesia. Our identification strategy relies on the unpredictable nature of the earthquake, including its timing, location, and severity, represented by the Modified Mercalli Intensity (MMI) index from the US Geological Survey (USGS) data.[3] By integrating this data with the Indonesian Family Life Survey (IFLS), we can connect individual characteristics with the MMI values. Employing a difference-in-differences approach, we aim to assess the earthquake's causal impact on mental health by comparing conditions of individuals in areas with varying MMI levels, both before and after the disaster. Our primary focus is on altered psychological states, including symptoms like feeling anxious, feeling depressed, having sleep disorders, and losing focus. To support our empirical strategy, we analyze responses to the earthquake from various subsamples and perform falsification tests. This study not only seeks to provide causal evidence of the impact of major disasters on mental health but also aims to explore pathways through which such events may heighten vulnerabilities. By examining changes in variables such as socioeconomic conditions and physical health status, we identify the primary drivers that contribute to the observed mental health effects, shedding light on how disasters can indirectly increase psychological distress.

Our findings show significant deteriorations in mental health in areas more intensely affected by the earthquake. Specifically, the disaster increases the likelihood of feeling anxious, depressed, and having sleep disorders by 8.39 %, 10.47 %, and 7.37 %, respectively, compared to pre-earthquake averages. These effects are particularly pronounced among vulnerable groups, including older adults, rural residents, and individuals from low-income families, though no significant differences were observed across genders. The robustness of our methodology is supported by consistent results across various treatment group definitions, including the use of binary MMI values, the exclusion of certain municipalities, and the execution of placebo tests, which collectively reinforce the validity of our assumptions. Furthermore, our analysis indicates that potential issues of endogenous migration and attrition do not bias our results. In exploring the mechanisms driving these mental health outcomes, we find that exposure to earthquakes leads to declines in both socioeconomic and physical health conditions. These adverse impacts on mental health appear closely linked to family casualties and deteriorations in physical health, which together contribute significantly to the overall effect. These findings also highlight the complex interaction between physical, social, and psychological factors in the aftermath of natural disasters.

This research aligns with the substantial body of literature investigating the relationship between natural disasters and mental health outcomes (Baryshnikova and Pham, 2019; Civelek, 2023; Kar et al., 2014; Lowe et al., 2015; Maclean et al., 2016; Mostafizur Rahman et al., 2023; Raker et al., 2019; Rhodes et al., 2010). In particular, this study adds to the specialized segment of the literature focusing on the mental health outcomes of earthquakes (Bertinelli et al., 2023; Kino et al., 2021; Livanou et al., 2005; Qu et al., 2012; Şalcioğlu et al., 2003; Sezgin and Punamäki, 2012; Zhang et al., 2011). Concerning the Yogyakarta earthquake, existing research with a causal emphasis has largely concentrated on its impact on well-being, education, social capital, and labor outcomes, as underlined in works by Bai and Li (2021), De and Thamarapani (2022), Kirchberger (2017), Shidiqi et al. (2023). However, there is limited research focusing on its impact on mental health.

We aim to contribute to literature in several ways. First, this paper analyzes the impact of the earthquake on self-reported mental health perceptions, with a focus on mild to moderate psychological distress symptoms. This approach complements existing research, which primarily focus on specific outcomes like PTSD and psychiatric disorders, as highlighted in studies by Zhang et al. (2011) and Bertinelli et al. (2023). Our work offers insights into the subtler, yet equally significant, psychological impacts of earthquakes, thus enriching the understanding of their broader mental health effects. Second, by employing panel data, we investigate the longitudinal effects of natural disasters on mental health. This methodology enables us to explore not only the immediate aftermath of the earthquake but also its prolonged impact, hence contributing an understanding of the long-term mental health tracks following such traumatic events.

Another substantial contribution of our study is we provide insight to the use of continuous MMI values rather than high exposure dummies to measure the earthquake intensity. The typical approach in earthquake studies often involves using distinct MMI thresholds to categorize areas as affected or unaffected as studied by Masiero and Santarossa (2020), Paudel and Ryu (2018), Shidiqi et al. (2023). To our understanding, continuous MMI values provide a more sensitive measure, less likely to be confounded.[4] This can also be particularly beneficial in understanding the gradations of effects on various outcomes, such as infrastructure damage, economic impacts, or human responses. Additionally, our research contributes to broadening the picture of the mechanisms driving the impact of natural disasters on mental health. This exploration is particularly crucial, given the limited evidence available on the long-term psychological impacts of such disasters and the underlying processes that contribute to them. Although the connection may be indirect, the insights derived from studying these mechanisms have potential implications for policy-making and economic planning.

The structure of this paper is as follows: Section 2 provides an overview of the Yogyakarta earthquake and explores the potential

[3] See https://www.usgs.gov/programs/earthquake-hazards/modified-mercalli-intensity-scale

[4] We are grateful to an anonymous referee for suggesting that the use of continuous values as opposed to dummy variable is much more convincing in this study.

relationship between natural disasters, earthquakes, and mental health. Section 3 details the data used in this study and presents summary statistics. Section 4 outlines our empirical strategy. The main results of the analysis are presented in Section 5. Section 6 conducts a series of robustness tests. Section 7 discusses potential mechanisms driving our findings. The paper concludes in Section 8, and the Appendix contains supporting data and additional results.

2. Background

2.1. The 2006 Yogyakarta earthquake

Indonesia is highly vulnerable to natural disasters, particularly earthquakes, due to its unique geographical and tectonic positioning (Priester, 2016). Over the years, the country has experienced numerous earthquakes of varying magnitudes and intensities, many of which have led to widespread destruction and significant loss of life. Table A1 in the Appendix provides a detailed account of major earthquakes in Indonesia, documenting the year, location, magnitude, damages, and casualties. Historically, Indonesia has experienced frequent seismic activity, with hundreds of earthquakes recorded between 1990 and 2015. However, the seismic activity in Yogyakarta Province and the surrounding areas has typically been characterized by low to moderate magnitudes.[5] This makes the extensive damage and destruction caused by the 2006 earthquake particularly unusual and unexpected for this region.[6]

Among the significant earthquakes in Indonesia, the Yogyakarta earthquake stands out as one of the most severe and unexpected in its impact (Amri et al.,2018). This earthquake struck Yogyakarta Province, located in the Java Island of Indonesia on May 27, 2006, at 5:52 local time, registering a magnitude of 5.9[7] on the Richter scale (Bappenas, 2006). In addition to the Richter scale,[8] the USGS meticulously recorded the intensity of this earthquake, assigning specific MMI values to each affected municipality based on observed impacts and shaking severity. Fig. 1 illustrates the geographic distribution of earthquake intensities across districts/municipalities in Java Island, with darker shades representing higher seismic intensities. The most intense shaking, depicted in the darkest red, was centered around the epicenter and gradually decreased in intensity further from the center.

While the magnitude was moderate compared to other significant events like the 2004 Aceh earthquake (9.1 on the Richter scale) or the 2018 Palu earthquake (7.5 on the Richter scale), the Yogyakarta earthquake resulted in substantial human and economic losses. The total death toll exceeded 5700, with more than 40,000 injuries reported. The earthquake severely affected all municipalities in Yogyakarta Province, including Bantul, Sleman, Yogyakarta City, Kulon Progo, Gunung Kidul, and one municipality in Central Java Province, Klaten. The severe damage caused by the earthquake was attributed to its shallow depth and the high population density in the affected areas (Walter et al., 2008). Additionally, the early morning timing of the earthquake, when most people were still asleep, contributed to the high number of fatalities. Communities in the most affected municipalities, particularly Bantul and Klaten, are predominantly lower-middle-class and share similar characteristics and living conditions. Moreover, Bantul and Klaten are among the ten most densely populated municipalities in Indonesia, each with a population density exceeding 1600 individuals per square kilometer (Bappenas, 2006).[9] The rapid population growth in these areas has heightened vulnerability, as many buildings and infrastructure were not constructed to withstand the intensity of the 2006 earthquake. This likely exacerbated the impact, leading to extensive damage and loss. Fig. A1 in the Appendix provides a breakdown of the destruction and casualties in each municipality according to the MMI values, illustrating the connection between increased seismic intensity and the extent of damage.

In addition to the physical destruction, the economic impact of the Yogyakarta earthquake was profound. It is estimated that the total loss associated with the disaster reached approximately US$3.1 billion (World Bank, 2006). These losses were primarily carried by the housing, productive, and social sectors, with the housing sector absorbing more than half of the total cost. Productive sectors, including small and medium-sized enterprises, accounted for roughly 30 % of the overall loss, while social sectors such as education and health suffered about 13 % of the damage. Reconstruction efforts started approximately one month after the disaster, as reported by Resosudarmo et al. (2012). The government prioritized rebuilding homes and public infrastructure while also focusing on revitalizing the economy in the affected municipalities. A year after the earthquake, the housing sector showed meaningful recovery, with approximately 62.5 % of houses in Yogyakarta Province being reconstructed (Brata et al., 2018).

Despite this progress in reconstruction, the economic sector during the same period reflected a concerning lack of improvement, with reduced output activity compared to pre-earthquake levels (Java Reconstruction Fund, 2007). The significant economic impact that occurred after the earthquake in Yogyakarta certainly has the potential to affect aspects of the lives of the affected communities. Beyond the visible destruction and high casualty rates, people faced ongoing economic challenges that weighed heavily on their mental well-being. The prolonged financial distress, coupled with the trauma of loss and confusion, could have profound implications for mental health. This underscores the necessity of incorporating mental health support into disaster response and recovery strategies, recognizing that the psychological aftermath is as critical to address as the physical and economic restoration.

2.2. Natural disaster, earthquakes, and mental health

The unpredictability of natural disaster such as earthquakes, coupled with human vulnerability to sudden disasters, can potentially place an emotional burden among those affected (Li and Li, 2022). In the aftermath of disaster, people often experience an urgent need to return to their productivity to fulfill economic necessities. Concurrently, some of them also battle with unpleasant feelings and thoughts that may intensify over weeks, months or even years, inhibiting daily activities. Particularly vulnerable are those who experience direct consequences of the disaster, such as physical injuries, fear of future loss, grief, restricted access to essential resources, and property damage, as well as individuals with pre-existing economic hardships and mental or physical health (Lowe et al., 2020). These experiences can heighten the risk of psychological distress, both in the immediate aftermath and in the long term. According to a conceptual framework introduced by Viertiö et al. (2021), psychological distress is a frequently utilized indicator of mental health, which is typically defined as a state of emotional suffering characterized by stress, anxiety, and depressive symptom. It manifests when an individual faces an overwhelming stressor, such as an adverse environmental event or a traumatic natural disaster experience.

[5] Prior to 2006, Yogyakarta Province last experienced a major earthquake in 1937, which registered a magnitude of 6.9 on the Richter scale with a maximum MMI of VIII

[6] The unexpected and unpredictable nature of this earthquake makes it as an exogenous event, which is important to our identification strategy.

[7] The USGS reported that the earthquake registered a magnitude of 6.3 on the moment magnitude scale, with a depth of 12.5 km (8 miles).

[8] Richter scale measures the magnitude of the earthquake at its epicenter.

[9] Yogyakarta Province is among Indonesia's top five most densely populated provinces (https://www.bps.go.id/indicator/12/141/1/population-density-by-province.html). The Municipality of Klaten in Central Java also has a high density, even above the average of four Municipalities in Yogyakarta Province (Bappenas, 2006).

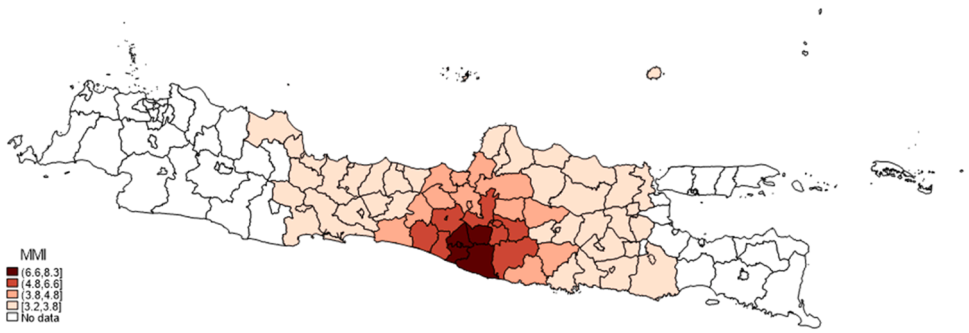

Fig. 1. Java Island and MMI Area at the District/Municipality Level. *Notes*: MMI values are recorded in the colored area. Darker shades reflect higher level of intensities (MMI) values.

A research by Norris et al. (2009) describe that there are six potential responses to distressing events: resistance, resilience, recovery, relapsing/remitting, delayed dysfunction, and chronic dysfunction, underscoring the significant variations in reactions to trauma among individuals. We believe this diversity in reaction to traumatic experiences may account for the varying results observed in studies on the impact of earthquakes on mental health. While some individuals demonstrate resilience, effectively adapting in the face of adversity (Timalsina et al., 2022; Xi et al., 2020), others may show signs of short and medium-term (Bertinelli et al., 2023; Messiah et al., 2014; Zhang et al., 2011) or even long-lasting distress (Gao et al., 2019; Kar et al., 2014; Kino et al., 2021; Livanou et al., 2005; Şalcioğlu et al., 2003). Individual capacities to overcome stress and trauma caused by natural disasters also vary significantly between individuals, influenced by a wide-ranging of factors including personal resilience, access to social support systems, previous experiences with trauma, socioeconomic status, and the availability of mental health resources (Bonanno et al., 2011; Galea et al., 2005; Lowe et al., 2020; Norris et al., 2008). In addition, genetic predisposition and cultural backgrounds play crucial roles in determining how effectively a person can adapt with the psychological impacts of such catastrophic events (Hinton and Lewis-Fernández, 2011; Stein et al., 2002).

Another dimension to consider is the differential impact of earthquakes on mental health that may varying according to demographic factors including gender, age, educational attainment, and income level. (Fu et al., 2021; Mao and Agyapong, 2021). For example, research conducted by Bertinelli et al. (2023) and Soqia et al. (2024) suggests that women are more likely to develop psychological distress than men following earthquakes. Additionally, Jia et al. (2010) find that the elderly population more susceptible to post-traumatic symptoms compared to younger adults. However, these findings are not universally consistent across all earthquake incidents. For instance, a study by Tsuboya et al. (2016) on East Japan earthquake shows that the impact on depressive symptom is more pronounced in male survivors. There are also cases where male and female survivors do not show significant differences, as pointed out by Livanou et al. (2005), Fergusson et al. (2014), and Geng et al. (2018). Furthermore, a study by Rafiey et al. (2016) demonstrate that older earthquake survivors exhibited higher levels of positive mental health compared to younger ones, suggesting that increasing age may not always correlate with greater vulnerability to natural disasters. This differential impact highlights the need for targeted mental health interventions that consider these vulnerabilities to effectively support diverse populations in the aftermath of disasters.

3. Data and statistics

3.1. Earthquake intensity

Measuring the strength of an earthquake can be stated in terms of intensity and magnitude. Even though each earthquake has the characteristics of a single epicenter and magnitude, the intensity can vary greatly from one location to another. To account for these variations, we use data on local exposure and earthquake intensities from a ShakeMap file provided by the USGS.[10] This database allows us to read the geographical spread of MMI, a metric that quantifies the severity of an earthquake's tremors at a specific spot by considering its influence on people and objects in the neighborhood. As stated by Masiero and Santarossa (2020), the MMI value is a more reflective measure as it pertains to the impact felt at the location of the earthquake. Moreover, MMI is exogenously recorded and hence less susceptible to biases that can arise from retrospective reporting (De and Thamarapani, 2022). To retrieve the earthquake's intensity value at the municipality level, we extract data from the ShakeMap file and yield a range of MMI values unique to the Yogyakarta earthquake, varying from a minimum of 3.2 to a maximum of 8.3.[11] Considering that the map file only covers certain areas on the Java Island, as depicted in Fig. 1, municipalities located outside the colored areas are likely to have very low intensity values.

Various studies determine different MMI values as thresholds to distinguish between areas affected and unaffected by earthquakes (De and Thamarapani, 2022; García Hombrados, 2020; Masiero and Santarossa, 2020; Paudel and Ryu, 2018; Shidiqi et al., 2023). As described earlier, we utilize the continuous values of MMI, instead of holding to a specific cutoff value, to act as exposure especially in our main analysis. The USGS notes that areas with lower MMI values generally experience earthquake shaking without experiencing physical damage, while higher MMI values are often associated with observable structural damage. This gradation underscores the justification behind the use of continuous values to understand the effect of varying intensities of the Yogyakarta earthquake. However, for the robustness, we additionally estimate our findings using a threshold value. In this perspective, we

[10] See https://earthquake.usgs.gov/earthquakes/eventpage/usp000ej1c/shakemap/intensity

[11] We acknowledge that within the larger areas, such as districts/municipalities, there may be variability in shaking intensity. However, the publicly available MMI data constrains our analysis to the municipality level. To address this, we explore the potential for interpolating the MMI data to estimate exposure at the sub-municipality/sub-district level. This interpolation is done using an Inverse Distance Weighting (IDW) method, which estimates the shaking intensity at unmeasured points based on the known intensities at surrounding locations. This method assumes that points closer to each other are more similar than those further apart, making it suitable for estimating the spatial variation of earthquake intensity. To validate the interpolation results, we cross-reference them with the GPS coordinates of the sub-municipality/sub-district. This allows us to assess the consistency of our findings when using a more refined exposure variable. We include a map of Java Island and the MMI area at the sub-municipality/sub-district level in the Appendix (Fig A2) to visually represent this finer level of analysis. The results of this analysis, as presented in Table A2 in the Appendix, are consistent with our main findings at the municipality level in Table 1, which strengthens our confidence in the robustness of our results.

Table 1
Impact of the Yogyakarta earthquake on mental health.

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
MMI_{cont} x post	0.0043**	0.0053***	0.0057***	0.0069***	0.0063*	0.0078***	0.0012	0.0019
	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0033)	(0.0030)	(0.0015)	(0.0015)
MMI_{cont}	−0.0015	−0.0011	−0.0018	−0.0019	−0.0011	−0.0020	−0.0001	−0.0001
	(0.0014)	(0.0013)	(0.0015)	(0.0015)	(0.0019)	(0.0019)	(0.0009)	(0.0010)
mean pre-earthquake	0.0631	0.0631	0.0659	0.0659	0.1059	0.1059	0.0224	0.0224
percentage change	6.81 %	8.39 %	8.65 %	10.47 %	5.95 %	7.37 %	5.36 %	8.48 %
Observation	24,984	24,984	24,984	24,984	24,984	24,984	24,984	24,984
R-squared	0.0192	0.0245	0.0039	0.0095	0.0230	0.0261	0.0296	0.0291
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (1) Sample: Java Island without controls, (2) Sample: Java Island with controls. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

define a municipality as affected if the MMI is equal to or greater than 7, and non-affected if the value is below 7, following the specification used in studies by Caruso and Miller (2015), Paudel and Ryu (2018), and García Hombrados (2020). According to the USGS, an intensity of 7 on the MMI scale corresponds to very strong perceived shaking and can cause moderate damage to buildings and structures.

3.2. Survey data

Our second data source is derived from the IFLS,[12] a comprehensive longitudinal survey presently consisting of five distinct waves,[13] covering roughly 83 % of the Indonesian population across 13 provinces (Strauss et al., 2016). The IFLS contains indicators covering demographics, socioeconomic status, and health at individual, household, and community levels, while ensuring minimal attrition rates. We specifically utilize data from the first, third, fourth, and fifth waves of the IFLS in our baseline model. The second wave is excluded due to the absence of critical data concerning our outcome variables. To formulate the estimation sample, we maintain individuals from the first wave who are over the age of 15,[14] tracking them up to the final survey wave. The survey's detailed migration history records greatly facilitated our efforts, enabling us to identify the municipality-level location of respondents from their birthdate up to the last survey wave. This process allows us to accumulate data on individual residences during the year of exposure and correlate this with municipality-level MMI values. Subsequently, we manage to retain individuals who were residing on Java Island at the time of the earthquake.[15] This procedure enables us to classify whether an individual was living in an area with a higher or lower intensity of earthquake.

The IFLS dataset offers critical information for our analysis, specifically related to the mental health status of respondents, which is our primary outcome of interest. We construct several perceived mental health indicators derived from respondents' answers to the following queries: "In the past week did you feel/experience [fear or anxiety?], [depressed?], [a hard time sleeping?], [difficulty concentrating on doing something?]". There are four categories of answers available to these self-reported questions on the original questionnaire. Individuals were coded as experiencing psychological distress (coded as 1) if they reported experiencing these symptoms "occasionally (3–4 days)" or "most of the time (5–7 days)". Responses indicating "rarely (≤1 day)" or "some days (1–2 days)" were coded as 0 (no).

While the IFLS contains numerous questions pertaining to mental health, we have chosen to focus on four specific areas: feeling anxious, feeling depressed, having a sleep disorder, and losing focus. The use of mild to moderate psychological distress symptoms in our analysis, while distinct from employing standardized measures like the Center for Epidemiologic Studies Depression Scale (CES-D) for scoring depression due to limited data,[16] is also considered a valid and informative approach. To validate our selected mental health indicators as proxies for the CESD-10 scoring, we calculated the correlation coefficients between the CESD scores from IFLS 4 and IFLS 5 and the indicators used in our main analysis (feeling anxious, feeling depressed, having sleep disorders, and losing focus). The results, presented in Table A3 in the Appendix, show significant positive correlations, confirming that these indicators seem to be reliable proxies for the standardized CESD measure.

3.3. Summary statistics

The summary statistics of our main variables are reported in Table A4 and illustrated in Fig.A3 in the Appendix. Table A4 presents sample means for the relevant mental health and individual characteristics in a pre- and post-earthquake context, differentiated between individuals residing in municipalities with a MMI ≥ 7, designated as the affected areas (treatment group), and those in municipalities that were not affected (control group). While our primary analysis employs continuous MMI values to measure exposure, we use binary classification of MMI for the summary statistics, as it enables a more

[12] The IFLS data can be obtained from https://www.rand.org/well-being/social-and-behavioral-policy/data/FLS/IFLS.html.

[13] IFLS1 (1992/1994); IFLS2 (1997/1998); IFLS3 (2000); IFLS4 (2007/2008); IFLS5 (2014/2015)

[14] We limit our analysis to individuals aged 15 and older, as psychological health data are only available for this age group.

[15] Our individual sample size decreases from 20,347 (covering all of Indonesia in the first wave) to 6246, as we focus on respondents with complete mental health information who were residing in Java Island at the time of the earthquake.

[16] In the IFLS dataset, specific to wave 1, there are only six questions directly related to self-reported mental health, and in wave 3, there are eight questions. It is important to note that in waves 4 and 5, the dataset was expanded to include two additional questions. This expansion allows for the application of the 10-Item CESD scoring. However, due to the absence of these two critical questions in wave 3 and the absence of four critical questions in wave 1, it is not feasible to compute the CESD score for the periods prior to the earthquake. This limitation is important to highlight, as it restricts our ability to apply a standardized depression measure consistently across the entire dataset, particularly for the pre-earthquake period. Consequently, our analysis relies on the specific questions available in the initial waves to assess mental health, acknowledging that this approach differs from the comprehensive CESD scoring possible in the later waves. This methodological adaptation is essential for maintaining the consistency of our longitudinal analysis across all waves of the IFLS data.

straightforward interpretation of the earthquake's impact. Detailed statistical evidence based on continuous MMI values is also presented in Fig.A3 of the Appendix, ensuring transparency and allowing for an in-depth assessment.

Prior to the event, the prevalence of all mental health outcomes is relatively comparable across groups, as indicated by the modest differences within the pre-earthquake context. Notably, in the post-earthquake period, significant increases in the mean values of feeling anxious and feeling depressed are observed for the affected group compared to the non-affected group. Conversely, the variable of having sleep disorder and losing focus do not demonstrate any notable differences post-earthquake, implying initial indication that these aspects may not be impacted by the earthquake. These findings suggest a substantive exacerbation of certain psychological conditions attributable to the earthquake. Demographically, the affected group is statistically older by about 2 years compared to the non-affected group. Individuals residing in affected municipalities have more years of education than those who were living in non-affected municipalities, both in pre- and post-earthquake.[17] The marital status remained relatively unchanged after the earthquake, with a non-significant difference, as shown in the Diff-Diff column.

Fig.A3 in the Appendix presents a visual representation of statistical evidence illustrating the sample means of psychological outcomes in each municipality, segmented by MMI continuous values, both pre- and post-earthquake. This graph broadly suggests that psychological distress conditions, including feelings anxious, feeling depressed, and having sleep disorder, tend to develop post-disaster and become more severe in municipalities with higher MMI values. However, consistent with the statistical findings presented in Table A4, we do not find a similar trend for the outcome of losing focus.

4. Empirical strategy

This paper analyzes the impact of the Yogyakarta earthquake on mental health using panel data from periods before and after the seismic event. To attain this, we align MMI values with individual data based on their locations during the earthquake in 2006, thereby distinguishing between individuals who experienced varying intensities of the earthquake. We employ a difference-in-differences approach to estimate the impact, comparing changes in mental health outcomes between individuals exposed to higher and lower intensities of the earthquake before and after its occurrence. Our identification strategy leverages the variation in earthquake intensity, while controlling for individual, municipality, and year fixed effects. The baseline specification is as follows:

$$Y_{ijt} = \alpha + \beta_1 \boldsymbol{Post_t} + \beta_2 \boldsymbol{MMI_{j(2006)}} + \beta_3 \left(\boldsymbol{Post_t} * \boldsymbol{MMI_{j(2006)}}\right) + \delta_i + \nu_t + \varnothing_{j(t)} + X_{it} + \epsilon_{ijt} \quad (1)$$

$\boldsymbol{Y_{ijt}}$ represents our main outcome of interest for individual i living in municipality j at period t. $\boldsymbol{Post_t}$ is an indicator that takes the value of one for the observation after the earthquake and zero for the observation before the earthquake. $\boldsymbol{MMI_{j(2006)}}$ captures the continuous values of MMI in municipality j based on the residence during the earthquake in 2006. $\boldsymbol{\beta_3}$ is the main parameter of interest, which gives the coefficient of the impact of the earthquake on psychological distress of individuals during the time of the earthquake in municipality j. The individual fixed effects $\boldsymbol{\delta_i}$ effectively control for unobserved time-invariant individual characteristics, the term $\boldsymbol{\nu_t}$ considers the year/wave fixed effects, and $\varnothing_{j(t)}$ represents the municipality fixed effects based on the individual's residence in each wave. It is important to note that the $\boldsymbol{Post_t}$ may be omitted due to perfect collinearity with the year fixed effects.[18] $\boldsymbol{X_{it}}$ is a vector of time-varying individual characteristics such as age and age squared, years of education, and marital status. As these control variables may also be affected by the earthquake,[19] we present the results of the estimations both with and with controls. The standard error is clustered at the municipality level to allow for serial correlations within each municipality.

This difference-in-difference specification enables us to assess whether areas experiencing higher intensities are more adversely affected compared to those experiencing lower intensities. To leverage the variation in shock intensity, we estimate Eq.(1) as our primary specification. However, due to the lack of a clear functional relationship between intensity and outcomes, we also present results using a binary treatment variable for easier interpretation as a robustness check in Section 6.

5. Effects of earthquake on mental health

5.1. Main results

Table 1 presents the estimated effects of the Yogyakarta earthquake on various mental health outcomes, using the interaction of continuous MMI values with a post-earthquake indicator as the key explanatory variable. The results, adjusting for individual, year, and municipality fixed effects, show that the earthquake is associated with statistically significant increases in self-reported symptoms of feeling anxious, feeling depressed, and having sleep disorders, by 8.39 %, 10.47 %, and 7.37 %, respectively, as calculated by the percentage change from the baseline pre-earthquake mean.[20] The models without additional controls, shown in odd-numbered columns, and those with controls for time-varying individual characteristics, shown in even-numbered columns, consistently indicate that the earthquake's impact on mental health is non-trivial. However, the analysis does not find statistically significant evidence that the earthquake led to an increase in self-reported loss of focus. These findings corroborate existing literature that suggests natural disasters exacerbate mental health challenges, highlighting the importance of considering mental health as a critical component of the post-disaster public health response. The absence of a detectable effect on loss of focus may suggest that this symptom is less sensitive to the effects of the earthquake or that the measures used to capture it are less reliable. Nonetheless, the overall pattern of results emphasizes the broad impact of the Yogyakarta earthquake on mental health.

In addition to the primary analysis, we conducted further analysis using eight extended mental health items available in IFLS 3, 4, and 5 to capture an expansive range of psychological distress. The results are shown in Table A6 in the Appendix, which provides insights into the

[17] Following a study by Shidiqi et al. (2023), individuals living in affected municipalities, especially Yogyakarta Province, tend to have a more years of education due to high number of educational institutions, including schools and universities located in this province.

[18] The impact of the post-earthquake period is fully captured by the year fixed effects, leading to the omission of the post indicator from the regression output. However, the inclusion of year fixed effects is crucial for controlling time-specific factors that could influence the outcomes.

[19] See Dodlova et al. (2023), Kirchberger (2017), and Pope et al.(2022) for discussions on the impact of natural disasters on education and marriage, respectively.

[20] Given the multiple comparisons, we also conduct a traditional Bonferroni correction by multiplying each p-value by the total number of tests, following studies by Conti et al. (2016). This approach leaves the original significance threshold unchanged while adjusting the p-values to account for multiple testing. Given that we analyze four main mental health outcomes in the main analysis, each estimated with two models (with and without controls), we adjust for a total of eight tests by multiplying each p-value by 8. In Table A5 in the Appendix, we present both the original and Bonferroni-adjusted p-values for transparency. After applying the Bonferroni correction, some previously significant outcomes become non-significant due to the more conservative adjustment. However, several key results remain statistically significant.

earthquake's impact on additional symptoms, including feelings of loneliness, being easily bothered, difficulty in getting going, and lack of energy. Specifically, the earthquake is associated with a 10 % increase in feelings of loneliness and a 6.77 % increase in difficulty getting going, calculated from the pre-earthquake mean. The findings show that these additional items also display significant increases post-earthquake in the most affected areas, though with varying degrees of intensity.

5.2. Heterogeneous effects

Certain groups may be more susceptible to psychological distress due to increased exposure and vulnerability to unfavorable circumstances (Jia et al., 2010; Joseph and Jaswal, 2021; Peek, 2008). Table 2 outlines the mental health outcomes following the Yogyakarta earthquake across different demographic groups, applying triple interaction terms to explore the heterogeneity of these effects. In Panel A, we observe that the earthquake significantly increased the likelihood of experiencing psychological distress among males, as indicated by the positive and statistically significant coefficients across all outcomes: feeling anxious, feeling depressed, having a sleep disorder, and losing focus. However, when examining the interaction term between the earthquake's impact and female gender, the coefficients are negative but not statistically significant, suggesting that there is no significant difference between males and females in the psychological response to the earthquake. This is further supported by the p-values from the tests for coefficients' equality, which show no significant differences between the genders across the outcomes studied.

Table 2
Heterogenous impact of the Yogyakarta earthquake on mental health.

	Feeling Anxious	*Feeling Depressed*	*Sleeping Disorder*	*Losing Focus*
Panel A: Gender				
MMI_cx post	0.0058***	0.0078***	0.0053*	0.0022***
	(0.0018)	(0.0024)	(0.0027)	(0.0015)
MMI_cx post x female	−0.0010	−0.0016	0.0045	0.0006
	(0.0028)	(0.0030)	(0.0043)	(0.0032)
Test for coefficients' equality, p-value	0.7137	0.5996	0.2988	0.8509
mean pre-earthquake	0.0735	0.0776	0.1121	0.0279
Panel B: Age group				
MMI_cx post	0.0024	0.0033**	0.0039	0.0031*
	(0.0016)	(0.0015)	(0.0026)	(0.0016)
MMI_cx post x above45	0.0062**	0.0081***	0.0083***	−0.0019
	(0.0024)	(0.0021)	(0.0028)	(0.0027)
Test for coefficients' equality, p-value	0.0103	0.0002	0.0035	0.4741
mean pre-earthquake	0.0714	0.0825	0.1335	0.0247
Panel C: Residential area				
MMI_cx post	0.0024	0.0038**	0.0049	0.0028
	(0.0025)	(0.0018)	(0.0032)	(0.0019)
MMI_cx post x rural	0.0070**	0.0074***	0.0072	0.0046**
	(0.0027)	(0.0024)	(0.0047)	(0.0022)
Test for coefficients' equality, p-value	0.0126	0.0021	0.1251	0.4741
mean pre-earthquake	0.0626	0.0655	0.1043	0.0241
Panel D: Household income				
MMI_cx post	0.0026*	0.0044**	0.0064**	0.0014
	(0.0015)	(0.0018)	(0.0029)	(0.0025)
MMI_cx post x low-income family	0.0050*	0.0046	0.0032	0.0013
	(0.0027)	(0.0034)	(0.0035)	(0.0030)
Test for coefficients' equality, p-value	0.0691	0.1808	0.3639	0.6669
mean pre-earthquake	0.0669	0.0674	0.1063	0.0231
Observation	24,984	24,984	24,984	24,984
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

In Panel B, the analysis shows that individuals over the age of 45[21] experience a greater psychological impact from the earthquake compared to younger individuals. Specifically, the coefficients for the interaction between MMI, the post-earthquake period, and being above 45 years of age are positive and statistically significant for feeling anxious, feeling depressed, and having a sleep disorder. This indicates that older individuals are more susceptible to the mental health impacts of the earthquake. The p-values associated with the tests for coefficients' equality confirm that these differences are statistically significant, particularly for feeling anxious, feeling depressed, and having a sleep disorder, highlighting the increased vulnerability of older adults in the aftermath of the earthquake.

Panel C focuses on the differences between urban and rural residents. The results show that individuals residing in rural areas are more likely to experience psychological distress due to the earthquake. The interaction term between MMI, the post-earthquake period, and residing in a rural area is positive and statistically significant for feeling anxious, feeling depressed, and losing focus. This suggests that rural residents face greater mental health challenges following the earthquake compared to their urban counterparts. The p-values for coefficients' equality tests indicate that the differences in psychological distress between rural and urban residents are statistically significant for feeling anxious and feeling depressed.

Finally, in Panel D, the analysis examines the differences in psychological distress based on household income levels. The results show that individuals from low-income families are more likely to experience increased of feeling anxious due to the earthquake, as indicated by the positive and statistically significant coefficient for the interaction between MMI, the post-earthquake period, and belonging to a low-income family. However, the interaction terms for feeling depressed, having a sleep disorder, and losing focus are not statistically significant, indicating no significant differences between income groups for these outcomes. The p-values associated with the tests for coefficients' equality further support this finding, showing no statistically significant differences in psychological distress between income groups.

The results suggest that while the earthquake has a broad impact on psychological distress, its effects are more pronounced among specific vulnerable groups, including older adults, rural residents, and individuals from low-income families. These findings highlight the importance of targeted mental health interventions in post-disaster contexts, particularly for these at-risk populations.

5.3. Event study estimates

To investigate the time pattern of the earthquake's effect, we operate an event study analysis for all outcome variables. Our event study framework is constrained by the availability of only four waves of data, two before and two after the Yogyakarta earthquake. Despite this limitation, we utilize the event study to observe any immediate changes in mental health indicators that can be attributed to the earthquake. The year 2000 serves as the reference period, allowing us to compare the relative changes in the subsequent periods. While the limited data points preclude a comprehensive analysis of long-term trends, they do enable us to assess the presence and direction of the earthquake's impact on mental health over the available time span. Fig. A4 in the Appendix

[21] The age is defined as the age at the time the earthquake occurred.

provides a visualization of the results of this analysis.[22] The figure shows the pre- and post-earthquake coefficients of the interaction for all outcomes and 95 per cent confidence intervals. We do not find any significant coefficient for the interaction term observed in the pre-earthquake periods across all outcome variables, except the outcome of losing focus. At the same time, we note an increase in psychological distress post-earthquake, as signaled by the positive and statistically significant coefficients for feeling anxious, feeling depressed, and having a sleep disorder.

While our event study did not reveal significant pre-trends, suggesting an absence of confounding trends prior to the earthquake, the increasing magnitude of the coefficients over time indicates that the earthquake's psychological impact may persist up to eight years after the event. This could reflect long-term effects often observed in disaster aftermaths, which are sometimes exacerbated by insufficient post-disaster psychological support or compounded by ongoing stressors. We recognize that humans often demonstrate the ability to survive and recover quickly from challenging situations, however some studies suggest that this is not universally guaranteed. For instance, empirical findings show that the psychological effects of disasters can persist beyond the initial event, resulting in long-term impacts that can last for several years (Cénat and Derivois, 2015; Kar et al., 2014; Livanou et al., 2005; Rhodes et al., 2010; Schwartz et al., 2017). Moreover, there is a possibility that individuals experience delayed dysfunction, where they initially exhibit resilience following a traumatic event, with psychological distress exhibiting later (Bonanno, 2004; Galea et al., 2005; Norris et al., 2009).

The lasting psychological impact observed in our study may also be partly attributed to the context of Indonesia's mental health infrastructure. Indonesia faces a notable challenge with a low ratio of mental health professionals and facilities compared to its population size (Mahendradhata et al., 2017; Trinidad and Protacio-De Castro, 2020). Additionally, the enactment of Law No. 18 in 2014, which specifically regulates mental health in Indonesia and aims to integrate basic mental health services into community health centers, came eight years after the earthquake. This systemic issue in mental health care provision may have contributed to the prolonged mental health consequences experienced by disaster survivors.

6. Robustness checks

6.1. Dummy for treatment

In our main analysis, we utilize continuous measurements to take advantage of the detailed variations in earthquake intensity, which provides an understanding of how different levels of exposure affect mental health outcomes. However, to ensure the robustness of our findings, we also perform analyses using a binary treatment variable, by classifying respondents into high-intensity and low-intensity exposure categories. Table A8 in the Appendix shows the results using this binary measure of earthquake intensity (MMI $\geq$ 7), confirming the statistically significant impact of the Yogyakarta earthquake on feelings of anxiety, depression, and sleep disorders, which increased by 4.36, 4.62, and 4.70 percentage points, respectively.

Further, we acknowledge that increases in MMI levels likely have non-linear impacts on mental health, particularly when comparing more severe transitions (e.g., from MMI 7–8) against milder changes (e.g., from MMI 3–4). To address this, this paper examines the impact of the Yogyakarta earthquake on mental health outcomes across varying levels of earthquake intensity, categorized by binned MMI scales. The MMI scale is divided into five categories, with the 0 MMI range serving as the reference group. The results, as presented in Table 3, indicate a clear trend, as the intensity of the earthquake increases, the psychological impact on individuals becomes more pronounced. Specifically, individuals in areas with moderate earthquake intensity (MMI 5.5–6.4) show significant increases in feelings of depression and sleep disorders compared to those in the reference category. As the intensity further increases (MMI 6.5–7.4 and MMI $\geq$ 7.5), the psychological distress becomes more severe, with significant effects observed across all mental health measures, except for losing focus. This non-linear relationship suggests that the mental health consequences of the earthquake are disproportionately higher in areas with more severe shaking, particularly in terms of feeling anxious, feeling depressed, and having a sleep disorder. The lack of significant effects on losing focus might indicate that this outcome is less sensitive to the earthquake's intensity or that it manifests differently in response to such events. Overall, these findings emphasize the importance of considering varying levels of exposure when assessing the mental health impacts of natural disasters.

6.2. Exclusion of municipalities

In our robustness analysis, we consider the potential impact of geographic proximity on the estimation of earthquake effects. Specifically, we replicate our main estimation by excluding observations of individuals who were residing in areas far from the most intensely shaken regions. This approach allows us to determine whether the results are robust to the exclusion of less affected municipalities that might differ significantly from the most affected ones. First, we exclude the regions outside the MMI coverage area, which extends approximately 300 km from the closest affected municipality. As shown in Fig. 1, the MMI coverage includes only the colored regions, indicating areas with recorded earthquake intensity values. Then, we narrow down the sample further by excluding municipalities located more than 150 km away from the nearest affected municipality, which is roughly half of the MMI coverage area.[23]

There is also a possibility of potential commuter behavior across municipalities borders that could bias the results. To address this concern, we exclude intermediate municipalities that are geographically adjacent to the core affected areas but are not within the most severely impacted zones, thereby creating a design similar to the donut approach. As illustrated in Fig. 1, the intermediate municipalities are those surrounding the darkest red areas but not within them, with MMI values ranging from 4.8 to 6.6. This method has been effectively applied in similar research to control for spillover effects and commuter behavior (see Anderson, 2020; Nian, 2023). The overall results, presented in Table A9 in the Appendix, remain statistically significant and of similar magnitude. This consistency suggests that our results are not driven by the inclusion of certain geographic areas but reflect a generalizable impact of the earthquake on mental health outcomes.

6.3. Placebo analysis

To validate that our mental health outcomes are truly caused by the Yogyakarta earthquake, we conducted a series of placebo tests by simulating fictitious earthquake locations and years. This approach aligns with established methodological practices to validate causal inferences in observational studies. Specifically, we identified individuals residing in municipalities on Sumatra Island; Bali and West Nusa Islands; and Kalimantan and Sulawesi Islands, as depicted in Figure A5 in the Appendix. These islands were selected due to their lack of any recorded seismic activity during the period of interest, thereby serving as counterfactuals to Java Island, which we deliberately excluded from the

[22] The results for the event study are reported in Table A7 in the Appendix, showing only the coefficients of the interaction terms.

[23] We perform geometry computations to obtain the latitude and longitude coordinates of each municipality. This allows us to establish a distance radius of 150 km between less affected municipalities and their nearest most affected municipalities.

Table 3
Impact of the Yogyakarta earthquake on mental health: series of binned MMI scales.

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
$MMI_{=0}$ *x post*	Reference category							
$MMI_{>0-3.4}$ *x post*	0.0298	0.0282	0.0179	0.0183	0.0232	0.0276	−0.0094	−0.0096
	(0.0211)	(0.0207)	(0.0277)	(0.0271)	(0.0174)	(0.0179)	(0.0169)	(0.0173)
$MMI_{\geq 3.5-5.4}$ *x post*	0.0065	0.0011	0.0014	0.0046	0.0032	0.0050	−0.0047	−0.0049
	(0.0114)	(0.0116)	(0.0096)	(0.0095)	(0.0149)	(0.0147)	(0.0106)	(0.0098)
$MMI_{\geq 5.5-6.4}$ *x post*	0.0749	0.0768	0.0859*	0.0861*	0.0320	0.0328	−0.0045	0.0013
	(0.0484)	(0.0525)	(0.0512)	(0.0525)	(0.0267)	(0.0261)	(0.0111)	(0.0109)
$MMI_{\geq 6.5-7.4}$ *x post*	0.0461***	0.0576***	0.0482***	0.0496***	0.0432**	0.0454***	0.0029	0.0037
	(0.0095)	(0.0102)	(0.0099)	(0.0124)	(0.0118)	(0.0200)	(0.0308)	(0.0303)
$MMI_{\geq 7.5}$ *x post*	0.0418***	0.0486***	0.0525***	0.0603***	0.0416**	0.0442***	0.0017	0.0072
	(0.0132)	(0.0117)	(0.0067)	(0.0068)	(0.0155)	(0.0158)	(0.0103)	(0.0101)
Observation	24,984	24,984	24,984	24,984	24,984	24,984	24,984	24,984
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

placebo sample to maintain the integrity of the test. The fictitious earthquake is simulated by randomly assigning a binary treatment indicator to municipalities on each selected island, designating municipalities as 'affected' if the indicator equals 1, and 'non-affected' if it equals 0. The random assignment ensures that, on average, the affected and non-affected municipalities are comparable on observed and unobserved pre-treatment characteristics, facilitating a credible estimation of causal effects.

The map presented in Figure A5 visualizes the results of this random assignment. Municipalities shaded in darker tones represent those that have been assigned with a fake earthquake, thus indicating affected status. In contrast, municipalities in lighter shades have been assigned a control status, indicating they have not been affected by the simulated earthquake. To assess the impact of this simulation on our outcome variables, we employ the same specification detailed in the main analysis, including controls for individual and year fixed effects. The underlying assumption of this approach is that if the actual earthquake influences mental health outcomes, we will not expect to observe significant effects in these placebo tests where the earthquakes are fictitious. Consistent with our expectations, the results presented in Table A10 in the Appendix demonstrate that the simulated earthquakes in these non-affected regions did not statistically influence our outcomes, strengthening the conclusion that the psychological distress observed is specifically attributable to the 2006 Yogyakarta earthquake.

In addition to our spatial placebo tests, we extend the robustness by designating alternative years for the occurrence of the earthquake, following the approach utilized by Gröger and Zylberberg (2016) (same locations – different years). This specification describes as if the Yogyakarta earthquake occurred in 1995 and 1997, rather than the actual event year of 2006. We then assign the continuous MMI values to individuals based on their residential locations during these fictive years. Employing the same regression specification as in our primary analysis, we conduct a placebo regression to assess the impact on psychological distress, including an extensive set of controls and fixed effects. The empirical results presented in Table A11 in the Appendix exhibit no significant association between the fictitious earthquake years and the outcomes. The coefficients for the interaction of MMI and the post- fake earthquake years are statistically indistinguishable from zero, indicating an absence of effect. The results thus reinforce our main findings that the psychological distress observed in the population is temporally connected to the actual 2006 Yogyakarta earthquake.

7. Migration and attrition

We investigate the potential migration response following the Yogyakarta earthquake, which is a crucial consideration given that migration could serve as a coping mechanism and might confound the estimates of the earthquake's impact on mental health outcomes. Another concern is that if individuals who migrate after the earthquake have different mental health profiles compared to those who do not migrate, it could introduce bias into the analysis. To address this concern, we use a difference-in-differences model specified in Eq.1 with migration as the dependent variable, incorporating pre-earthquake mental health conditions as control variables. This approach allows us to isolate the impact of the earthquake on migration behavior while accounting for pre-existing differences in mental health. The analysis is conducted for the entire Java Island sample and for subsets of the population within the MMI coverage area, within 150 km of the most affected areas, and excluding regions adjacent to the most affected areas (donut design). The estimated coefficients across all specifications, as presented in Table A12 in the Appendix, are small and not statistically significant, even after controlling for pre-earthquake mental health conditions, suggesting that the earthquake did not lead to a significant likelihood of migration. We also perform an additional analysis in which we exclude individuals who moved to different municipalities post-earthquake. By eliminating these movers, we ensure that any potential selection bias caused by migration is minimized. The results, presented in Table A13 in the Appendix, provide further evidence that the mental health impacts identified in the study are not the result of selection bias caused by migration due to the earthquake.

In addition to our migration checks, we examine attrition between survey waves within our dataset to investigate potential biases. Our primary objective is to determine whether individuals from affected municipalities are more likely to drop out due to the earthquake. To maintain a consistent and focused analysis, we assess attrition for periods that include both pre- and post-earthquake data, using a difference-in-differences design as specified in Eq.1. Specifically, we observe attrition between wave 3–4 (6 years prior to and 1 year after the earthquake) and wave 3–5 (6 years prior to and 8 years after the earthquake), and between wave 1–4 (13 years prior to and 1 year after the earthquake) and wave 1–5 (13 years prior to and 8 years after the earthquake). Attrition is defined as one if the individual is present in one wave but absent in the following wave, and zero otherwise. Similar to the migration analysis, we include pre-earthquake measures of feeling anxious, feeling depressed, and having sleep disorders as control variables in our attrition analysis to account for any baseline differences in mental health that could influence an individual's likelihood of dropping out of the sample. The estimated coefficients, presented in Table A14 in the Appendix, are small and statistically insignificant, suggesting that attrition in our sample is not systematically associated

with the earthquake. This also indicates that the observed mental health impacts are unlikely to be driven by selective attrition based on pre-existing conditions.

8. Potential mechanisms

This section explores potential pathways through which the 2006 Yogyakarta earthquake may have influenced mental health outcomes. The earthquake's immediate and indirect effects on affected individuals' environments, resources, and physical health likely shaped the observed psychological impact. We focus on damage and losses, socio-economic changes, and physical health deterioration as the primary mechanisms that may explain heightened psychological distress. These factors capture the multidimensional disruptions caused by the earthquake, which collectively contribute to anxiety, depression, and stress in the affected population.

The earthquake caused significant destruction in affected areas, leading to extensive housing damage, financial hardship, and family casualties. Using data from the fourth and fifth waves of the IFLS, we capture post-earthquake conditions through indicators such as destroyed or damaged houses, asset loss, and household casualties.[24] To test whether higher earthquake intensity correlates with increased damage and losses, we employ a difference-in-differences model specified in Eq.1, where these indicators serve as dependent variables. The result, presented in Table 4, shows the association between earthquake intensity and damage-related outcomes, confirming that higher earthquake intensity led to greater property destruction, asset loss, and increased likelihood of death or injury among family members. These findings provide evidence that damage and loss serve as critical pathways influencing the psychological distress caused by the earthquake. The significant rise in these adverse outcomes suggests that the direct experience of loss and disruption could contribute substantially to elevated levels of anxiety, depression, and stress within the affected population.

Table 4
Impact of the Yogyakarta earthquake on damages and losses.

	Destroyed/ damaged house	Asset loss	Family casualties
MMI_{cont} x post	0.0493**	0.0509**	0.0097**
	(0.0223)	(0.0208)	(0.0036)
MMI_{cont}	−0.0116	−0.0098	−0.0001
	(0.0102)	(0.0094)	(0.0016)
mean pre-earthquake	0.0641	0.0792	0.0240
% change	76.91 %	64.27 %	40.41 %
Observation	18,738	18,738	18,738
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes

Notes: Each coefficient comes from a different regression. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

[24] In our analysis, we encounter a limitation regarding the availability of pre-earthquake data on natural disasters. Specifically, the first (1993) and third (2000) waves of the IFLS do not contain information about individual or household experiences of natural disasters. This lack of data posed a challenge for constructing a pre-earthquake baseline using those waves. To address this gap, we utilized retrospective disaster data from the fourth wave (2007), which provided detailed information on natural disasters that occurred within the five years preceding the survey. By integrating this retrospective data, we were able to create variables reflecting pre-earthquake conditions.

The psychological distress caused by earthquakes may also be partially attributable to the disruption of socio-economic conditions and deterioration of physical health. Empirical evidences in academic literature has linked emotional well-being to individuals socio-economic circumstances and physical health status (Conversano, 2019; Lorant et al., 2003; Ohrnberger et al., 2017; Reiss et al., 2019; Ruiz-Pérez et al., 2017; Turner and Kelly, 2000). To explore this assumption, we further employ the IFLS data concerning socio-economic status and physical health indicators. Our objective is to examine whether the earthquake influences specific aspects of socio-economic conditions, as indicated by occupational status, per capita expenditure, social engagement, and eating frequency.[25] Additionally, we assess the earthquake's impact on physical health dimensions, such as general health and physical ability.[26] A deterioration in these factors due to the earthquake would corroborate our preliminary findings. For a formal examination, we apply the same difference-in-differences models as in Eq.(1), with socio-economic and physical health variables set as the dependent variables.

Table 5 presents the changes in socio-economic conditions following the earthquake. We hypothesize that the earthquake will lead to an increase in unemployment status in affected areas due to the destruction of workplaces and the disruption of economic activities. In alignment with our expectations, the result indicates a statistically significant increase

Table 5
Changes in individual's socio-economic conditions.

	Unemployed	Per capita exp	Lack of social engagement	Non-adequate eating frequency
MMI_{cont} x post	0.0074***	−0.0019	0.0181***	0.0099***
	(0.0026)	(0.0051)	(0.0048)	(0.0031)
MMI_{cont}	0.0046	−0.0205**	0.0371	0.0005
	(0.0067)	(0.0080)	(0.0432)	(0.0022)
mean pre-earthquake	0.3505	12.2326	0.3884	0.0799
% change	2.11 %	0.00 %	4.66 %	12.37 %
Observation	24,984	24,984	17,822	24,984
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes

Notes: Each coefficient comes from a different regression. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

[25] Occupational status indicates whether a person is employed or unemployed, regardless of type and place of employment. It is equal to one if individual is unemployed at the time of the survey. Per capita expenditure reflects the average monthly consumption per household member, in the form of natural logarithm. Lack of social engagement equals to one if a person does not participate in any formal community or social activities at the time of the survey. Eating frequency is coded as one for individual whose food consumption falls below the standard adequacy level, as determined by the Food Consumption Score (FCS) (see Dembedza et al., 2022).

[26] Unhealthy refers to a general state of poor health, encompassing a range of symptoms and conditions, including chronic illnesses, temporary illnesses, and general disease. General health is coded as one for the presence of an unhealthy condition and zero otherwise. Low physical ability refers to a reduced capacity to perform physical tasks and engage in daily activities, such as carrying heavy loads, walking short and long distances, and standing up without assistance. This may result from injury, chronic conditions, or general physical weakness. Low physical ability is coded as one for the presence of reduced physical capacity and zero otherwise.

of 2.11 % relative to the pre-earthquake mean. However, we observe an increase in unemployment that did not correspond with a significant decrease in per capita expenditure. This seemingly paradoxical finding suggests that households may have employed coping mechanisms to stabilize their consumption levels despite the loss of income due to unemployment. To investigate this further, we explored the role of private transfers from relatives or friends as potential mitigating factors.[27] These forms of financial support could have compensated for the reduction in household income caused by increased unemployment, thereby preventing a decline in consumption levels. Using a difference-in-differences approach, we conduct additional analyses to examine the impact of the earthquake on the probability of receiving such transfers. The results, as presented in Table A15 in the Appendix, indicate that households in areas more severely affected by the earthquake were indeed more likely to receive financial support in the form of private transfers by 7.17 %, with respect to the pre-earthquake mean. This external financial resource likely plays a crucial role in maintaining household per capita expenditure, despite the adverse effects of increased unemployment.

We also predict an increase in lack of social engagement post-earthquake, as community infrastructures are disrupted, and individuals focus more on immediate survival and recovery needs. Supporting this hypothesis, we obtain a significant increase of 4.66 % in lack of social engagement relative to the pre-earthquake average. With regards to per capita expenditure, we also expect a reduction reflecting economic hardships, as evidenced in a study by Rosales-Rueda (2018). However, we obtain a very small and statistically insignificant decrease. Additionally, the non-adequate of eating frequency rises significantly by 12.37 %, with respect to the pre-event mean, pointing to a deterioration in nutritional habits following the disaster.

Table 6 shows that individuals in areas experiencing higher earthquake intensity exhibit marked declines in physical health. Notably, there is a statistically significant increase in the prevalence of unhealthy conditions and low physical abilities, by 13.33 % and 7.14 %, respectively, compared to the pre-earthquake mean. The observed changes in physical health parameters, coupled with the socio-economic changes, suggest a complex interaction between factors influencing post-disaster psychological distress.

Table 6
Changes in individual's physical health conditions.

	Unhealthy	Low physical ability
MMI_{cont} x post	0.0100**	0.0030*
	(0.0041)	(0.0015)
MMI_{cont}	−0.0044	−0.0042
	(0.0119)	(0.0086)
mean pre-earthquake	0.0752	0.0418
% change	13.33 %	7.14 %
Observation	24,984	24,984
Controls	Yes	Yes
Year FE	Yes	Yes
Individual FE	Yes	Yes
Municipality FE	Yes	Yes

Notes: Each coefficient comes from a different regression. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

[27] Private transfers from relatives or friends differ from government aid in this context. To further explore the role of government aid, we present an analysis of its interaction effects, emphasizing the importance of structured and timely aid programs as a key recommendation. The results of this analysis are provided in Table A16 in the Appendix.

To further explore potential pathways through which the earthquake impacted mental health, we incorporate identified mechanisms, such as damages, losses, physical health, and socio-economic factors, as control variables in our main model.[28] This approach allows us to assess their collective influence on mental health outcomes. If the primary earthquake coefficient diminishes after these factors are included, it suggests that they contribute to explaining the psychological impact of the earthquake. The results, as presented in Table A17 in the Appendix, show that while the psychological distress outcomes remain robust, the main coefficient decreases, indicating that these factors collectively play a role in mediating the earthquake's mental health effects.

Among these potential pathways, family casualties and general health deterioration appear particularly influential, emphasizing the significant role of both immediate personal loss and physical health decline in exacerbating mental health issues. Importantly, the continued significance of some psychological distress outcomes, even with these controls, suggests that additional, potentially unobserved, elements influencing mental health post-earthquake. These findings underscore the complex nature of psychological impacts following natural disasters, where multiple, interrelated factors are likely at play. While the identified pathways capture several key influences, further exploration into additional mechanisms may help to deepen our understanding of the full picture of mental health effects induced by the earthquake.

9. Conclusion

This study investigates the substantial mental health impact of sudden catastrophic events, focusing on the 2006 Yogyakarta earthquake in Indonesia. Leveraging the unpredictability of this devastating event, our analysis draws on extensive individual-level panel data from the IFLS integrated with detailed seismic intensity data from the US Geological Survey. By comparing individuals exposed to different MMI levels, we empirically demonstrate that those in higher MMI regions were significantly more likely to report severe psychological distress. Specifically, the findings reveal an increased probability of experiencing anxiety, depression, and sleep disorders among individuals in high-impact areas. The analysis of robustness checks, including alternative treatment group definitions and falsification analyses, strengthens the causal interpretation of these findings.

To further understand the mechanisms underlying these mental health outcomes, we test several potential channels that may be driving the effects. Our results show that family casualties and declines in physical health contribute significantly to the documented negative mental health effects. While these variables explain much of the earthquake's impact, we acknowledge that other potential channels, which remain unexamined due to data limitations, could also be playing a role.

Our mechanism investigation suggests that effective policy interventions for post-disaster recovery should prioritize multiple dimensions. Addressing immediate physical damage, economic losses, and family casualties is critical. For example, grief counseling, mental health support programs, and community-based services can help survivors cope with the loss of loved ones, which has a profound effect on psychological well-being. Economic support also proves essential; our analysis of interaction effects with government aid underscores that such support plays a crucial role in mitigating earthquake-induced psychological distress. More specifically, we document that receiving disaster aid significantly lowers the likelihood of experiencing anxiety and depression post-earthquake. This result highlights the need for structured and timely aid programs that not only address immediate physical needs but also facilitate mental health recovery. Strengthening healthcare services is equally important to minimize the decline in

[28] We draw inspiration from the process undertaken by Decker and Schmitz (2016) and Eibich (2015), who utilize a simple analysis to investigate potential mechanisms.

physical health, a major determinant of psychological well-being. Finally, labor market policies aimed at integrating affected individuals in the labor market can provide crucial economic stability, reducing financial pressures that compound mental health challenges.

Despite the valuable insights provided by this study, we want to acknowledge a number of limitations. Our reliance on self-reported mental health indicators, while useful for assessing psychological states, inherently lacks the objectivity of clinical diagnostic measures. Self-reported data is subjective and can be influenced by factors such as cultural norms, individual experiences, or response biases. Such biases could arise from the influence of social desirability, or the stigma associated with mental illness, potentially leading to over- or under-reporting. Although objective clinical measures would be ideal (see Bertinelli et al. (2023); Wang and Fattore, (2020), such data is not available in the IFLS. Nevertheless, self-reported indicators remain a widely accepted approach in large-scale population studies, offering meaningful insights into the psychological effects of natural disasters.

In conclusion, this research highlights the far-reaching mental health impacts of natural disasters and the critical importance of comprehensive post-disaster interventions. Effective support strategies must address not only the direct physical and economic consequences of disasters, but also the broader health and socio-economic pathways that shape mental health outcomes. The observed positive impact of government aid in reducing psychological distress underscores the necessity of structured and responsive aid programs in raising resilience and recovery. By enhancing our understanding of the pathways through which disasters affect mental health, this study offers policymakers actionable insights for designing strategies that can more effectively support affected populations, contributing to a resilient and healthier society in the aftermath of such catastrophic events.

Authorship confirmation

We hereby declare that all individuals listed as authors have made significant contributions to the research, analysis, and writing of this manuscript. Each author has participated sufficiently in the work to take public responsibility for its content and agrees with the conclusions presented.

We confirm that all authors have thoroughly reviewed the final version of the manuscript and approve its submission for publication in Economics and Human Biology. Furthermore, we assert that this manuscript represents our original work and has not been previously published nor is it under consideration for publication elsewhere.

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CRediT authorship contribution statement

Judit Vall Castelló: Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Andika Ridha Ayu Perdana:** Writing – original draft, Software, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Appendix

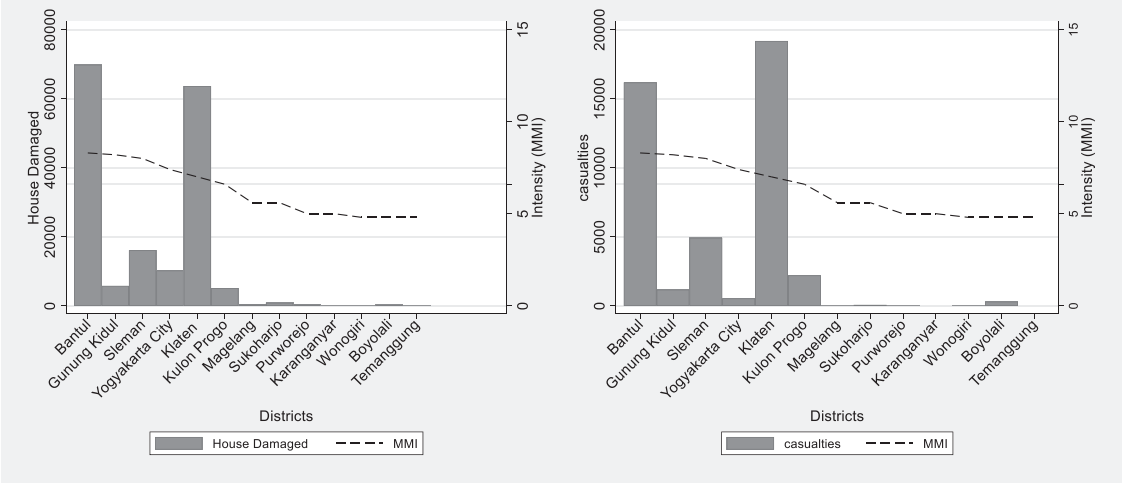

Fig.A1. Total Number of Damages and Casualties based on Districts/Municipalities and MMI Values.

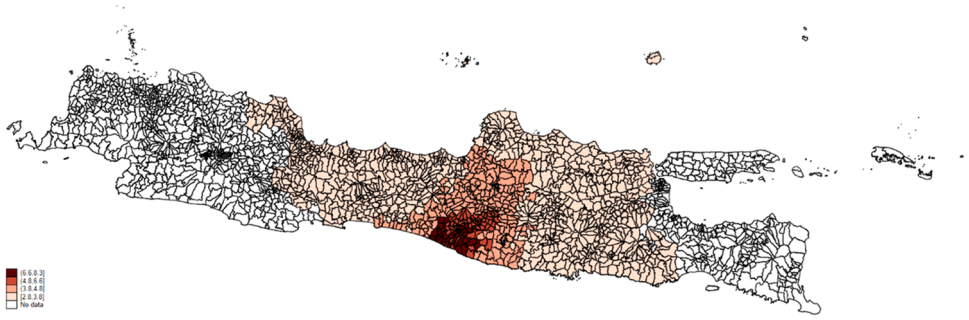

Fig.A2. Java Island and MMI Area at the Sub-District/Sub-Municipality Level. Notes: MMI values are recorded in the colored area. Darker shades reflect higher level of intensities (MMI) values.

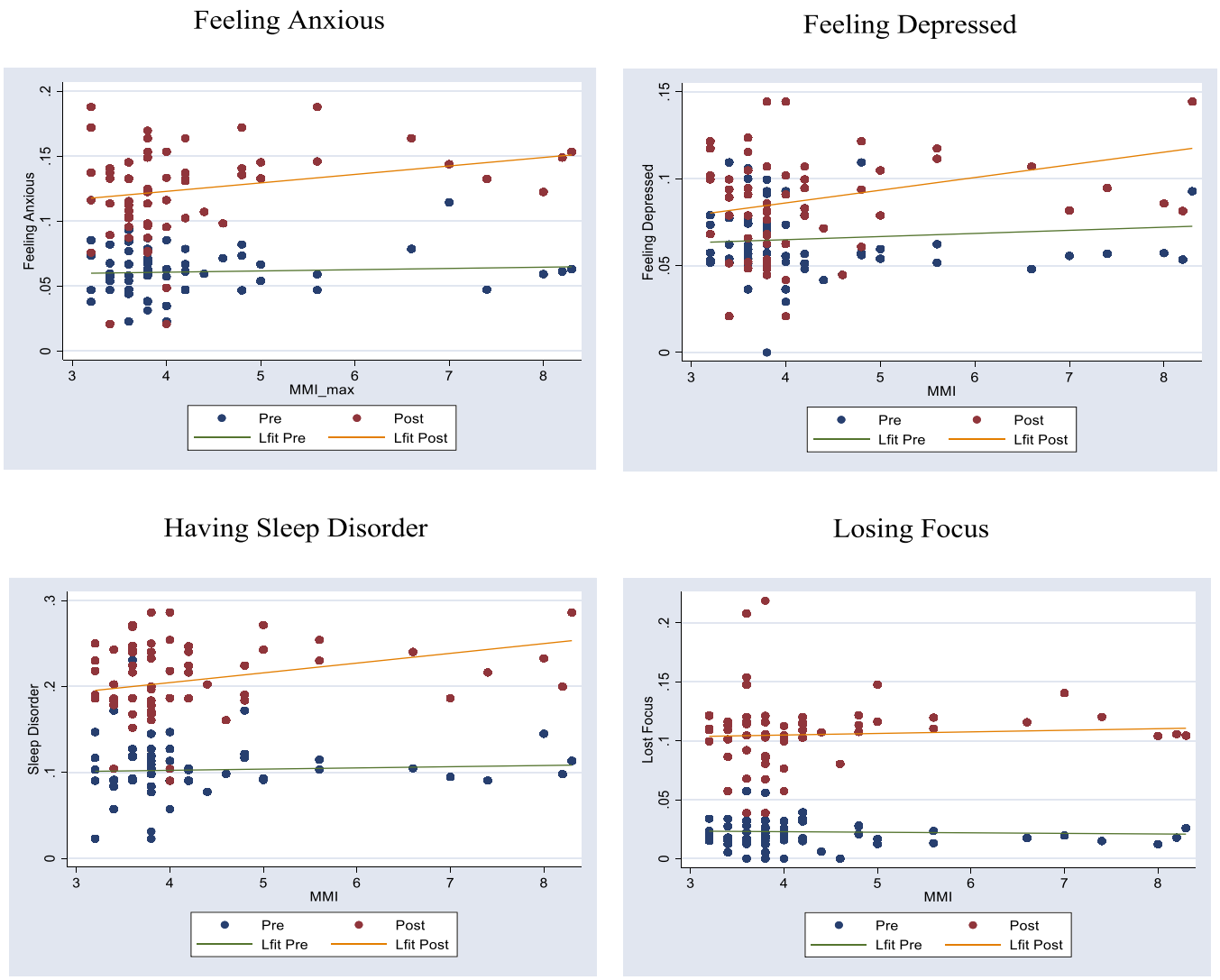

Fig.A3. Mental Health Outcomes based on Municipalities and the Range of MMI Values. *Notes*: Blue dots indicate the pre-earthquake means, while red dots show the post-earthquake means.

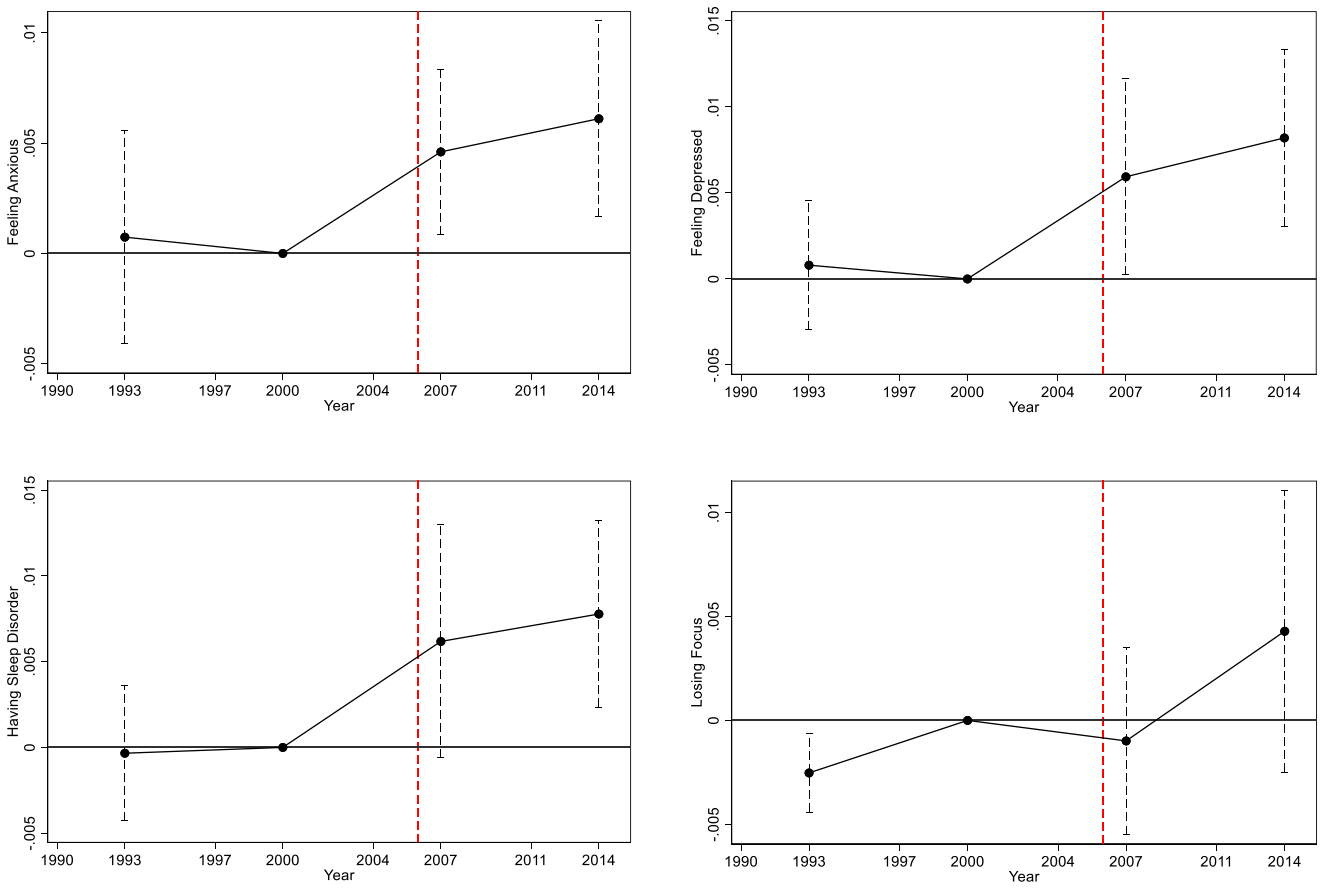

Fig.A4. Effect of the Yogyakarta earthquake on mental health over the available time span. *Notes*: This figure shows the coefficients and 95 percent confidence intervals from event study regressions that estimate interactions between year and continuous values of MMI on mental health outcomes. Year 2000 is the omitted category. The red vertical line indicates the time of the earthquake (2006). All regressions control for the year and individual fixed effect, and standard errors are clustered by municipality level.

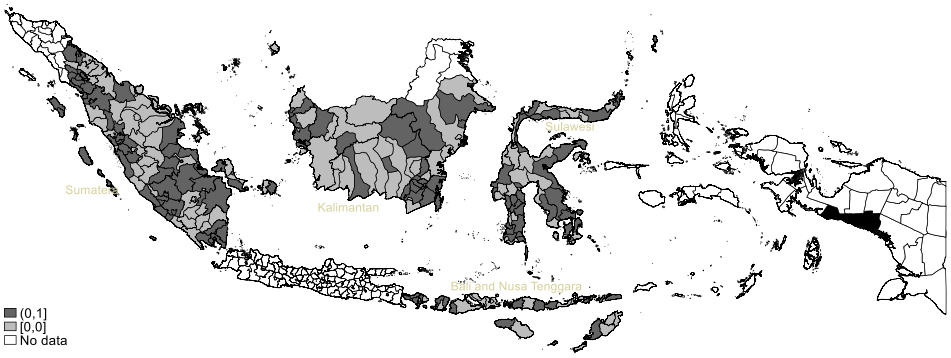

Fig.A5. Randomly Assigned of Fake Locations of Earthquakes. Note: Java Island is excluded from this estimate

Table A1
Major Earthquakes in Indonesia 1990–2018
Source: EM-DAT, The International Disaster Database

Year	Location	Magnitude (Richter)	Maximum MMI Scale	Damages (USD)	Casualties (Deaths/Injuries)
1992	Flores (Nusa Tenggara)	7.8	VIII	$100 million	2500 deaths, 2,103+ injuries
2000	Bengkulu (Sumatera)	6.7	VIII	$41 million	103 deaths, 2,714+ injuries
2004	Aceh (Sumatera)	9.1	IX	$4.5 billion	230,000 deaths, 125,000+ injuries

(*continued on next page*)

Table A1 (*continued*)

Year	Location	Magnitude (Richter)	Maximum MMI Scale	Damages (USD)	Casualties (Deaths/Injuries)
2005	Nias (Sumatera)	8.6	VIII	$1 billion	915 deaths, 1,146+ injuries
2006	Yogyakarta (Java)	5.9	VIII	$3.1 billion	5778 deaths, 38,000+ injuries
2009	Padang (Sumatera)	6.6	VIII	$700 million	1195 deaths, 1798 injuries
2009	Tasikmalaya (Java)	7.0	VI	$160 million	128 deaths, 1,442+ injuries
2018	Palu (Sulawesi)	7.5	IX	$911 million	4140 deaths, 10,000+ injuries
2018	Banten (Java)	5.9	IV-V	$250 million	453 deaths, 14,059+ injuries

Table A2
Impact of the Yogyakarta Earthquake on mental health: shaking exposure at sub-district/sub-municipality level

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
MMI_{cont} x post	0.0065***	0.0073***	0.0077***	0.0087***	0.0069**	0.0081**	0.0008	0.0014
	(0.0016)	(0.0015)	(0.0014)	(0.0017)	(0.0034)	(0.0030)	(0.0016)	(0.0017)
MMI_{cont}	−0.0001	0.0006	−0.0010	−0.0006	−0.0001	−0.0007	0.0002	0.0001
	(0.0011)	(0.0012)	(0.0014)	(0.0017)	(0.0013)	(0.0015)	(0.0007)	(0.0007)
mean pre-earthquake	0.0642	0.0642	0.0699	0.0699	0.1020	0.1020	0.0221	0.0221
percentage change	10.12 %	11.37 %	11.02 %	12.45 %	6.76 %	7.94 %	3.62 %	6.33 %
Observation	24,984	24,984	24,984	24,984	24,984	24,984	24,984	24,984
R-squared	0.0218	0.0265	0.0094	0.0160	0.0260	0.0306	0.0335	0.0373
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (1) Sample: Java Island without controls, (2) Sample: Java Island with controls. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the sub-district/sub-municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A3
Correlation between measures

	1	2	3	4	5
1. CESD −10	1.00				
2. Feeling anxious	0.21***	1.00			
3. Feeling depressed	0.21***	0.28***	1.00		
4. Having sleep disorder	0.24***	0.31***	0.26***	1.00	
5. Losing focus	0.22***	0.21***	0.27***	0.21***	1.00

Notes: This table presents correlations between CESD-10 scores and selected mental health indicators. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and * indicates significance at the 10 % level.

Table A4
Summary Statistics of mental health and individual characteristics

	Pre-Earthquake			Post-Earthquake			Diff-Diff
	Not Affected (Control)	Affected (Treatment)	Diff	Not Affected (Control)	Affected (Treatment)	Diff	
Feeling Anxious	0.063	0.067	0.004	0.125	0.169	0.044***	0.040***
	(0.242)	(0.249)	(0.007)	(0.331)	(0.375)	(0.010)	(0.011)
Feeling Depressed	0.065	0.074	0.009	0.083	0.134	0.051***	0.042***
	(0.247)	(0.262)	(0.015)	(0.276)	(0.341)	(0.018)	(0.009)
Having a sleep disorder	0.105	0.113	0.008	0.210	0.261	0.051	0.043
	(0.307)	(0.317)	(0.009)	(0.407)	(0.440)	(0.033)	(0.028)
Losing Focus	0.022	0.026	0.004	0.106	0.109	0.003	−0.0011
	(0.147)	−0.16	(0.005)	(0.308)	(0.311)	(0.009)	(0.009)
Male	0.453	0.447	−0.006	0.453	0.447	−0.006	
	(0.498)	(0.497)	(0.015)	(0.498)	(0.497)	(0.015)	
Age (in years)	36.226	38.398	2.172	50.350	52.629	2.279	0.107
	(12.595)	(14.238)	(0.389)	(12.575)	(14.121)	(0.389)	(0.076)
Married	0.768	0.727	−0.041***	0.805	0.798	−0.007	0.034
	(0.422)	(0.446)	(0.013)	(0.396)	(0.402)	(0.012)	(0.037)
Education (years)	5.954	7.336	1.381***	6.053	7.401	1.348***	−0.034
	(4.111)	(4.568)	(0.127)	(4.374)	(4.818)	(0.135)	(0.066)
Observations	11,306	1186	12,492	11,306	1186	12,492	

Table A5
Impact of the Yogyakarta Earthquake on mental health: p-value adjustment for multiple hypothesis testing using Bonferroni approach

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
MMI_{cont}x post	0.0043**	**0.0053****	**0.0057****	**0.0069****	0.0063*	**0.0078****	0.0012	0.0019
	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0033)	(0.0030)	(0.0015)	(0.0015)
Corresponding p-value	0.021	0.002	0.000	0.000	0.055	0.009	0.431	0.202
Adjusted p-value	0.168	*0.016*	*0.000*	*0.000*	0.440	*0.072*	1	1

Notes: The coefficients are derived from the main estimation in Table 1. (1) Sample: Java Island without controls, (2) Sample: Java Island with controls. Standard errors, in parentheses, are clustered at the municipality level. Adjusted p-values are calculated using the conservative Bonferroni method. Significant results after adjustment are marked in bold, and the adjusted p-values for significant results are italicized. Adjusted p-values that exceed 1 are set to 1. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A6
Impact of Yogyakarta Earthquake on mental health using extended mental health items

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
MMI_cx post	**0.0046****	**0.0054****	**0.0060****	**0.0070****	0.0058*	0.0066**	0.0010	0.0019
	(0.0014)	(0.0016)	(0.0018)	(0.0017)	(0.0029)	(0.0027)	(0.0019)	(0.0020)
mean pre-earthquake	0.056	0.056	0.062	0.062	0.102	0.102	0.022	0.022
percentage change	8.21 %	9.64 %	9.67 %	11.29 %	5.69 %	6.47 %	4.54 %	8.63 %
Corresponding p-value	0.001	0.000	0.001	0.000	0.053	0.018	0.692	0.344
Adjusted p-value	*0.016*	*0.000*	*0.016*	*0.000*	0.848	0.288	1	1
	Feeling Lonely		Easily Bothered		Couldn't get going		Lack of Energy	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
MMI_cx post	**0.0057****	**0.0062****	0.0018	0.0019	0.0042*	0.0046*	0.0026	0.0027
	(0.0015)	(0.0016)	(0.0019)	(0.0021)	(0.0020)	(0.0022)	(0.0020)	(0.0020)
mean pre-earthquake	0.062	0.062	0.059	0.059	0.068	0.068	0.071	0.071
percentage change	9.19 %	10 %	3.05 %	3.22 %	6.18 %	6.77 %	3.66 %	3.80 %
Corresponding p-value	0.000	0.000	0.667	0.382	0.073	0.057	0.880	0.583
Adjusted p-value	*0.000*	*0.000*	1	1	1	0.912	1	1
Observation	18,738	18,738	18,738	18,738	18,738	18,738	18,738	18,738
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (1) Sample: Java Island without controls, (2) Sample: Java Island with controls. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. Adjusted p-values are calculated using the conservative Bonferroni method. Significant results after adjustment are marked in bold, and the adjusted p-values for significant results are italicized. Adjusted p-values that exceed 1 are set to 1. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A7
Impact of Yogyakarta Earthquake on mental health: Leads and Lags for Difference-in-Difference estimation

	Feeling Anxious	Feeling Depressed	Sleeping Disorder	Losing Focus
Lag (2) 1993	0.0007	0.0008	−0.0003	−0.0025**
	(0.0025)	(0.0019)	(0.0020)	(0.0010)
Lead (1) 2007	0.0046**	0.0059**	0.0062*	−0.0010
	(0.0019)	(0.0029)	(0.0036)	(0.0023)
Lead (2) 2014	0.0061***	0.0081***	0.0078***	0.0043
	(0.0023)	(0.0026)	(0.0028)	(0.0035)
Observation	24,984	24,984	24,984	24,984
R-squared	0.0201	0.0096	0.0262	0.0297
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes

Notes: Lag (1) 2000 is the omitted category. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A8
Impact of the Yogyakarta Earthquake on mental health: binary measure of MMI

	Feeling Anxious		Feeling Depressed		Sleep Disorder		Lost Focus	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
$MMI_{\geq 7}$x post	0.0402***	0.0436***	0.0421***	0.0462***	0.0434	0.0468*	−0.0011	0.0027
	(0.0113)	(0.0103)	(0.0087)	(0.0090)	(0.0285)	(0.0256)	(0.0086)	(0.0085)
$MMI_{\geq 7}$	0.0035	0.0108	−0.0042	0.0015	−0.0053	−0.0034	0.0123	0.0137
	(0.0127)	(0.0124)	(0.0162)	(0.0171)	(0.0184)	(0.0203)	(0.0086)	(0.0081)
mean pre-earthquake	0.0631	0.0631	0.0659	0.0659	0.1059	0.1059	0.0224	0.0224
Observation	24,984	24,984	24,984	24,984	24,984	24,984	24,984	24,984

(*continued on next page*)

Table A8 (*continued*)

	Feeling Anxious		Feeling Depressed		Sleep Disorder		Lost Focus	
R-squared	0.0147	0.0171	0.0047	0.0097	0.0234	0.0267	0.0295	0.0291
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A9
Impact of the Yogyakarta Earthquake on mental health by geographical proximity

PANEL A:	Feeling Anxious			Feeling Depressed		
	MMI Coverage	150 km	Donut Shape	MMI Coverage	150 km	Donut Shape
MMI_{cont} ***x post***	0.0131***	0.0120***	0.0051***	0.0147***	0.0146***	0.0058***
	(0.0023)	(0.0034)	(0.0019)	(0.0033)	(0.0029)	(0.0016)
MMI_{cont}	0.0025	0.0026	−0.0012	−0.0028	−0.0004	−0.0012
	(0.0033)	(0.0042)	(0.0015)	(0,0038)	(0.0050)	(0.0016)
Mean pre-earthquake	0.0586	0.0595	0.0630	0.0649	0.0609	0.0679
PANEL B:	Sleeping Disorder			Losing Focus		
	MMI Coverage	150 km	Donut Shape	MMI Coverage	150 km	Donut Shape
MMI_{cont} ***x post***	0.0136**	0.0169***	0.0063*	0.0022	0.0018	0.0017
	(0.0052)	(0.0058)	(0.0032)	(0.0029)	(0.0036)	(0.0009)
MMI_{cont}	−0.0043	−0.0048	−0.0010	0.0013	0.0006	0.0005
	(0.0039)	(0.0053)	(0.0022)	(0.0019)	(0.0020)	(0.0010)
Mean pre-earthquake	0.1021	0.1006	0.1072	0.0214	0.0201	0.0233
Observation	14,195	9163	23,316	14,195	9163	23,316
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The sample is determined based on the distance to the nearest affected municipalities. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A10
Effects of false location of earthquake on mental health

	Feeling Anxious	Feeling Depressed	Sleeping Disorder	Losing Focus
Sample: Sumatra Island				
$MMI_{\geq 7}$ ***x post***	−0.0071	−0.0185	0.0090	−0.0101
	(0.0104)	(0.0135)	(0.0141)	(0.0131)
Observation	7068	7068	7068	7068
Sample: Bali and West Nusa				
$MMI_{\geq 7}$ ***x post***	−0.0116	0.0010	−0.0138	0.0089
	(0.0187)	(0.0152)	(0.0132)	(0.0109)
Observation	4984	4984	4984	4984
Sample: Kalimantan and Sulawesi				
$MMI_{\geq 7}$ ***x post***	−0.0012	0.0035	0.0144	0.0199
	(0.0160)	(0.0113)	(0.0180)	(0.0161)
Observation	3860	3860	3860	3860
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes

Notes: Each coefficient comes from a different regression. Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A11
Effects of False Years of Earthquake on Mental Health

	Feeling Anxious	Feeling Depressed	Sleeping Disorder	Losing Focus
False Year: 1995				
MMI_{cont} ***x post***	0.002	0.001	0.004	0.002
	(0.001)	(0.002)	(0.002)	(0.001)
Observation	12,536	12,536	12,536	12,536
False Year: 1997				
MMI_{cont} ***x post***	0.001	0.000	0.001	0.002

(*continued on next page*)

Table A11 (*continued*)

	Feeling Anxious	Feeling Depressed	Sleeping Disorder	Losing Focus
	(0.001)	(0.002)	(0.003)	(0.001)
Observation	12,512	12,512	12,512	12,512
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A12
Impact of the Yogyakarta Earthquake on migration

	Migration			
Sample:	Java Island	MMI Coverage	150KM	Donut Shape
MMI_{cont} x post	0.0048	−0.0020	0.0068	−0.0062
	(0.0042)	(0.0072)	(0.0064)	(0.0043)
MMI_{cont}	−0.0225***	−0.0121*	−0.0075	−0.0234***
	(0.0071)	(0.0068)	(0.0086)	(0.0079)
Mean pre-earthquake	0.1956	0.1297	0.1036	0.1962
R-squared	0.2863	0.1419	0.1124	0.1419
Observation	24,984	14,195	9163	23,316
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes
Pre-mental health controls	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Pre-mental health conditions include feeling anxious, feeling depressed, and having sleep disorders. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and * indicates significance at the 10 % level.

Table A13
Impact of the Yogyakarta Earthquake on mental health (excluding individuals who migrate to other municipalities)

	Feeling Anxious		Feeling Depressed		Sleeping Disorder		Losing Focus	
	baseline	excl.mig	baseline	excl.mig	baseline	excl.mig	baseline	excl.mig
MMI_{cont} x post	0.0053***	0.0054**	0.0069***	0.0076***	0.0078***	0.0082**	0.0027	0.0014
	(0.0016)	(0.0019)	(0.0014)	(0.0014)	(0.0030)	(0.0032)	(0.0085)	(0.0019)
MMI_{cont}	−0.0011	−0.0013	−0.0019	−0.0025	−0.0020	−0.0021	0.0137	0.0005
	(0.0013)	(0.0015)	(0.0015)	(0.0018)	(0.0019)	(0.0023)	(0.0081)	(0.0011)
Mean pre-earthquake	0.0631	0.0628	0.0659	0.0671	0.1059	0.1041	0.0224	0.0221
Observation	24,984	20,964	24,984	20,964	24,984	20,964	24,984	20,964
R-squared	0.0245	0.0170	0.0095	0.0103	0.0261	0.0356	0.0291	0.0383
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A14
Attrition between survey waves

	1st and 4th	1st and 5th	3rd and 4th	3rd and 5th
	(2)	(3)	(4)	(4)
MMI_{cont} x post	−0.0026	−0.0063	0.0044	0.0036
	(0.0067)	(0.0113)	(0.0027)	(0.0029)
R-squared	0.1393	0.2372	0.3227	0.3142
Observation	9124	9124	7658	8796
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes
Pre-mental health controls	Yes	Yes	Yes	Yes

Notes: The dependent variable is equal to 1 if an individual observed in one wave but not in the following wave. Individual controls include age, age squared, education, and marital status. Pre-mental health conditions include feeling anxious, feeling depressed, and having sleep disorders. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and * indicates significance at the 10 % level.

Table A15
Impact of the Yogyakarta Earthquake on probability of receiving transfer from families

	Receiving transfer
MMI_{cont} x post	0.0042**
	(0.0021)
MMI_{cont}	0.0201***
	(0.0052)
mean pre-earthquake	0.0586
% change	7.17 %
Observation	24,984
Controls	Yes
Year FE	Yes
Municipality FE	Yes
Individual FE	Yes

Notes: Each coefficient comes from a separate regression. Individual controls include age, age squared, education, marital status, home ownership, unemployment status, and household size. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A16
Impact of the Yogyakarta Earthquake on mental health by Government aid/assistance

	Feeling Anxious	Feeling Depressed	Sleeping Disorder	Losing Focus
MMI_c x post	0.0031	0.0021	0.0033	0.0009
	(0.0029)	(0.0028)	(0.0032)	(0.0024)
MMI_c x post x receiving disaster aid	−0.0056**	−0.0062***	−0.0067	−0.0012
	(0.0027)	(0.0023)	(0.0051)	(0.0032)
Test for coefficients' equality, p-value	0.0292	0.0030	0.1025	0.5642
mean pre-earthquake	0.0368	0.0449	0.0341	0.0377
Observation	11,805	11,805	11,805	11,805
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes

Notes: Individual controls include age, age squared, education, and marital status. Standard errors, in parentheses, are clustered at the municipality level. *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Table A17
Effect on mental health including all additional controls

	Feeling Anxious		Feeling Depressed		Sleeping Disorder	
	(1)	(2)	(3)	(4)	(5)	(6)
MMI_{cont} x post	0.0053***	0.0021**	0.0069***	0.0046***	0.0078**	0.0038
	(0.0016)	(0.0015)	(0.0018)	(0.0019)	(0.0029)	(0.0035)
MMI_{cont}	−0.0011	−0.0012	−0.0019	−0.0007	−0.0020	0.0003
	(0.0013)	(0.0015)	(0.0015)	(0.0016)	(0.0019)	(0.0020)
Destroyed house		0.0221		0.0130		0.0270
		(0.0347)		(0.0283)		(0.0278)
Asset loss		0.0131		0,0049		0.0207
		(0.0292)		(0.0142)		(0.0241)
Family casualties		0.0653***		0.0239*		0.0514***
		(0.0221)		(0.0140)		(0.0164)
Unemployed		0.0044		0.0087		0.0239**
		(0.0075)		(0.0083)		(0.0092)
Lack of social engagement		−0.0058		0.0046		0.0018
		(0.0074)		(0.0067)		(0.0098)
Non-adequate eating frequency		0.0037		0.0021		0.0162*
		(0.0086)		(0.0074)		(0.0093)
Unhealthy		0.0480***		0.0307***		0.0468***
		(0.0132)		(0.0106)		(0.0106)
Low physical ability		0.0254**		0.0330***		0.0377***
		(0.0114)		(0.0100)		(0.0137)
Observation	24,984	17,822	24,984	17,822	24,984	17,822
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The reduction in the number of observations is due to missing values for some observed potential mediators. All control variables are included simultaneously. Standard errors, in parentheses, are clustered at the municipality level *** indicates significance at the 1 % level, ** indicates significance at the 5 % level, and *indicates significance at the 10 % level.

Data availability

Data will be made available on request.

References

Amri, M.R., Yulianti, G., Yunus, R., Wiguna, S., W. Adi, A., Ichwana, A.N. and Randongkir, Roling Evans Septian, R.T. (2018). Risiko Bencana Indonesia (Disasters Risk of Indonesia). In *RBI (Risiko Bencana Indonesia)*, *BNPB Direktorat Pengurangan Risiko Bencana.* https://doi.org/10.1007/s13753-018-0186-5.

Anderson, M.L., 2020. As the wind blows: the effects of long-term exposure to air pollution on mortality. J. Eur. Econ. Assoc. 18 (4), 1886–1927. https://doi.org/10.1093/jeea/jvz051.

Bai, Y., Li, Y., 2021. More suffering, more involvement? The causal effects of seismic disasters on social capital. World Dev. 138, 105221. https://doi.org/10.1016/j.worlddev.2020.105221.

Bappenas. (2006). *Preliminary Damage and Loss Assessment Yogyakarta and Central Java Natural Disaster. June*, 140. http://siteresources.worldbank.org/INTINDONESIA/Resources/226271-1150196584718/PackageJune13_HIRES_FINAL.pdf.

Baryshnikova, N.V., Pham, N.T.A., 2019. Natural disasters and mental health: a quantile approach. Econ. Lett. 180, 62–66. https://doi.org/10.1016/j.econlet.2019.04.016.

Bertinelli, L., Mahé, C., Strobl, E., 2023. Earthquakes and mental health. World Dev. 169, 106283. https://doi.org/10.1016/j.worlddev.2023.106283.

Bonanno, G.A., 2004. Loss, trauma, and human resilience: have we underestimated the human capacity to thrive after extremely aversive events. Am. Psychol. 59 (1), 20–28. https://doi.org/10.1037/0003-066X.59.1.20.

Bonanno, G.A., Westphal, M., Mancini, A.D., 2011. Resilience to loss and potential trauma. Annu. Rev. Clin. Psychol. 7, 511–535. https://doi.org/10.1146/annurev-clinpsy-032210-104526.

Brata, A.G., de Groot, H.L.F., Zant, W., 2018. The impact of the 2006 Yogyakarta earthquake on local economic growth. Econ. Disasters Clim. Change 2 (2), 203–224. https://doi.org/10.1007/s41885-018-0026-5.

Caruso, G., Miller, S., 2015. Long run effects and intergenerational transmission of natural disasters: a case study on the 1970 Ancash Earthquake. J. Dev. Econ. 117, 134–150. https://doi.org/10.1016/j.jdeveco.2015.07.012.

Cénat, J.M., Derivois, D., 2015. Long-term outcomes among child and adolescent survivors of the 2010 Haitian earthquake. Depress Anxiety 32 (1), 57–63. https://doi.org/10.1002/da.22275.

Cipollone, P., Rosolia, A., 2007. Social interactions in high school: lessons from an earthquake. Am. Econ. Rev. 97 (3), 948–965. https://doi.org/10.1257/aer.97.3.948.

Civelek, Y., 2023. The effect of hurricanes on mental health over the long term. Econ. Hum. Biol. 51 (October 2022), 101312. https://doi.org/10.1016/j.ehb.2023.101312.

Conti, G., Heckman, J.J., Pinto, R., 2016. The effects of two influential early childhood interventions on health and healthy behaviour. Econ. J. 126 (596), F28–F65. https://doi.org/10.1111/ecoj.12420.

Conversano, C., 2019. Common psychological factors in chronic diseases. Front. Psychol. 10 (2727). https://doi.org/10.1037/hea0000578.

De, P.K., Thamarapani, D., 2022. Impacts of negative shocks on wellbeing and aspirations – evidence from an earthquake. World Dev. 154, 105876. https://doi.org/10.1016/j.worlddev.2022.105876.

De Silva, M.J., 2015. Making mental health an integral part of sustainable development: the contribution of a social determinants framework. Epidemiol. Psychiatr. Sci. 24 (2), 100–106. https://doi.org/10.1017/S2045796015000049.

Decker, S., Schmitz, H., 2016. Health shocks and risk aversion. J. Health Econ. 50, 156–170. https://doi.org/10.1016/j.jhealeco.2016.09.006.

Dembedza, V.P., Mapara, J., Mpofu-Hamadziripi, N., Kembo, G., Macheka, L., 2022. Impact of Climate Change Induced Natural Disasters on Nutrition Outcomes: A Case of Cyclone Idai. Zimbabwe 1–16. https://doi.org/10.21203/rs.3.rs-1986844/v1.

Deryugina, T., 2017. The fiscal cost of hurricanes: disaster aid versus social insurance. Am. Econ. J.: Econ. Policy 9 (3), 168–198. https://doi.org/10.1257/pol.20140296.

Deuchert, E., Felfe, C., 2015. The tempest: short- and long-term consequences of a natural disaster for children's development. Eur. Econ. Rev. 80 (March 2013), 280–294. https://doi.org/10.1016/j.euroecorev.2015.09.004.

Di Pietro, G., Mora, T., 2015. The effect of the L'Aquila earthquake on labour market outcomes. Environ. Plan. C: Gov. Policy 33 (2), 239–255. https://doi.org/10.1068/c12121r.

Dodlova, M., Escobar, M., Grimm, M., 2023. The effects of the 2010 Haiti earthquake on children's nutrition and education. SSRN Electron. J. *16195*. https://doi.org/10.2139/ssrn.4477993.

Eibich, P., 2015. Understanding the effect of retirement on health: mechanisms and heterogeneity. J. Health Econ. 43, 1–12. https://doi.org/10.1016/j.jhealeco.2015.05.001.

Fergusson, D.M., Horwood, L.J., Boden, J.M., Mulder, R.T., 2014. Impact of a major disaster on the mental health of a well-studied cohort. JAMA Psychiatry 71 (9), 1025–1031. https://doi.org/10.1001/jamapsychiatry.2014.652.

Fu, M., Hall, B.J., Xi, J., Guo, J., 2021. Gender differences in trajectories of mental health symptoms among Chinese earthquake survivors. J. Psychiatr. Res. 142 (July), 117–124. https://doi.org/10.1016/j.jpsychires.2021.07.034.

Galea, S., Nandi, A., Vlahov, D., 2005. The epidemiology of post-traumatic stress disorder after disasters. Epidemiol. Rev. 27, 78–91. https://doi.org/10.1093/epirev/mxi003.

Gallagher, J., Hartley, D., 2017. Household finance after a natural disaster: the case of Hurricane Katrina. Am. Econ. J.: Econ. Policy 9 (3), 199–228. https://doi.org/10.1257/pol.20140273.

Gao, X., Leng, Y., Guo, Y., Yang, J., Cui, Q., Geng, B., Hu, H., Zhou, Y., 2019. Association between earthquake experience and depression 37 years after the Tangshan earthquake: a cross-sectional study. BMJ Open 9 (8), 1–8. https://doi.org/10.1136/bmjopen-2018-026110.

García Hombrados, J., 2020. The lasting effects of natural disasters on property crime: evidence from the 2010 Chilean earthquake. J. Econ. Behav. Organ. 175, 114–154. https://doi.org/10.1016/j.jebo.2020.04.008.

Geng, F., Zhou, Y., Liang, Y., Fan, F., 2018. A longitudinal study of recurrent experience of earthquake and mental health problems among chinese adolescents. Front. Psychol. 9 (JUL), 1–9. https://doi.org/10.3389/fpsyg.2018.01259.

Goebel, J., Krekel, C., Tiefenbach, T., Ziebarth, N.R., 2015. How natural disasters can affect environmental concerns, risk aversion, and even politics: evidence from Fukushima and three European countries. J. Popul. Econ. 28 (4), 1137–1180. https://doi.org/10.1007/s00148-015-0558-8.

Gröger, A., Zylberberg, Y., 2016. Internal labor migration as a shock coping strategy: evidence from a typhoon. Am. Econ. J.: Appl. Econ. 8 (2), 123–153. https://doi.org/10.1257/app.20140362.

Herrera-Almanza, C., Cas, A., 2021. Mitigation of long-term human capital losses from natural disasters: evidence from the Philippines. World Bank Econ. Rev. 35 (2), 436–460. https://doi.org/10.1093/wber/lhaa001.

Hinton, D.E., Lewis-Fernández, R., 2011. The cross-cultural validity of posttraumatic stress disorder: implications for DSM-5. Depress Anxiety 28 (9), 783–801. https://doi.org/10.1002/da.20753.

Hobfoll, S.E., Watson, P., Bell, C.C., Bryant, R.A., Brymer, M.J., Friedman, M.J., Friedman, M., Gersons, B.P.R., De Jong, J.T.V.M., Layne, C.M., Maguen, S., Neria, Y., Norwood, A.E., Pynoos, R.S., Reissman, D., Ruzek, J.I., Shalev, A.Y., Solomon, Z., Steinberg, A.M., Ursano, R.J., 2007. Five essential elements of immediate and mid-term mass trauma intervention: empirical evidence. Psychiatry 70 (4), 283–315. https://doi.org/10.1521/psyc.2007.70.4.283.

Java Reconstruction Fund. (2007). *ONE YEAR AFTER THE JAVA EARTHQUAKE AND TSUNAMI: Reconstruction Achievements and the Results of the Java Reconstruction Fund*.

Jenkins, R., 2019. Global mental health and sustainable development 2018. BJPsych Int. 16 (02), 34–37. https://doi.org/10.1192/bji.2019.5.

Jia, Z., Tian, W., Liu, W., Cao, Y., Yan, J., Shun, Z., 2010. Are the elderly more vulnerable to psychological impact of natural disaster? A population-based survey of adult survivors of the 2008 Sichuan earthquake. BMC Public Health *10*. https://doi.org/10.1186/1471-2458-10-172.

Joseph, J., Jaswal, S., 2021. Elderly and disaster mental health: understanding older persons' vulnerability and psychosocial well-being two years after tsunami. Ageing Int. 46 (3), 235–252. https://doi.org/10.1007/s12126-020-09375-w.

Kar, N., Krishnaraaj, R., Rameshraj, K., 2014. Long-term mental health outcomes following the 2004 Asian tsunami disaster. Disaster Health 2 (1), 35–45. https://doi.org/10.4161/dish.24705.

Khanal, B., 2022. The impacts of the 2015 Gorkha earthquake on Children's health in Nepal. World Dev. 153, 105826. https://doi.org/10.1016/j.worlddev.2022.105826.

Kino, S., Aida, J., Kondo, K., Kawachi, I., 2021. Persistent mental health impacts of disaster. Five-year follow-up after the 2011 great east Japan earthquake and tsunami: Iwanuma Study. J. Psychiatr. Res. 136 (August 2020), 452–459. https://doi.org/10.1016/j.jpsychires.2020.08.016.

Kirchberger, M., 2017. Natural disasters and labor markets. J. Dev. Econ. 125 (November 2014), 40–58. https://doi.org/10.1016/j.jdeveco.2016.11.002.

König, H.H., Neumann-Böhme, S., Sabat, I., Schreyögg, J., Torbica, A., van Exel, J., Barros, P.P., Stargardt, T., Hajek, A., 2023. Health-related quality of life in seven European countries throughout the course of the COVID-19 pandemic: evidence from the European COvid Survey (ECOS. Qual. Life Res. 32 (6), 1631–1644. https://doi.org/10.1007/s11136-022-03334-5.

Li, L.M.W., Li, W.Q., 2022. Chronic vulnerability to natural disasters and subjective well-being. Curr. Res. Ecol. Soc. Psychol. 3 (March 2021), 100041. https://doi.org/10.1016/j.cresp.2022.100041.

Livanou, M., Kasvikis, Y., Başoğlu, M., Mytskidou, P., Sotiropoulou, V., Spanea, E., Mitsopoulou, T., Voutsa, N., 2005. Earthquake-related psychological distress and associated factors 4 years after the Parnitha earthquake in Greece. Eur. Psychiatry 20 (2), 137–144. https://doi.org/10.1016/j.eurpsy.2004.06.025.

Lorant, V., Deliège, D., Eaton, W., Robert, A., Philippot, P., Ansseau, M., 2003. Socioeconomic inequalities in depression: a meta-analysis. Am. J. Epidemiol. 157 (2), 98–112. https://doi.org/10.1093/aje/kwf182.

Lowe, S.R., Joshi, S., Pietrzak, R.H., Galea, S., Cerdá, M., 2015. Mental health and general wellness in the aftermath of Hurricane Ike. Soc. Sci. Med. 124. https://doi.org/10.1016/j.socscimed.2014.11.032, 162e170-170.

Lowe, S.R., Raker, E.J., Zacher, M.L., 2020. Extremes in context: a life-course approach to disaster mental health. One Earth 2 (6), 497–499. https://doi.org/10.1016/j.oneear.2020.05.022.

Maclean, J.C., Popovici, I., French, M.T., 2016. Are natural disasters in early childhood associated with mental health and substance use disorders as an adult. Soc. Sci. Med. 151 (2016), 78–91. https://doi.org/10.1016/j.socscimed.2016.01.006.

Mahendradhata, Y., Trisnantoro, L., Listyadewi, S., Soewondo, P., MArthias, T., Harimurti, P., Prawira, J., 2017. The Republic of Indonesia Health System Review 7 (1).

Mao, W., Agyapong, V.I.O., 2021. The role of social determinants in mental health and resilience after disasters: implications for public health policy and practice. Front. Public Health 9 (May), 1–15. https://doi.org/10.3389/fpubh.2021.658528.

Masiero, G., Santarossa, M., 2020. Natural disasters and electoral outcomes. Eur. J. Political Econ. 67 (ember), 101983. https://doi.org/10.1016/j.ejpoleco.2020.101983.

Messiah, A., Acuna, J.M., Castro, G., Rodríguez de la Vega, P., Vaiva, G., Shultz, J.M., Neria, Y., De La Rosa, M., 2014. Mental health impact of the 2010 Haiti earthquake

on the Miami Haitian population: a random-sample survey. Disaster Health 2 (3–4), 130–137. https://doi.org/10.1080/21665044.2015.1014216.
Mostafizur Rahman, M., Alam Shobuj, I., Tanvir Hossain, M., Tasnim, F., 2023. Impact of Disaster on mental health of women: a case study on 2022 flash flood in Bangladesh. Int. J. Disaster Risk Reduct. 96 (April), 103935. https://doi.org/10.1016/j.ijdrr.2023.103935.
Mureşan, G.M., Văidean, V.L., Mare, C., Achim, M.V., 2022. Were we happy and we didn't know it? A subjective dynamic and financial assessment pre-, during and post-COVID-19. Eur. J. Health Econ. 24 (5), 749–768. https://doi.org/10.1007/s10198-022-01506-1.
Nandi, A., Mazumdar, S., Behrman, J.R., 2018. The effect of natural disaster on fertility, birth spacing, and child sex ratio: evidence from a major earthquake in India. J. Popul. Econ. 31 (1), 267–293. https://doi.org/10.1007/s00148-017-0659-7.
Nian, Y., 2023. Incentives, penalties, and rural air pollution: evidence from satellite data. J. Dev. Econ. 161 (December 2020), 103049. https://doi.org/10.1016/j.jdeveco.2023.103049.
Norris, F.H., Stevens, S.P., Pfefferbaum, B., Wyche, K.F., Pfefferbaum, R.L., 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. Am. J. Community Psychol. 41 (1–2), 127–150. https://doi.org/10.1007/s10464-007-9156-6.
Norris, F.H., Tracy, M., Galea, S., 2009. Looking for resilience: understanding the longitudinal trajectories of responses to stress. Soc. Sci. Med. 68 (12), 2190–2198. https://doi.org/10.1016/j.socscimed.2009.03.043.
Ohrnberger, J., Fichera, E., Sutton, M., 2017. The relationship between physical and mental health: a mediation analysis. Soc. Sci. Med. 195 (ember), 42–49. https://doi.org/10.1016/j.socscimed.2017.11.008.
Paudel, J., Ryu, H., 2018. Natural disasters and human capital: the case of Nepal's earthquake. World Dev. 111, 1–12. https://doi.org/10.1016/j.worlddev.2018.06.019.
Peek, L., 2008. Children and disasters: understanding vulnerability, developing capacities, and promoting resilience — an introduction. Child. Youth Environ. 18 (1), 1–29. https://doi.org/10.1353/cye.2008.0052.
Pope, D.H., McMullen, H., Baschieri, A., Philipose, A., Udeh, C., Diallo, J., McCoy, D., 2022. What is the current evidence for the relationship between the climate and environmental crises and child marriage? A scoping review. Glob. Public Health 18 (1). https://doi.org/10.1080/17441692.2022.2095655.
Priester, L.De, 2016. An approach to the profile of disaster risk of Indonesia. Emerg. Disaster Rep. 3 (2), 66.
Qu, Z., Tian, D., Zhang, Q., Wang, X., He, H., Zhang, X., Huang, L., Xu, F., 2012. The impact of the catastrophic earthquake in China's Sichuan province on the mental health of pregnant women. J. Affect. Disord. 136 (1–2), 117–123. https://doi.org/10.1016/j.jad.2011.08.021.
Rafiey, H., Momtaz, Y.A., Alipour, F., Khankeh, H., Ahmadi, S., Khoshnami, M.S., Haron, S.A., 2016. Are older people more vulnerable to long-term impacts of disasters. Clin. Interv. Aging 11, 1791–1795. https://doi.org/10.2147/CIA.S122122.
Raker, E.J., Lowe, S.R., Arcaya, M.C., Johnson, S.T., Rhodes, J., Waters, M.C., 2019. Twelve years later: the long-term mental health consequences of Hurricane Katrina. Soc. Sci. Med. 242 (July), 112610. https://doi.org/10.1016/j.socscimed.2019.112610.
Rehdanz, K., Welsch, H., Narita, D., Okubo, T., 2015. Well-being effects of a major natural disaster: the case of Fukushima. J. Econ. Behav. Organ. 116, 500–517. https://doi.org/10.1016/j.jebo.2015.05.014.
Reiss, F., Meyrose, A.K., Otto, C., Lampert, T., Klasen, F., Ravens-Sieberer, U., 2019. Socioeconomic status, stressful life situations and mental health problems in children and adolescents: results of the German BELLA cohort-study. PLoS ONE 14 (3), 1–16. https://doi.org/10.1371/journal.pone.0213700.
Resosudarmo, B.P., Sugiyanto, C., Kuncoro, A., 2012. Livelihood recovery after natural disasters and the role of aid: the case of the 2006 Yogyakarta earthquake. Asian Econ. J. 26 (3), 233–259. https://doi.org/10.1111/j.1467-8381.2012.02084.x.
Rhodes, J., Chan, C., Paxson, C., Rouse, C.E., Waters, M., Fussell, E., 2010. The impact of hurricane Katrina on the mental and physical health of low-income parents in New Orleans. Am. J. Orthopsychiatry 80 (2), 237–247. https://doi.org/10.1111/j.1939-0025.2010.01027.x.
Rosales-Rueda, M., 2018. The impact of early life shocks on human capital formation: evidence from El Niño floods in Ecuador. J. Health Econ. 62, 13–44. https://doi.org/10.1016/j.jhealeco.2018.07.003.
Ruiz-Pérez, I., Bermúdez-Tamayo, C., Rodríguez-Barranco, M., 2017. Socio-economic factors linked with mental health during the recession: a multilevel analysis. Int. J. Equity Health 16 (1), 1–8. https://doi.org/10.1186/s12939-017-0518-x.
Şalcioğlu, E., Başoğlu, M., Livanou, M., 2003. Long-term psychological outcome for non-treatment-seeking earthquake survivors in Turkey. J. Nerv. Ment. Dis. 191 (3), 154–160. https://doi.org/10.1097/01.NMD.0000054931.12291.50.
Schwartz, R.M., Gillezeau, C.N., Liu, B., Lieberman-Cribbin, W., Taioli, E., 2017. Longitudinal impact of hurricane sandy exposure on mental health symptoms. Int. J. Environ. Res. Public Health 14 (9). https://doi.org/10.3390/ijerph14090957.
Sezgin, U., Punamäki, R.L., 2012. Earthquake trauma and causal explanation associating with PTSD and other psychiatric disorders among South East Anatolian women. J. Affect. Disord. 141 (2–3), 432–440. https://doi.org/10.1016/j.jad.2012.03.005.
Shidiqi, K.A., Di Paolo, A., & Choi, Á. (2023). Earthquake exposure and schooling: Impacts and mechanisms. *Economics of Education Review,* 94(March). https://doi.org/10.1016/j.econedurev.2023.102397.
Song, M., 2020. Psychological stress responses to COVID-19 and adaptive strategies in China. World Dev. 136, 105107. https://doi.org/10.1016/j.worlddev.2020.105107.
Soqia, J., Ghareeb, A., Hadakie, R., Alsamara, K., Forbes, D., & Jawich, K. (2024). *The mental health impact of the 2023 earthquakes on the Syrian population: cross-sectional study*. 1–6. https://doi.org/10.1192/bjo.2023.598.
Stein, M.B., Jang, K.L., Taylor, S., Vernon, P.A., Livesley, W.J., 2002. Genetic and environmental influences on trauma exposure and posttraumatic stress disorder symptoms: a twin study. Am. J. Psychiatry 159 (10), 1675–1681. https://doi.org/10.1176/appi.ajp.159.10.1675.
Strauss, J., Witoelar, F., & Sikoki, B. (2016). The Fifth Wave of the Indonesia Family Life Survey: Overview and Field Report: Volume 1. *The Fifth Wave of the Indonesia Family Life Survey: Overview and Field Report: Volume 1*, *April 2009*. https://doi.org/10.7249/wr1143.1.
Timalsina, R., Songwathana, P., Sae-Sia, W., 2022. Factors explaining resilience among Nepalese older adults experiencing disasters: a cross-sectional study. Int. J. Disaster Risk Reduct. 69 (April 2021), 102756. https://doi.org/10.1016/j.ijdrr.2021.102756.
Trinidad, A.C., Protacio-De Castro, E., 2020. The institutionalization of mental health and psychosocial support in emergencies in Indonesia. Int. J. Disaster Risk Reduct. 51 (May), 101918. https://doi.org/10.1016/j.ijdrr.2020.101918.
Tsuboya, T., Aida, J., Hikichi, H., Subramanian, S.V., Kondo, K., Osaka, K., Kawachi, I., 2016. Predictors of depressive symptoms following the Great East Japan earthquake: a prospective study. Soc. Sci. Med. 161, 47–54. https://doi.org/10.1016/j.socscimed.2016.05.026.
Turner, J., Kelly, B., 2000. Culture and medicine: emotional dimensions of chronic disease. West J. Med. 172 (February), 124–128.
United Nations Office for Disaster Risk Reduction. (2020). The human cost of disasters: an overview of the last 20 years (2000-2019). In Human Cost of Disasters. https://doi.org/10.18356/79b92774-en.
Viertiö, S., Kiviruusu, O., Piirtola, M., Kaprio, J., Korhonen, T., Marttunen, M., Suvisaari, J., 2021. Factors contributing to psychological distress in the working population, with a special reference to gender difference. BMC Public Health 21 (1), 1–17. https://doi.org/10.1186/s12889-021-10560-y.
Walter, T.R., Wang, R., Luehr, B.G., Wassermann, J., Behr, Y., Parolai, S., Anggraini, A., Günther, E., Sobiesiak, M., Grosser, H., Wetzel, H.U., Milkereit, C., Sri Brotopuspito, P.J.K., Harjadi, P., Zschau, J., 2008. The 26 May 2006 magnitude 6.4 Yogyakarta earthquake south of Mt. Merapi volcano: Did lahar deposits amplify ground shaking and thus lead to the disaster? Geochem. Geophys. Geosystems 9 (5), 1–9. https://doi.org/10.1029/2007GC001810.
Wang, Y., Fattore, G., 2020. The impact of the great economic crisis on mental health care in Italy. Eur. J. Health Econ. 21 (8), 1259–1272. https://doi.org/10.1007/s10198-020-01204-w.
Wang, Z., Wang, F., 2023. Well-being effects of natural disasters: evidence from China's Wenchuan earthquake. J. Happiness Stud. 24 (2), 563–587. https://doi.org/10.1007/s10902-022-00609-z.
World Bank. (2006). Penilaian Awal Kerusakan dan Kerugian. *Laporan Bersama BAPPENAS, Pemerintahan Provinsi Dan Daerah D.I. Yogyakarta, Pemerintahan Provinsi Dan Daerah Jawa Tengah, Dan Mitra International*.
World Health Organization. (2022). World mental health report: transforming mental health for all. In *Geneva: World Health Organization.Licence*: *CC BY-NC-SA 3.0 IGO*.
Xi, Y., Yu, H., Yao, Y., Peng, K., Wang, Y., Chen, R., 2020. Post-traumatic stress disorder and the role of resilience, social support, anxiety and depression after the Jiuzhaigou earthquake: a structural equation model. Asian J. Psychiatry 49 (December 2019), 101958. https://doi.org/10.1016/j.ajp.2020.101958.
Zhang, Z., Shi, Z., Wang, L., Liu, M., 2011. One year later: mental health problems among survivors in hard-hit areas of the Wenchuan earthquake. Public Health 125 (5), 293–300. https://doi.org/10.1016/j.puhe.2010.12.008.