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松岡　洋子

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博士論文

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CONTENTS

ABSTRACT

Disaster-related relocation is associated with depression and post-traumatic stress disorder (PTSD), specifically in older adults. Disaster-related relocation often deprives disaster survivors of opportunities for group participation, potentially resulting in the deterioration of their mental health. This study explored the unproven mediation effects of disaster-related relocation on mental health via changes in group participation. I and co-authors analyzed the pre/post-disaster dataset of functionally independent older adults from the Japan Gerontological Evaluation Study. Following the 2013 survey, a follow-up survey was conducted seven months after the 2016 Kumamoto earthquake and floods. We utilized the pre/post-disaster dataset to make a causal inference of the natural direct and indirect effect estimates of disaster-related relocation on the mental health of participants via changes in group participation (n = 828). Results of the inverse odds ratio-weighted mediation analyses indicated that compared to no relocation, the relative risk (RR) of developing major depressive episodes (MDE) as the natural direct effect estimate of relocation to temporary housing was 3.79 [95% confidence interval: 1.70–6.64]. However, the RR of the natural indirect effect estimate via renewed (either ceased or started) group participation on MDE was 0.60 [0.34–0.94]. No clear associations were observed in relation to PTSD symptoms.

The environment in the temporary housing built after the 2016 Kumamoto earthquake may have optimized social ties among residents, protecting them against depression.

1. INTRODUCTION

1.1. Natural Disasters and Mental Health

A disaster is defined as "a severe disruption, ecological and psychological, which greatly exceeds the coping capacity of the affected community" [1(p2)]. Disasters devastate people's lives, resulting in a change in their living environments such as relocation, which subsequently affects their mental health. After disasters, mental health issues arise from various causes such as pre-existing mental health conditions, disaster-induced stress reactions, and complications with humanitarian aid [2, 3]. These issues include but are not limited to post-traumatic stress disorder (PTSD), depression (major depressive disorder), substance use disorder, and psychological symptoms, such as generalized anxiety disorder, sleep disruption, and prolonged grief disorder, and are prevalent among disaster-affected people [2, 3]. In literature on post-disaster mental health, disasters are categorized into natural disasters (e.g., earthquakes, floods, hurricanes) and man-made disasters (e.g., technological disasters, terrorism, wars, and mass violence) [1, 2, 4, 5]. This study focuses on the impact of natural disasters on mental health. Natural disasters, such as earthquakes, cause long-lasting impairments in the mental health of disaster-affected people, regardless of age [2, 4, 6-9]. Changes in the living environment caused by natural disasters were found to be associated with the

onset of depression and PTSD, though the prevalence of PTSD tends to be lower than in cases of man-made disasters [2, 10, 11].

In the short-term period following a disaster, while disaster-affected people equally experience distress, the recovery process varies among different individuals in the long term [2-4, 12, 13]. Regardless of the speed of recovery or the timing of the onset of mental health issues, disaster survivors generally experience the same course of changes in psychological states immediately following a disaster. Raphael [14] modeled the process of psychological response following natural disasters with regard to different time phases [15]. Right after a disaster, affected people may feel fear or agitation (i.e., "warning" to "impact" phases) then become increasingly altruistic and cooperative with others (i.e., "honeymoon" phase). After that, in the long-term, they may feel anger, grief, and helplessness (i.e., "disillusionment" phase) [14]. The "warning" and "impact" phases start immediately after the disaster occurs and last for a few days; the "honeymoon" phase lasts for a few months; and the final "disillusionment" phase may last for a few years [16].

In terms of the Disaster Management Cycle [17], the "warning" to "impact," "honeymoon," and "disillusionment" phases approximately correspond to the "hyperacute phase" (within 72 hours) to "acute phase" (within seven days) , "subacute phase" (within one month), and "chronic phase" (within three years) or "silent phase" (three years after

disasters), respectively [16, 18-20]. It is important to distinguish short-term (collectively called the "acute phase," which includes the "hyperacute phase" to "subacute phase") and long-term (collectively called the "medium- to long-term phase," which includes the "chronic phase" to "silent phase") [16, 18-20]. As for psychological responses after natural disasters, short-term agitation may subside then turn into depression in the long term. While most disaster-affected people recover from mental health issues within one year, some continue to struggle with their mental health for several years after the disaster [2, 4, 6, 21]. Thus, most disaster survivors are resilient or able to return to pre-disaster conditions naturally even without interventions by specialists, but those who continue to have difficulties need specialized psychiatric or psychological services [2-4, 12, 13]. This phenomenon is referred to as "scissors-like differences" [16], which points out polarization in psychological recovery, and studies on the trajectories of mental health support a similar trend [2, 21-23]. As for mental health issues after natural disasters such as earthquakes, PTSD and depression were widely studied [9, 24]. However, guidelines [3] recommend not to excessively focus on PTSD while neglecting other serious mental health issues. For example, depression tended to prevail longer than PTSD among those affected by the Great East Japan Earthquake of 2011 [9]. This may be because the onset of PTSD may be brought on by damage immediately after a disaster ("acute stressors"), while the onset of depression is more likely to be affected by changes in living environments which occur after

the disaster ("secondary stressors" or "chronic stressors") [2, 4, 6, 10]. Therefore, important measures to prevent the onset and prolongation of mental health issues after disasters involves not only dealing with acute stressors but also diminishing secondary stressors.

1.2. Impact of Natural Disasters on Older Adults' Mental Health

As mentioned above, natural disasters pose acute and secondary stressors on all affected people, but experiencing a natural disaster may be more harmful for vulnerable populations. Regardless of the vulnerability of disaster-affected areas according to place or building environment, identifying socially vulnerable people is important in order to provide them with intensive care following a disaster [25]. Although the definition of socially vulnerable populations varies depending on the literature or guidelines [3, 12, 13, 25-28], older adults are generally included in this definition. In US literature, socially vulnerable populations include older adults, children, women, disabled people, those with health problems, lower socioeconomic status groups, immigrants, homeless people, and racial, ethnic, or sexual minorities [25]. Similarly, in Japan, the existence of socially vulnerable populations during natural disasters has been recognized since the 1980s, and older adults, disabled people, foreigners, and pregnant women are among those listed as examples of vulnerable populations in need of assistance [26].

Compared to younger people, older adults are considered more susceptible to stressors after natural disasters. Literature mentions the following reasons for this: first, older adults tend to have functional limitations and sensory or cognitive impairments, which prevent them from seeking self-protecting measures; second, they are likely to have chronic diseases such as cardiovascular, respiratory, or renal diseases or diabetes, which need regular medication, and delays in prescription brought on by disasters leads to worsening health conditions; third, seeking help becomes difficult if they are socially isolated or economically disadvantaged [25, 29, 30] . In terms of mental health issues, a meta-analysis showed that for older adults, the odds ratio of PTSD was 2.11 and that of adjustment disorders was 1.73 compared with younger adults [24]. In addition, evidence indicates that disrupted access to psychiatric medical care services was associated with an increased risk of depression in older adults after the Great East Japan Earthquake of 2011 [31].

1.3. Natural Disaster-Related Stressors and Mental Health

1.3.1. Acute Stressors: Natural Disaster Damage and Mental Health

Immediately after natural disasters, people in the affected areas are exposed to several acute stressors. For example, many people may simultaneously experience threats to their lives, physical damage, witnessing the deaths of others, loss of family or friends, loss of

properties, and instability in communities [4]. In large-scale disasters, the number of affected people is multiplied, and the social impact of the disaster could be so severe that it would take time for recovery. Acute stressors following disasters may possibly affect the mental health of disaster survivors because they often experience several sudden and unanticipated changes over a short period of time. Indeed, most acute stressors are regarded as stressful life events in literature; for example, death of a spouse or family and injuries or illnesses are ranked as highly stressful among other life events [32]. Therefore, during the acute phases of disasters, affected people are at risk of acute stress reactions (ASRs) and/or acute stress disorders (ASD) [33]. Although some who experience ASRs or ASDs may recover and these symptoms are not necessarily related to the onset of PTSD, others may develop PTSD after acute phases [11, 33].

Findings regarding the association between acute stressors and mental health vary among prior studies. For example, one study on the general population in Thailand affected by the 2004 Indian Ocean earthquake and tsunami found that the loss of family members and livelihood by tsunami were associated with the development of PTSD and depression two months after the disaster [34]. On the other hand, one study on disaster-affected older adults showed that property damage was associated with enhanced depressive symptoms, but the death of family or friends had no clear associations with mental health issues two and a half

years after the Great East Japan Earthquake of 2011 [31]. The results indicate that the types of acute stressors that are associated with mental health issues may vary depending on age, while property damage may negatively impact mental health among disaster-affected people.

1.3.2. Acute/Secondary Stressors: Natural Disaster-related Relocation and Mental Health

Natural disaster-related relocation and changes in both physical and psychosocial environments (or socio-physical environment) accompanied by relocation may both affect the mental health of displaced disaster survivors [35-37]. The impact of relocation may begin immediately after the disasters and may even continue in the long-term depending on the level of change in the socio-physical environment. In general, relocation is regarded as a stressful life event [32]. However, during the silent phase, both positive and negative associations between relocation and mental health were observed for older adults [38]. These results may be attributed to the difference between voluntary and involuntary relocation and changes in social relationships due to relocation. For example, voluntary relocation and the maintenance of social relationships before and after relocation can lead to positive mental health outcomes in older adults [39, 40]. On the other hand, involuntary relocation accompanying forced displacement could have a negative impact on mental health. Most disaster-related relocation

is considered to be involuntary relocation (e.g., due to the collapse of a house) with possible negative impacts on mental health.

Prior studies have reported the impact of disaster-related relocation on health issues such as depression [41-47] and PTSD [46, 48]. Among older adults, the increased risks of depression [41, 42, 45, 46] and PTSD [46] brought on by disaster-related relocation have been reported. In addition, several studies reported that due to changes in socio-physical environments attributable to relocation [35, 36], the social relationships of displaced people after disasters were also disrupted. For example, disaster-related relocation was associated with a decline in social contact with friends or neighbors and a decline in the perceived number of available social support in general disaster survivors after the 1999 earthquake in Turkey [47]. Further investigation of the effects of changes in social relationships triggered by disaster relocation on mental health is necessary.

Moreover, some post-earthquake studies in Japan indicated that the impacts of disaster-related relocation on mental health may differ according to relocation type (individual vs. group relocation) or the type of housing. At the time of the Great Hanshin-Awaji Earthquake of 1995 and the Great East Japan Earthquake of 2011, the social isolation of individually relocated evacuees became a social issue [49, 50]. Among the older adults affected by the latter earthquake, those who experienced individual relocation reported a

decline in “social cohesion” [50]. In addition, higher risks of depression were prevalent among those who relocated to government-provided prefabricated temporary housing (hereinafter, referred to as “temporary housing”) than other types, such as private housing after the Great East Japan Earthquake of 2011 [41, 51]. In contrast, at the time of the Great East Japan Earthquake of 2011, some of the disaster-affected people experienced the government community-based group relocation program to the temporary housing complex that included others who came from the same pre-disaster community. In the case of group relocation, older adults frequently participated in social groups and had an abundance of social contact with friends [50]. In addition, general disaster survivors who experienced group relocation to temporary housing tended to receive more social support than those who relocated individually [52].

1.3.3. Secondary Stressors: Changes in Social Relationships after Natural Disasters and Mental Health

Natural disasters are also known to disrupt social relationships, which may affect the mental health of all disaster-affected people, regardless of relocation status [4, 6, 37]. In general, social relationships (or social connection) can be classified according to “structural,” “functional,” “quality,” or “resource” aspects (e.g., social capital) [53-55] . Structural aspects

include “social networks” and functional aspects include “social supports” [53-55]. Social network is defined as “the web of social relationships that surround an individual and the characteristics of those ties” [56(p145)] . Social support is defined as “aid and assistance exchanged through social relationships and interpersonal transactions” [57(p191)]. In general contexts (not necessarily limited to disasters), literature has reported that social relationships have an impact on mental health, along with physical health and health-related behaviors [58-65].

I highlight three viewpoints with regard to macro-level changes in society, social relationships, and mental health, based on important theories derived from literature on public health. First, changes in society could reshape individual social relationships and thus affect individual mental health. Berkman et al. [56, 58] describe that macro-level “social change” shapes or activates social networks through frequent organizational participation or other factors. House et al. [64] also mentioned the possibility that macro-level changes in society would alter social relationships. Natural disasters would be no exception to social change, resulting in the restructuring of existing social relationships among individuals and affecting their mental health.

Second, in terms of social relationships, the frequency of social interactions (or states of group participation) could affect the formation of social ties/networks and exchanges of social support afterwards. House et al. [62-64] depict models of the structural and functional

aspects of social relationships and health. These models imply that the existence of social ties or frequency of social interactions (i.e., social integration or social isolation) affect the structures of social networks and the functions of social relationships, such as social support. Similarly, Lin et al. [65] explain that within the domain of structural aspects of social relationships (i.e., "support structure"), group participation (i.e., "community participation") affects social network (i.e., "network relations"), which leads to the formation of social ties (i.e., "intimate ties") . Next, social supports (i.e. "support function") are provided through that "support structure" [65]. Berkman et al. [56, 58] also describe that social networks (i.e., structural aspects of social relationships) influence functional aspects of social relationships, such as social support. Therefore, frequent interactions with others or group participation could be regarded as the foundation of social ties or network formation, followed by exchanges of social support. Natural disasters may block social interactions or group participation and deter the overall process.

Third, structural or functional aspects of social relationships affect mental health, as stated by Berkman et al. [56, 58], but each aspect is considered to influence mental health through different mechanisms. The main effect model and stress-buffering model are two commonly suggested explanatory models using different mechanisms [61-64]. House et al. [62-64] and other literature reviews provide the following differences: structural measures such as social ties or

social integration were mostly directly associated with health (i.e., main effects), but functional measures such as perceived availability of social support buffered the effects of stress on mental health [66, 67]. The implications are that structural aspects could independently affect mental health regardless of the existence of stressors, but functional aspects alleviate the negative impact of stressors on mental health in the presence of stressors, such as natural disasters.

In the context of natural disasters, prior studies reported that regardless of whether disaster-affected people were relocated or not, changes in social relationships had an impact on their mental health. With regard to changes in structural aspects, gaining neighborhood ties after a disaster reduced the risk of depression in older adults after the Great East Japan Earthquake of 2011 [68], while a decrease in social contacts with neighbors or social isolation was associated with psychological distress in general disaster survivors after the 2004 Niigata–Chuetsu earthquake in Japan and the Great East Japan Earthquake of 2011 [43, 69]. In addition, group participation mitigated the psychological distress of general disaster-affected people who relocated to temporary housing [51, 70]. Participating in group exercise improved the severity of depression in older adults after the Great East Japan Earthquake of 2011 [71]. With regard to functional aspects, perceived availability of emotional social support on an individual and community level improved the severity of depression among the general

disaster-affected population relocated to temporary housing after the Great East Japan Earthquake of 2011 [70]. As for other aspects, pre-disaster individual and community level "social cohesion," one of the quality aspects, was associated with a lower risk of PTSD among older adults after the Great East Japan Earthquake of 2011 [72], and a decline in "social cohesion" on the individual level was weakly associated with a higher risk of major depressive episodes (MDE) among male older adults after the 2016 Kumamoto earthquake [73].

1.4. Changes in Social Relationships after Natural Disasters: Unproven Potential Mediators between Natural Disaster-Related Relocation and Mental Health

There may be mediating factors that can mitigate the negative impacts of natural disaster-related relocation on mental health of disaster-affected people, specifically older adults; however, no study to date has found any mediators. To reduce the burden of acute and/or secondary stressors resulting from natural disasters and disaster-related relocation, focusing on the social relationships of disaster-affected people as a target of intervention seems adequate, as stated in literature [4, 6, 37]. However, only a few studies have simultaneously investigated associations among disaster-related relocation, changes in social relationships, and mental health [45, 51, 70, 74, 75]. For example, literature shows that among general disaster survivors who relocated to temporary housing, group participation was seen as protective

against psychological distress after the Great East Japan Earthquake of 2011, although a mechanism was not derived from causal mediation analysis [51, 70]. Since group participation is the foundation of social ties/network formation, opportunities for group participation could be more significant for those who relocated after disasters than those who did not relocate in order to restore their social relationships which were disrupted by disaster-related relocation [37, 75]. In addition, the degree of change in the group participation of older adults could differ according to the type of relocation [50]. Specifically, focusing on the difference between relocation to temporary housing and other types of housing could be important as government policies for temporary housing has changed since the Great East Japan Earthquake of 2011. For example, at the time of the 2016 Kumamoto earthquake, prefectural-level efforts were put into establishing building standards for temporary housing (called "Kumamoto Type Default") [76] to maintain a comfortable socio-physical environment. Furthermore, temporary housing was designed carefully to encourage residents to meet, through the establishment of public gathering places following the concept of "Minna No Ie" (meaning "Home for All"), which was a project undertaken at the time of the Great East Japan Earthquake of 2011 [77]. Based on personal communications with the local government and public health staff members of Mifune Town (belonging to the Kumamoto Prefecture and among the affected areas of the 2016 Kumamoto earthquake), the town adopted the group relocation policy for

temporary housing and opened public gathering places in accessible distances to prevent social isolation among the relocated people. These administrative efforts at the time of the 2016 Kumamoto earthquake may be reflected in the group participation status of residents in temporary housing. As group participation may spring from potential ties with relatives and acquaintances [56, 58], the group relocation policy of bringing together people from the same pre-disaster community may have maintained pre-disaster social relationships or group participation status. Alternatively, residents of temporary housing may begin engaging in group participation at public gathering places with new neighbors [78]. Therefore, it is reasonable to consider the group participation of those who relocated to temporary housing as distinct from those who relocated to other types of housing, as a result of these efforts. It is worthwhile to evaluate the difference between relocation types (in terms of its importance in relation to changes in group participation after disaster-related relocation) as mediators for the negative impact of relocation on the mental health of older adults, as group participation that could be fostered by administrative efforts may be an appropriate target for intervention.

2. OBJECTIVES

Integrating the ideas of the existing conceptual frameworks of social relationships and health mentioned in Section 1.1.3, as well as the related empirical evidence introduced above, the potential associations among disaster-related relocation, changes in social relationships (group participation), and mental health of disaster-affected people are summarized in Figure 1. While disaster-related relocation could directly affect mental health as suggested by previous studies [41-48] (the "direct effects," the path [2] in Figure 1) [62-64] , I have hypothesized that the effects of disaster-related relocation follow an indirect pathway to mental health which is mediated by changes in group participation or "community participation" as proposed by Lin et al. [65] (the first half of the path [1] in Figure 1) . Changes in group participation may alter social networks and social ties (within the box of <structure> in Figure 1)[56, 58, 61-65]. After relocation, people may change their social relationships with the people they know, including their relatives and acquaintances [56, 58] and may also create new unanticipated relationships with their new neighbors [78]. Although the association between group participation and mental health has been evaluated in some studies in the disaster context [51, 70, 71], the overall pathway of indirect effects [1] in Figure 1 from disaster-related relocation to mental health as mediated by changes in group participation has not been investigated. As stated earlier, specifically at the time of the 2016 Kumamoto earthquake,

administrative efforts for temporary housing such as the group relocation policy and the establishment of public gathering places may have influenced the group participation status of those who relocated to temporary housing. Thus, it is important to examine changes in group participation as mediators between disaster-related relocation and mental health according to types of housing; if the existence of mediation effects is elucidated, group participation may be an intervention target to protect the mental health of disaster-affected people. Therefore, the purpose of this study was to apply causal mediation analysis to longitudinal data to examine whether changes in group participation causally mediated the relationship between disaster-related relocation and mental health, by comparing types of housing. In this study, due to the administrative efforts on temporary housing at the time of the 2016 Kumamoto earthquake, the types of housing (temporary vs. other types of housing) reflected patterns of relocation (group vs. individual relocation) and the socio-physical environment of residences. In conducting the causal mediation analyses, I hypothesized that disaster-related relocation may increase the risks of mental health issues of older adults as a direct effect, [41, 42, 45, 46] and changes in group participation may act as a stressor for older adults (who generally have difficulties adjusting to new environments [39, 40]) and the mediator for the negative impact of the relocation, which may increase the risks of mental health issues as an indirect effect. However, I also hypothesized that the importance of the mediator is smaller in the case of

relocation to temporary housing than relocation to other types of housing. In temporary housing, most of the changes in group participation may be a result of started group participation [50] fostered by the administrative efforts such as group relocation policies and public gathering places, but in other types of housing, most of the changes may be due to ceased group participation. While there is another path from social networks or ties to social support that buffers the detrimental effects of disaster-related stressors on mental health (Stress-Buffering Model) [2, 4, 56, 58, 61-65, 79, 80] in Figure 1, I did not explicitly investigate this path as other empirical studies have already suggested the existence of the path, [70, 81] and social support may not be the mediator as implied by other studies [74, 82].

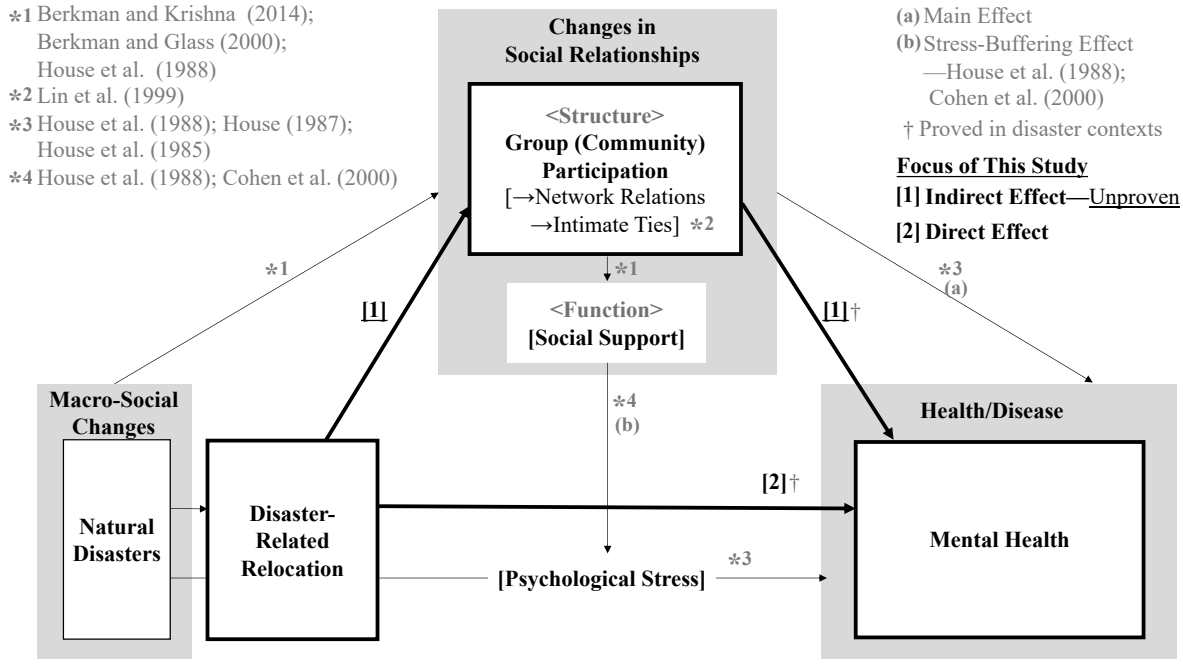

Figure 1: Hypothetical social relationships and health model of this study.

3. METHODS

3.1. Study Design, Settings and Participants

For this study, I and co-authors utilized longitudinal data extracted from a prospective cohort study called the Japan Gerontological Evaluation Study (JAGES) [83, 84]. The study site was the Mifune Town of Kumamoto Prefecture in Japan (Figure 2). The population of Mifune Town was 17,237 people from 6,317 households, and the population aging rate was 31.6% (5,440 were aged ≥ 65 years) in the 2015 census year [85]. The town was affected by the 2016 Kumamoto earthquake. Kumamoto and nearby prefectures were hit by earthquakes and consecutive aftershocks in April 2016, and two major earthquakes of magnitude (Mw) 6.2 and 7.2 occurred on April 14 and 16, respectively [86]. As a consequence of the Kumamoto earthquake in Mifune Town, seven people lost their lives, 4,640 houses were damaged, and 6,191 people were evacuated [87]. Moreover, a flood occurred coincidentally on June 20, 2016, and 66 houses were damaged or inundated [88].

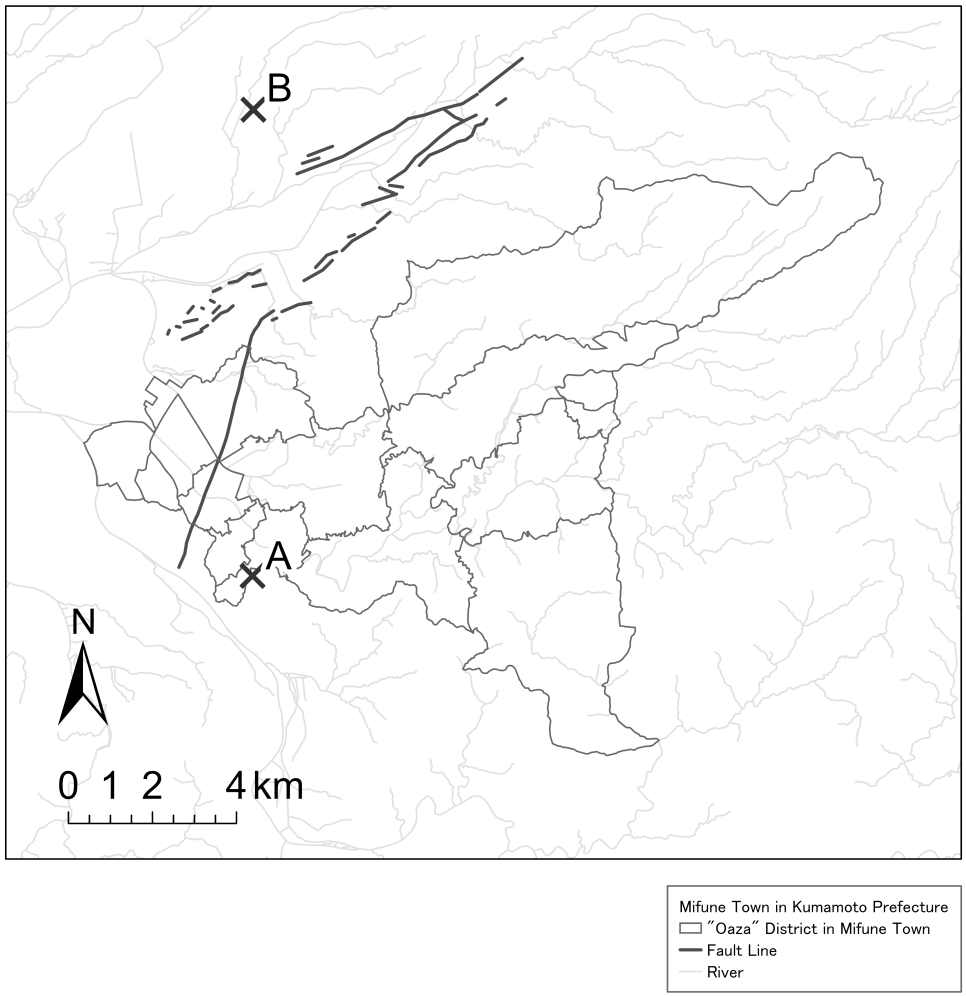

Figure 2: Map of Mifune Town, Kumamoto Prefecture in Japan, 2013–2016. Point A is the epicenter of the Kumamoto Earthquake on April 14, 2016. Point B is the epicenter of the Kumamoto Earthquake on April 16, 2016 [89].

We used a pre/post-disaster dataset of Mifune Town using the mail-based questionnaire survey of the JAGES datasets of 2013 (30 months before the Kumamoto earthquake) and 2016 (seven months after the earthquake or early "chronic phase" in the Disaster Management Cycle) [16, 18-20]. We also connected geographical and demographic information (area slope and population density calculated by district levels) [90] to the dataset.

We leveraged the pre/post-disaster dataset as the 2016 Kumamoto earthquake and the 2016 flood hit between the two waves of the JAGES surveys conducted every three years. Mifune Town had not experienced major earthquakes for nearly 80 years until the foreshock of the 2016 Kumamoto earthquake [91], and the earthquake was presumed to be an unpredictable event for most of the residents. Therefore, we treated these events as exogenous shocks, and the pre/post-disaster dataset allowed us to estimate the effects with minimum recall bias.

The study population of the JAGES was functionally independent adults (aged ≥ 65 years). Mifune Town distributed questionnaires to half of the randomly sampled population during baseline, 2013 (n = 2,000), and to the whole study population in 2016 (n = 4,821). The response rate was 71.9% (n = 1,432) in 2013 and 64.4% (n = 3,104) in 2016. In this study, we limited the data to those who lived in Mifune Town, both in 2013 and 2016, and responded to both waves. Respondents who had invalid gender and/or age responses, were lost to follow-up, or had no baseline response were excluded, and the final respondents included in the analyses were determined (n = 828) (Figure 3).

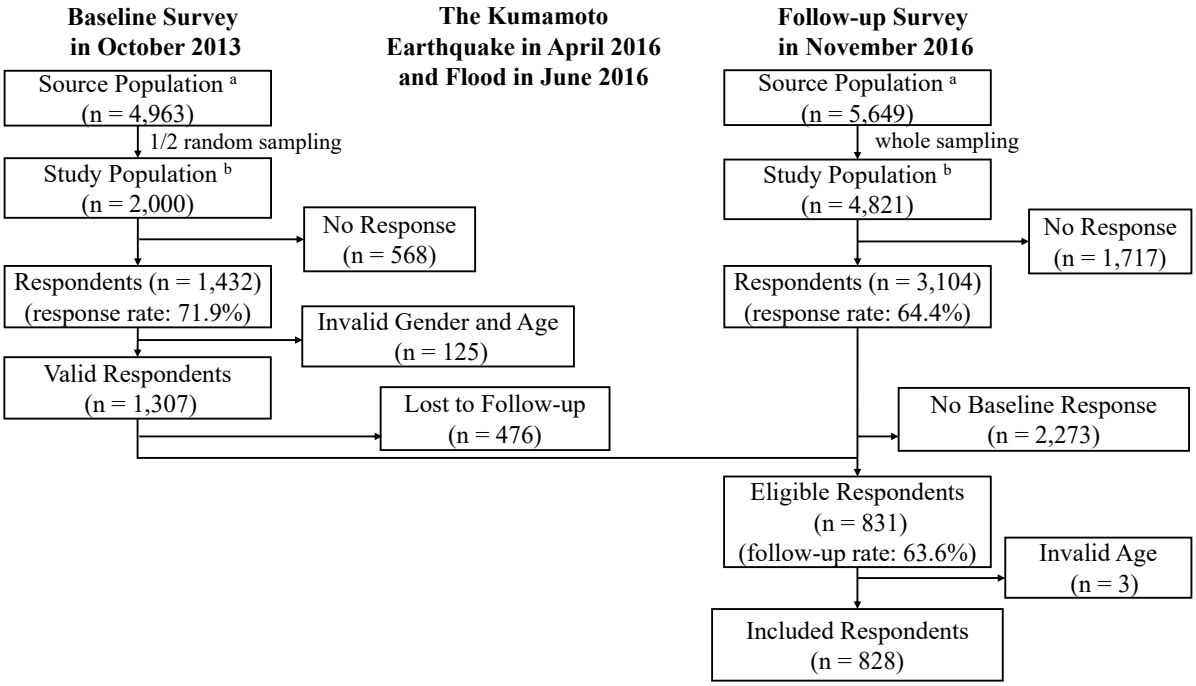

Figure 3: Flowchart of the selection of the respondents included in the analyses (n = 828), Mifune, Japan, 2013–2016. The source population [a] contains older adults (≥ 65 years old) from Mifune during each survey year. The study population [b] contains older adults (≥ 65 years old) of the source population, without certification of long-term care needs, from Mifune in each survey year.

3.2. Outcomes

We tested two mental health issues: major depressive episodes (MDE) and PTSD symptoms. These were measured using the Screening Questionnaire for Disaster Mental Health (SQD) [92, 93], which was also used in another study of the Kumamoto earthquake [73]. The SQD was developed [93] based on the Post-Traumatic Symptom Scale [94] and the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV) [95]. The SQD consisted of nine items on PTSD (SQD-P) and six items on MDE (SQD-D), which were

validated [93] against the Clinician Administered PTSD Scale [96] and the Structured Clinical Interview for DSM-III-R Major Depression Section [97], respectively. The receiver operating characteristic curves and its standard error (SE) for the SQD-P and SQD-D were 0.91 (SE = 0.04) and 0.94 (SE = 0.03) [93]. We followed the cut-offs from guideline [92] , and adopted the cut-off for PTSD symptoms as five or more SQD scores, which included at least one symptom of intrusion, and for MDE as four or more scores, either with depressed mood or diminished interest. All the outcomes were binary variables. In addition, depressive symptoms were measured using the 15-item Geriatric Depression Scale (GDS-15) [98] with a cut-off score of five (GDS ≥ 5)[31, 41, 99, 100].

3.3. Exposures

The exposure was a categorical variable of the three states that indicated relocation to temporary housing, relocation to other types of housing, and no relocation after the 2016 Kumamoto earthquake or floods in 2016. Temporary housing built after the earthquake opened for disaster-affected people from June 5, 2016 [101]. Other types of housing included public rental housing, private rental housing, privately owned houses, or others stated by respondents. Based on personal communication with the town government and public health staff members at Mifune, Mifune Town adopted a group relocation policy for those who

relocated to temporary housing and set up public gathering places for temporary housing complexes. The total number of the temporary housing complexes in Mifune Town was 21, consisting of 425 units. Therefore, we concluded that the majority of the relocation to temporary housing was group relocation, and relocation to the other types of housing was individual relocation, including voluntary movement to the places found by disaster survivors themselves.

3.4. Potential Mediators

In this study, to use the measurement of change in group participation as a mediator, we defined group participation as belongingness to any social group. Specifically, we defined it as whether or not a person participated in any one of the following social groups at least a few times a year: volunteer groups, sports groups or clubs, hobby activity groups, senior citizen clubs, community associations, study or cultural groups, nursing care prevention activities, or activities that taught skills or passed experiences to others [102]. If one belonged to any social group before and no longer participated after the Kumamoto earthquake, their state of group participation was considered “ceased.” Inversely, if one belonged to no group before and joined any group after the earthquake, their state of group participation was considered “started.” If one kept the same group participation before and after the earthquake, their state

remained “sustained.” Thus, we focused on changes in group participation in terms of the change from the presence to the absence of any social group to which each participant belongs and vice versa. This was because changes regarding the presence or absence of group participation could be directly linked to gaining or losing opportunities for forming social networks or social ties. This in turn could be critical for relocated people who may have experienced a disruption of social relationships after disaster-related relocation and have a need to restore their social networks [37, 75].

3.5. Covariates

We included the covariates of the baseline personal or regional characteristics from 2013. Baseline personal characteristics included gender [73], age [69, 103], equivalent household income (< 200 million yen (low income): under the mean of older adults’ households in 2013 [104]), years of education (≤ 9 years of compulsory education indicated low education) [47, 103], lived alone or not, had an illness or not [103, 105], had a job or not [69], had group participation or not, and had depressive symptoms based on cut-offs of GDS scores as not depressed (0-4), moderately depressed (5-9), and depressed (10-15) [100]. Baseline regional characteristics included standardized population density (originally, person/km^2) [90] and standardized area slope (originally, %) [90]. Original data of the population density and area slope were measured

at the district level (called “Oaza”) of the town. We displayed these regional characteristics on maps at “Oaza” level, using ArcGIS Pro 2.8 (Esri, Redlands, CA, USA; Figure 4, Figure 5). As shown in the maps, the western part of the town was flatter with a higher population density, and the eastern part was more mountainous with a lower population density. We also adjusted for disaster damage obtained from the follow-up survey in 2016, such as housing damage based on the administrative criteria (“totally-collapsed” vs. “almost-collapsed” vs. “half-collapsed” vs. “minor damage” vs. “no damage”) and farmland damage based on self-report (“severely-damaged” vs. “partially-damaged” vs. “no damage or no farmland”).

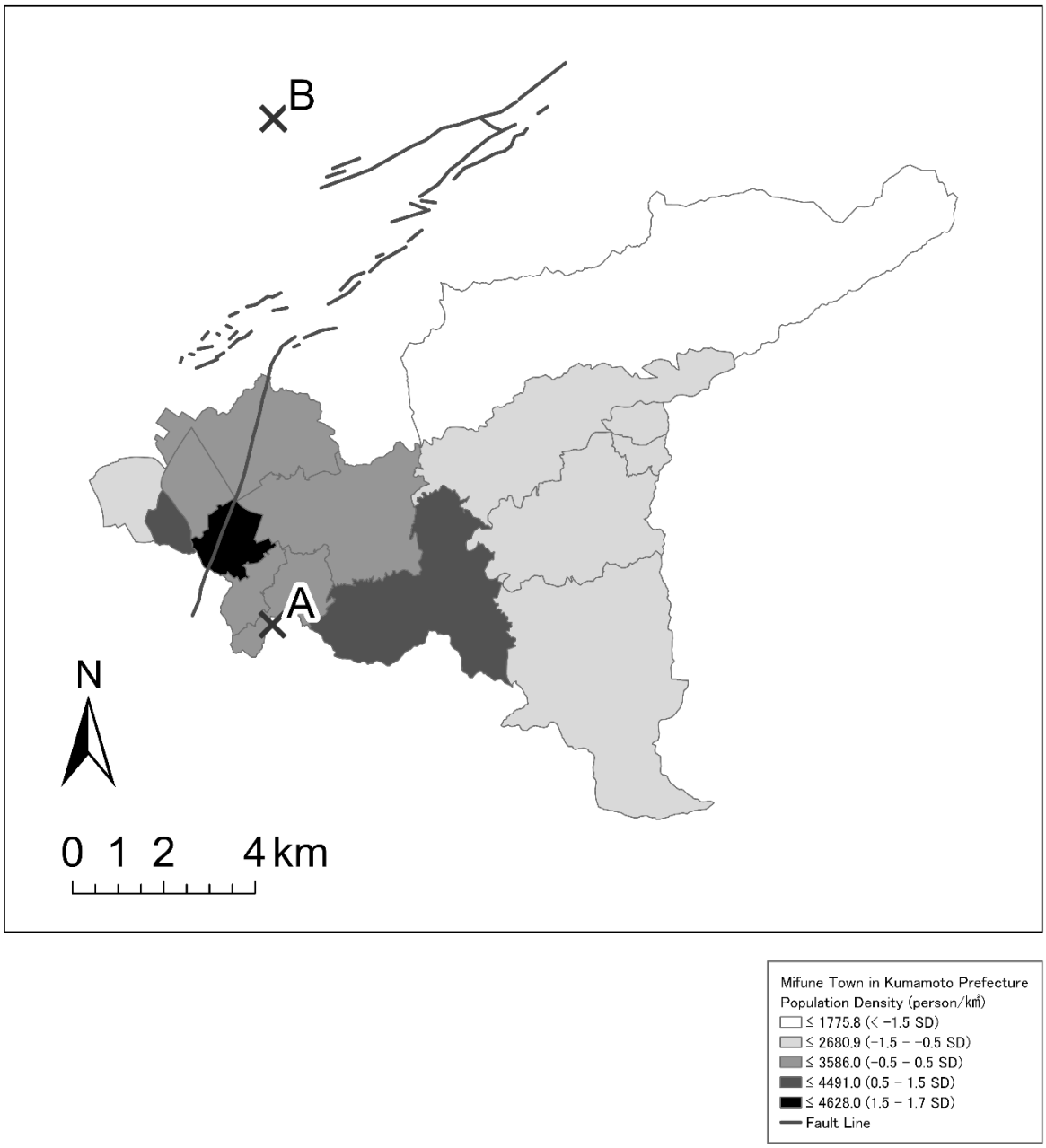

Figure 4: Population Density of Mifune Town, Kumamoto Prefecture in Japan, 2013–2016. Point A is the epicenter of the Kumamoto Earthquake on April 14, 2016. Point B is the epicenter of the Kumamoto Earthquake on April 16, 2016 [89]. SD is standard deviation.

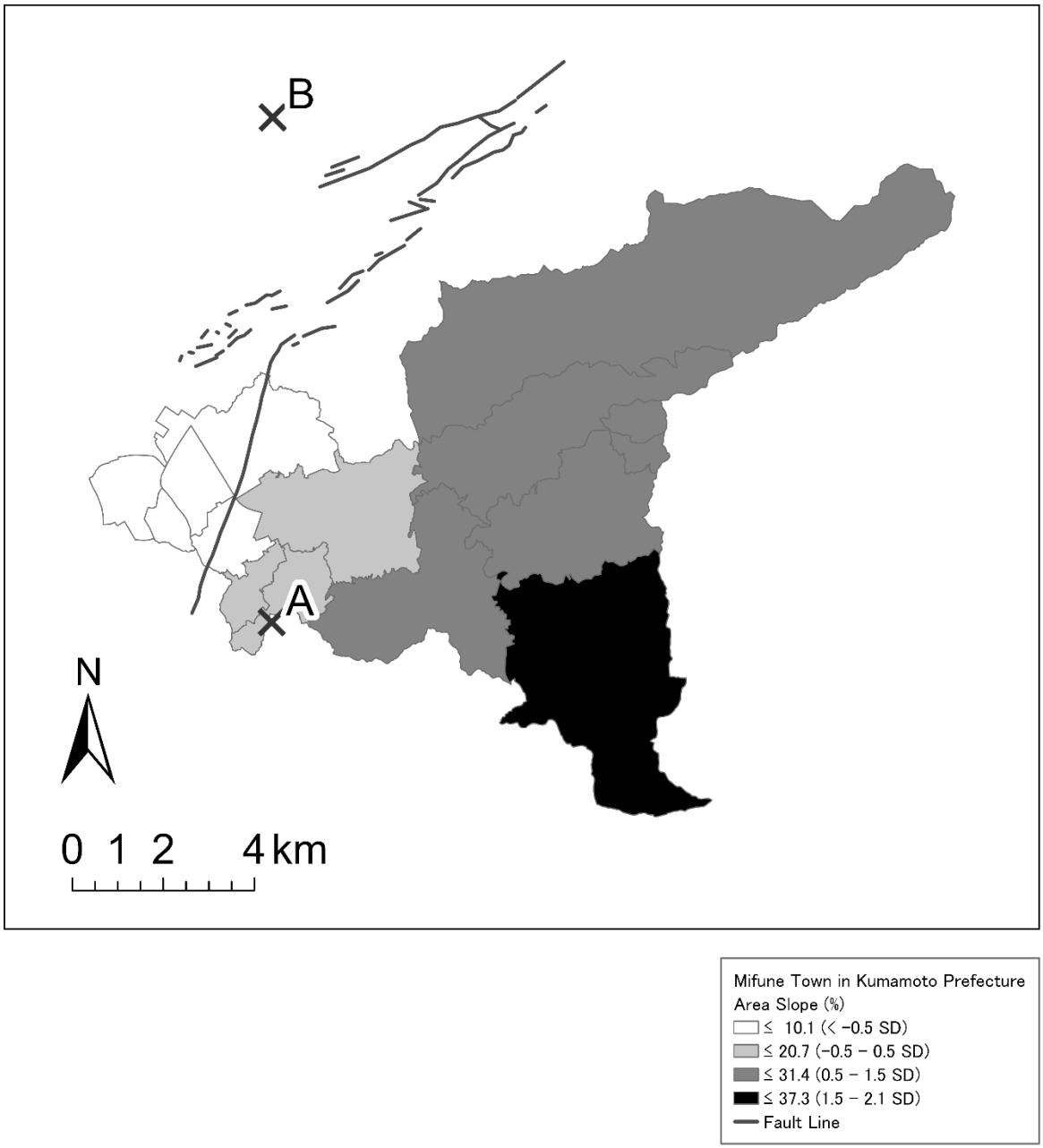

Figure 5: Area Slope of Mifune Town, Kumamoto Prefecture in Japan, 2013–2016. Point A is the epicenter of the Kumamoto Earthquake on April 14, 2016. Point B is the epicenter of the Kumamoto Earthquake on April 16, 2016 [89]. SD is standard deviation.

3.6. Statistical Methods

The hypothetical causal model for this study is summarized in Figure 6. We assumed that in this causal model, baseline covariates, exposure, potential mediators, and outcomes would be consistent with the chronological order and that there was no exposure-induced mediator-outcome confounder [106]. It should be noted that exposure, potential mediators, and outcomes were measured during the same wave (second). However, the relocation started at least five months before the second wave, around the time when temporary housing opened. Additionally, we assumed that changes in group participation occurred immediately after disaster-related relocation, as the result of the disruption of community structures induced by the displacement of people [37, 50]. As the onset of mental health issues does not necessarily follow disasters immediately, and with reviews suggesting that psychological symptoms after disasters peak in the first year [4, 8], we assumed that people may experience mental health issues after exposure to multiple stressors induced by disasters. Therefore, we hypothesized that in disaster-related relocation, changes in group participation and mental health issues occurred in chronological order. The distribution of the exposure and occurrence of disaster-related relocation were nearly randomized since the earthquake and the flood hit the area indiscriminately.

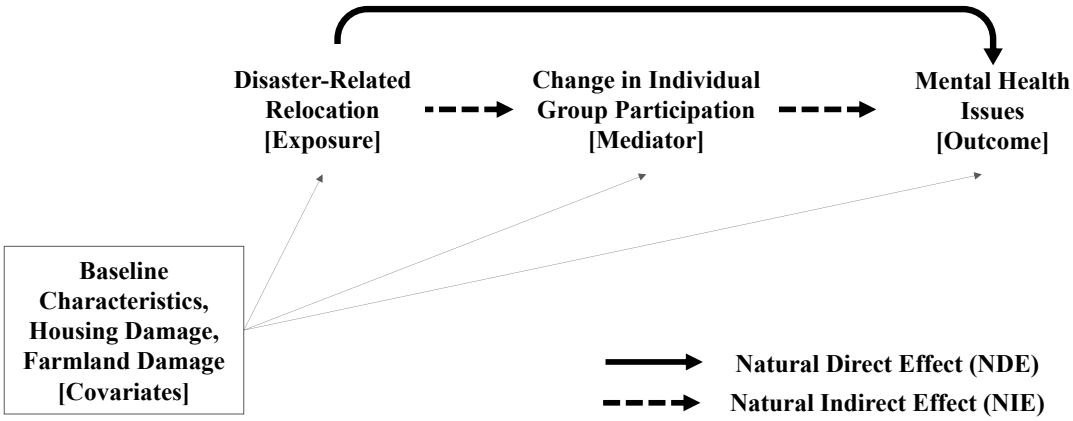

Figure 6: Hypothetical paths tested and the variables modelled in this study for the respondents included in the analyses (n = 828), Mifune, Japan, 2013–2016.

We conducted a first-leg analysis to compare the pre/post-disaster differences of group participation by relocation type (relocation to temporary housing vs. other types of housing; group relocation vs. individual relocation) to confirm whether a similar trend was observed, as in a previous study [50]. Specifically, we conducted a multinomial logistic regression for "ceased" or "started" group participation on relocation type and Poisson regression for "renewed" (either "ceased" or "started") group participation on relocation type. We included the relocation type because the socio-physical environments after relocation could vary. In particular, relocation to temporary housing reflected Mifune Town's policies, such as group relocation and the setting of public gathering places. Accordingly, the

associations between changes in group participation and relocation may vary according to the relocation type.

We conducted causal mediation analyses based on the inverse odds ratio-weighted (IORW) method [107, 108]. The IORW method has been applied in the examination of relocation and mediation effects of the Moving to Opportunity projects on adolescents' health in the US, [107, 109-111] and several flexibilities of the model or variable selection suitable for our analyses were allowed. The IORW method has several strengths in the mediation analysis. First, it allowed for a wider flexibility for the selection of regression models, and multiple mediators or any types of variables can be included in models [107, 110, 112]. Second, interactions between exposure and mediators were allowed because they were condensed into weights after controlling for covariates [107, 109]. Third, the model specification was practically more feasible because we only needed an assumption of exposure variable distribution [112]. Thus, we applied this method to confirm the relocation and mediation effects of disaster-related relocation on older adults' mental health. We referred to a practical guideline [107] and adopted the inverse odds weight (IOW) for the analyses. Weights for categorical exposure (each relocation type) were calculated using a multinomial logistic regression [113] to derive weights for 3-type categorical exposure variables, and the weights were applied in the Poisson regression to derive the effect estimates. Overall, we approximated the effect estimates of relative risk (RR)

for Poisson regressions [114] and bootstrapped the effect estimates 1,000 times to derive a bias-corrected 95% confidence interval (CI) [107]. The estimates included the total effect (i.e., an overall change in a counterfactual outcome due to a change in exposure with reference to another level) [106, 115] and the natural direct effect (i.e., a change in a counterfactual outcome due to a change in exposure, if a mediator did not intercept) [115-117] derived from unweighted and weighted Poisson regressions, respectively [107]. Subsequently, we calculated the natural indirect effect (i.e., a change in a counterfactual outcome due to exposure via a change in a mediator) [106, 115-117] estimate by subtracting the coefficient of the natural direct effect estimate from the coefficient of the total effect estimate [107, 108, 115, 118], as the total effect could be the sum of the natural direct effect and the natural indirect effect, even in non-linear models, in the counterfactual-based approach [106, 115]. The steps for the calculation mentioned above are summarized in the Flowchart.

➢ Mediation Analysis by Inverse Odds Weight for 3-Level Exposures

1) We calculated Inverse Odds Weight (IOW) by multinomial logistic regressions of an exposure (A) on a mediator (M) and covariates (C).
2) We estimated the total effect from unweighted Poisson regressions of an outcome (Y) on an exposure (A) and covariates (C).
3) Additionally, we used IOW and estimated the natural direct effect from weighted Poisson regressions of an outcome (Y) on an exposure (A) and covariates (C).
4) Next, for the effect decomposition, we subtracted the coefficient of the natural direct effect estimate from the coefficient of the total effect estimate and derived the coefficient of the natural indirect effect estimate.
(i.e., $\log NIE = \log TE - \log NDE$)
5) Thereafter, we bootstrapped the effect estimates for 1,000 times and derived bias-corrected 95% Confidence Interval for the natural indirect effect, the natural direct effect, and the total effect estimates.

Flowchart: Calculation steps of the mediation analysis by inverse odds weight for 3-level exposures based on the practical guidance of Nguyen et al. [107] (from step 1 to step 5 with some modifications)

In the mediation analyses of this study, we included a binary variable, "renewed" (either "ceased" or "started") group participation, as the mediator, which referred to the "sustained" state. We integrated "ceased" and "started" into one category ("renewed") to avoid ceiling or floor effects of the variables, since those who belonged to no group could not "cease" group participation and those who already belonged to any group could not "start" it. Thus, we tested how changes in group participation mediated the relationship between relocation exposure and mental health issues. Additionally, we set the no-relocation group as a reference and compared the results of relocation to temporary housing and other types of housing.

For sensitivity analyses, we tested models which included one mediator each of "ceased" or "started" group participation separately in mediation analyses to examine directionalities. Moreover, we conducted a mediation analysis for depressive symptoms measured by the GDS, alternatively to MDE.

For all the analyses, based on the assumption of missing at random (MAR), we used datasets where variables included in the regressions were imputed by multiple imputation by chained equation (MICE). We assumed missing at random and utilized 20 imputed datasets by MICE. All analyses were conducted using STATA version 14.2 (StataCorp, College Station, TX, USA).

4. RESULTS

The summary statistics of the respondents included in the analyses by relocation type before imputation are shown in Table 1. For those who relocated to temporary or other types of housing, or those who did not relocate, the proportions of MDE were 34.0% vs. 23.0% vs. 10.2%, respectively. The proportions of PTSD symptoms were 34.0% vs. 36.5% vs. 20.1%, respectively. The proportions of depression measured by GDS were 32.1% vs. 24.3% vs. 15.3% (at the baseline, 22.6% vs. 10.8% vs. 14.8%, in the aggregated proportions of those who were "moderately depressed" and "depressed"), respectively. In terms of change in group

participation, the proportions of those who ceased group participation were 5.7% vs. 10.8% vs. 4.5%, respectively. The proportions of those who started group participation were 5.7% vs. 2.7% vs. 4.4%, and the proportions of those who sustained the former group participation status were 37.7% vs. 39.2% vs. 47.5%, respectively. At the baseline, the proportions of no group participation were 20.8% vs. 18.9% vs. 18.4%. As for the socio-economic differences in baseline personal characteristics, the proportions of those of female gender were 56.6% vs. 67.6% vs. 53.2%, those of age 75 or over were 43.4% vs. 39.2% vs. 36.9%, those with low income were 52.8% vs. 44.6% vs. 50.0%, those with low education were 43.4% vs. 35.1% vs. 39.0%, those living alone were 5.7% vs. 12.2% vs. 10.0%, those with illness were 81.1% vs. 70.3% vs. 79.7%, and those with no job were 64.2% vs. 63.5% vs. 69.1%, respectively. As for baseline regional characteristics, the means of population density (person/km^2) were 3396.1 vs. 3464.4 vs. 3280.6, respectively, and the means of area slope (%) were 12.3 vs. 10.0 vs. 14.3, respectively. As for differences in disaster damage, the proportions of housing damage (aggregation from “minor damages” to “totally-collapsed”) were 94.3% vs. 95.9% vs. 82.0%, and the proportions of farmland damage (aggregation of “partially-damaged” and “severely-damaged”) were 26.4% vs. 18.9% vs. 19.1%, respectively. On the other hand, upon comparing between the participants included in the analyses (n = 828) and non-participants, who were lost to follow-up (n = 476), the prevalence of depression (the aggregated

proportions of those who were “moderately depressed” and “depressed”) at baseline was 14.6% among participants in all waves and that of non-participants of the follow-up survey was 22.9% (Table 2). Thus, depressed people may have been selectively lost to follow-up. In addition, for participants and non-participants, the proportions of no group participation at baseline were 18.4% vs. 23.9%. In terms of socio-economic differences in baseline personal characteristics, the proportions of females were 56.4% vs. 49.2%, those of age 75 or over were 40.9% vs. 59.5%, those with low income were 51.0% vs. 49.4%, those with low education were 40.8% vs. 49.4%, those living alone were 10.6% vs. 14.5%, those with illness were 79.3% vs. 82.4%, and those with no job were 67.3% vs. 67.2%. As for baseline regional characteristics, the means of population density (person/km^2) were 3289.0 vs. 3240.6, and the means of area slope (%) were 14.3 vs. 15.3.

The first-leg analysis showed that relocation to temporary housing and other types of housing were both positively associated with ceased group participation compared to no relocation [for relocation to temporary housing, RR = 2.89, 95% CI: 1.35–6.19; for relocation to other types of housing, RR = 10.32, 95% CI: 3.21–32.22] (Table 3). Similarly, relocation to other types of housing was negatively associated with started group participation [RR = 0.12, 95% CI: 0.00–0.73] (relocation to temporary housing showed the same direction [RR = 0.53, 95% CI: 0.01–1.73]). Renewed (either ceased or started) group participation was positively

associated with relocation to other types of housing [RR = 2.14, 95% CI: 1.43–3.85] (relocation to temporary housing displayed the same direction [RR = 1.37, 95% CI: 0.97–2.08]). It should be noted that the results should be interpreted with caution as status of group participation has a ceiling or a floor, and because no group participation at baseline (one of the adjusted covariates) has high probability of having multicollinearity.

The main results of the mediation analyses showed that for relocation to temporary housing, the RR for the natural indirect effect estimate of relocation via renewed group participation on MDE was 0.60 [95% CI: 0.34–0.94] (Table 4). The RR for the natural direct effect estimate of relocation on MDE was 3.79 [95% CI: 1.70–6.64]. No clear natural indirect effect estimate or natural direct effect estimate was observed for the outcome of PTSD symptoms, although the directionalities of the effect estimates were the same as those of the MDE outcome [for natural indirect effect, RR = 0.70, 95% CI: 0.38–1.16; for natural direct effect, RR = 2.02, 95% CI: 0.90–3.56]. Alternatively, no clear natural indirect effect was observed in relocation to other types of housing [for MDE, RR = 0.97, 95% CI: 0.62–1.95; for PTSD symptoms, RR = 1.05, 95% CI: 0.70–1.57]. Additionally, the natural direct effect estimate of relocation to other types of housing was not clear, while directionalities may indicate increased risks for MDE and PTSD symptoms [for MDE, RR = 1.62, 95% CI: 0.59–3.16; for PTSD symptoms, RR = 1.44, 95% CI: 0.77–2.30].

For the sensitivity analyses, we included the mediators of ceased or started group participation separately for the outcome of MDE (Table 5) and PTSD symptoms (Table 6) to examine the directionalities of each mediator. The results of this separate mediator analysis were not comparable with the result of the mediator of "renewed group participation" due to the differences in references. However, we found that both ceased and started group participation showed a clear natural indirect effect estimate that may attenuate risk of MDE [for the ceased group, RR = 0.59, 95% CI: 0.31–0.93; for the started group, RR = 0.61, 95% CI: 0.39–0.89] and a natural direct effect estimate that may increase risk of MDE in terms of relocation to temporary housing [for the ceased group, RR = 3.88, 95% CI: 1.89–8.09; for the started group, RR = 3.75, 95% CI: 1.61–6.43]. Similarly, no clear natural indirect effect estimate [for the ceased group, RR = 0.98, 95% CI: 0.62–1.89; for the started group, RR = 1.16, 95% CI: 0.73–2.36] or natural direct effect estimate [for the ceased group, RR = 1.60, 95% CI: 0.61–3.04; for the started group, RR = 1.36, 95% CI: 0.45–2.64] was observed in terms of relocation to other types of housing. Both types of relocation showed no clear associations with the outcome of PTSD symptoms.

Moreover, the result of another mediation analysis that used the GDS as an alternative measure of depression (GDS ≥ 5) (Table 7) showed that for relocation to temporary housing, no clear natural indirect effect estimate was observed [RR = 0.80, 95%

CI: 0.49–1.24], but the directionality was the same as the natural indirect effect estimate of the previous mediation analysis for MDE (Table 4). The RR for the natural direct effect estimate was 2.09 [95% CI: 1.15–3.33], which was in the same direction as that of MDE. Likewise, for relocation to other types of housing, no clear natural indirect effect estimate [RR = 0.94, 95% CI: 0.69–1.33] or natural direct effect estimate was observed [RR = 1.80, 95% CI: 0.97–3.28].

Table 1: Summary Statistics of the Participants (n = 828) by 3-types of Relocation Exposure (Before Imputation), Mifune, Japan, 2013–2016

	3-types of relocation exposure (missing: n = 173)															
	no relocation (n = 528)				relocation to temporary housing (n = 53)				relocation to other types of housing (n = 74)				Total [a] (n = 828)			
	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
OUTCOMES																
MDE	54	10.2%			18	34.0%			17	23.0%			108	13.0%		
no MDE	452	85.6%			34	64.2%			56	75.7%			676	81.6%		
(missing)	22	4.2%			1	1.9%			1	1.4%			44	5.3%		
PTSD symptoms	106	20.1%			18	34.0%			27	36.5%			183	22.1%		
no PTSD symptoms	399	75.6%			33	62.3%			45	60.8%			592	71.5%		
(missing)	23	4.4%			2	3.8%			2	2.7%			53	6.4%		
depression (GDS≥5)	81	15.3%			17	32.1%			18	24.3%			148	17.9%		
no depression	355	67.2%			22	41.5%			35	47.3%			503	60.7%		
(missing)	92	17.4%			14	26.4%			21	28.4%			177	21.4%		
POTENTIAL MEDIATORS																
change in group participation:																
renewed (ceased)	24	4.5%			3	5.7%			8	10.8%			43	5.2%		
renewed (started)	23	4.4%			3	5.7%			2	2.7%			36	4.3%		
sustained	251	47.5%			20	37.7%			29	39.2%			348	42.0%		
(missing)	230	43.6%			27	50.9%			35	47.3%			401	48.4%		

	3-types of relocation exposure (missing: n = 173)															
	no relocation (n = 528)				relocation to temporary housing (n = 53)				relocation to other types of housing (n = 74)				Total [a] (n = 828)			
	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
COVARIATES																
baseline personal characteristics (before earthquake)																
gender:																
female	281	53.2%			30	56.6%			50	67.6%			467	56.4%		
male	247	46.8%			23	43.4%			24	32.4%			361	43.6%		
(missing)	0	0.0%			0	0.0%			0	0.0%			0	0.0%		
age:																
65-69	156	29.5%			11	20.8%			20	27.0%			230	27.8%		
70-74	177	33.5%			19	35.8%			25	33.8%			259	31.3%		
75-79	99	18.8%			12	22.6%			15	20.3%			173	20.9%		
80-84	70	13.3%			8	15.1%			8	10.8%			112	13.5%		
85+	26	4.9%			3	5.7%			6	8.1%			54	6.5%		
(missing)	0	0.0%			0	0.0%			0	0.0%			0	0.0%		
low income (< 200 million yen)	264	50.0%			28	52.8%			33	44.6%			422	51.0%		
not low income	161	30.5%			16	30.2%			22	29.7%			224	27.1%		
(missing)	103	19.5%			9	17.0%			19	25.7%			182	22.0%		
low education (< 9 years)	206	39.0%			23	43.4%			26	35.1%			338	40.8%		
not low education	307	58.1%			28	52.8%			47	63.5%			469	56.6%		
(missing)	15	2.8%			2	3.8%			1	1.4%			21	2.5%		
living alone	53	10.0%			3	5.7%			9	12.2%			88	10.6%		
not living alone	428	81.1%			49	92.5%			63	85.1%			676	81.6%		
(missing)	47	8.9%			1	1.9%			2	2.7%			64	7.7%		

	3-types of relocation exposure (missing: n = 173)															
	no relocation (n = 528)				relocation to temporary housing (n = 53)				relocation to other types of housing (n = 74)				Total [a] (n = 828)			
	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
no illness	67	12.7%			7	13.2%			14	18.9%			108	13.0%		
with illness	421	79.7%			43	81.1%			52	70.3%			657	79.3%		
(missing)	40	7.6%			3	5.7%			8	10.8%			63	7.6%		
no job	365	69.1%			34	64.2%			47	63.5%			557	67.3%		
with job	101	19.1%			13	24.5%			17	23.0%			160	19.3%		
(missing)	62	11.7%			6	11.3%			10	13.5%			111	13.4%		
no group participation at baseline	97	18.4%			11	20.8%			14	18.9%			152	18.4%		
with group participation at baseline	309	58.5%			30	56.6%			42	56.8%			463	55.9%		
(missing)	122	23.1%			12	22.6%			18	24.3%			213	25.7%		
depressive symptoms at baseline:																
not depressed	371	70.3%			35	66.0%			54	73.0%			568	68.6%		
moderately depressed	61	11.6%			11	20.8%			6	8.1%			96	11.6%		
depressed	17	3.2%			1	1.9%			2	2.7%			25	3.0%		
(missing)	79	15.0%			6	11.3%			12	16.2%			139	16.8%		
baseline regional characteristics (before earthquake)																
population density (person/km^2) [b]	528		3280.6	862.5	53		3396.1	745.7	74		3464.4	792.6	828		3289.0	847.5
area slope (%) [b]	528		14.3	9.0	53		12.3	9.3	74		10.0	7.0	828		14.3	9.1

	3-types of relocation exposure (missing: n = 173)															
	no relocation (n = 528)				relocation to temporary housing (n = 53)				relocation to other types of housing (n = 74)				Total [a] (n = 828)			
	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD	n	%	Mean	SD
disaster damage (after earthquake)																
housing damage:																
no damage	90	17.0%			3	5.7%			2	2.7%			135	16.3%		
minor damages	233	44.1%			1	1.9%			6	8.1%			296	35.7%		
half-collapsed	171	32.4%			23	43.4%			21	28.4%			238	28.7%		
almost-collapsed	23	4.4%			9	17.0%			15	20.3%			52	6.3%		
totally-collapsed	6	1.1%			17	32.1%			29	39.2%			56	6.8%		
(missing)	5	0.9%			0	0.0%			1	1.4%			51	6.2%		
farmland damage:																
no damage/no farmland	304	57.6%			22	41.5%			36	48.6%			407	49.2%		
partially-damaged	64	12.1%			7	13.2%			6	8.1%			89	10.7%		
severely-damaged	37	7.0%			7	13.2%			8	10.8%			58	7.0%		
(missing)	123	23.3%			17	32.1%			24	32.4%			274	33.1%		

Abbreviations: SD, standard deviation

[a] Total number (N) is not equal to the summation of the left three columns because it includes participants with missing relocation variable (n = 173)

[b] Variables are standardized after multiple imputation to avoid multicollinearity and for ease of interpretation

Table 2: Summary Statistics of Comparison between the Participants included in the analyses (n = 828) and Non-Participants (n = 476) (Before Imputation), Mifune, Japan, 2013–2016

	Participants [a] (n = 828)				Non-Participants [b] (n = 476)			
	n	%	Mean	SD	n	%	Mean	SD
COVARIATES								
baseline personal characteristics (before earthquake)								
gender:								
female	467	56.4%			234	49.2%		
male	361	43.6%			242	50.8%		
(missing)	0	0.0%			0	0.0%		
age:								
65-69	230	27.8%			77	16.2%		
70-74	259	31.3%			116	24.4%		
75-79	173	20.9%			113	23.7%		
80-84	112	13.5%			93	19.5%		
85+	54	6.5%			77	16.2%		
(missing)	0	0.0%			0	0.0%		
low income (< 200 million yen)	422	51.0%			235	49.4%		
not low income	224	27.1%			99	20.8%		
(missing)	182	22.0%			142	29.8%		
low education (< 9 years)	338	40.8%			235	49.4%		
not low education	469	56.6%			220	46.2%		
(missing)	21	2.5%			21	4.4%		
living alone	88	10.6%			69	14.5%		
not living alone	676	81.6%			360	75.6%		
(missing)	64	7.7%			47	9.9%		
no illness	108	13.0%			47	9.9%		
with illness	657	79.3%			392	82.4%		
(missing)	63	7.6%			37	7.8%		
no job	557	67.3%			320	67.2%		
with job	160	19.3%			73	15.3%		
(missing)	111	13.4%			83	17.4%		
no group participation at baseline	152	18.4%			114	23.9%		
with group participation at baseline	463	55.9%			225	47.3%		
(missing)	213	25.7%			137	28.8%		

	Participants [a] (n = 828)				Non-Participants [b] (n = 476)			
	n	%	Mean	SD	n	%	Mean	SD
depressive symptoms at baseline:								
not depressed	568	68.6%			261	54.8%		
moderately depressed	96	11.6%			80	16.8%		
depressed	25	3.0%			29	6.1%		
(missing)	139	16.8%			106	22.3%		
baseline regional characteristics (before earthquake)								
Population density (person/km^2) [c]	828		3289.0	847.5	472		3240.6	881.1
area slope (%) [c]	828		14.3	9.1	472		15.3	8.7

Abbreviations: SD, standard deviation

[a] Participants: those who participated both the baseline survey in 2013 and the follow-up survey in 2016

[b] Non-participants: those who participated only the baseline survey in 2013 and did not participate the follow-up survey in 2016

[c] Variables are standardized after multiple imputations to avoid multicollinearity and for ease of interpretation

Table 3: Relative Risks with 95% Confidence Intervals: Results of First-leg Analysis of Multinomial Logistic Regression or Poisson Regression with Multiple Imputation by Chained Equation for Ceased, Started, or Renewed (Ceased or Started) Group Participation on Types of Relocation (n = 828), Mifune, Japan, 2013–2016

	Ceased group participation			Started group participation			Renewed (ceased or started) group participation		
Exposure (ref. no relocation)	RR [a]	95% CI [c]		RR [a]	95% CI [c]		RR [b]	95% CI [c]	
Relocation to temporary housing	2.89	1.35	6.19	0.53	0.01	1.73	1.37	0.97	2.08
Relocation to other types of housing	10.32	3.21	32.22	0.12	0.00	0.73	2.14	1.43	3.85

Abbreviations: RR, relative risk; CI, Confidence Interval; MICE, multiple imputation by chained equation

[a] Result of multinomial regression: the outcome is ceased or started group participation ("sustained" as a reference)

[b] Result of Poisson regression: the outcome is renewed (ceased or started) group participation ("sustained" as a reference)

[c] Bootstrapped 1,000 times, 95% CI displays bias-corrected Confidence Interval

NOTE:

(i) RRs are adjusted for the baseline covariates of gender, age, equivalent household income (< 200 million yen: low income), years of education (≤ 9 years of compulsory education indicated low education), lived alone or not, had an illness or not, had a job or not, with group participation or not, depressive symptoms, standardized population density (originally, person/km^2) and standardized area slope (originally, %), and disaster damage in 2016 such as housing damage, and farmland damage

(ii) RR measures should be interpreted with caution because status of group participation has a ceiling (those with group participation at baseline cannot start it) or a floor (those without group participation at baseline cannot cease it) and because no group participation at baseline, (one of the adjusted covariates) has high probability of having multicollinearity.

Dataset: Imputed dataset by MICE (m=20), including an exposure, a mediator, and covariates as imputed variables

Table 4: Natural Indirect Effects, Natural Direct Effects, and Total Effects of the Relocation on Major Depressive Episodes and Post-traumatic Stress Disorder Symptoms via the Mediator of Renewed (Ceased or Started) Group Participation by Types of Relocation: Mediation Analysis by Inverse Odds Weight from Inverse Odds Ratio-Weighted Methods Using Poisson Regression with Multiple Imputation by Chained Equation (n = 828), Mifune, Japan, 2013–2016

	MDE			PTSD symptoms		
	RR	95% CI [a]		RR	95% CI [a]	
1: Relocation to temporary housing						
Natural Indirect Effect (via renewed group participation)	0.60	0.34	0.94	0.70	0.38	1.16
Natural Direct Effect (of relocation)	3.79	1.70	6.64	2.02	0.90	3.56
Total Effect	2.28	1.36	3.81	1.41	0.86	2.13
2: Relocation to other types of housing						
Natural Indirect Effect (via renewed group participation)	0.97	0.62	1.95	1.05	0.70	1.57
Natural Direct Effect (of relocation)	1.62	0.59	3.16	1.44	0.77	2.30
Total Effect	1.58	0.91	2.54	1.50	1.03	2.21

Abbreviations: NIE, the natural indirect effect; NDE, the natural direct effect; TE, the total effect; MDE, major depressive episodes; PTSD, post-traumatic stress disorder; RR, relative risk; CI, Confidence Interval; MICE, multiple imputation by chained equation

NOTE: Adjusted for the baseline covariates of gender, age, equivalent household income (< 200 million yen: low income), years of education (≤ 9 years of compulsory education indicated low education), lived alone or not, had an illness or not, had a job or not, with group participation or not, depressive symptoms, standardized population density (originally, person/km^2) and standardized area slope (originally, %), and disaster damage in 2016 such as housing damage, and farmland damage

[a] Bootstrapped 1,000 times, 95% CI displays bias-corrected Confidence Interval

Dataset: Imputed dataset by MICE (m=20), including an outcome (MDE or PTSD symptoms), an exposure, a mediator, and covariates as imputed variables

Table 5: Natural Indirect Effects, Natural Direct Effects, and Total Effects of the Relocation on Major Depressive Episodes via a Single Mediator (Ceased or Started Group Participation) by Types of Relocation: Mediation Analysis by Inverse Odds Weight from Inverse Odds Ratio-Weighted Methods Using Poisson Regression with Multiple Imputation by Chained Equation (n = 828), Mifune, Japan, 2013–2016

	MDE					
	M1: ceased group participation [a]			M2: started group participation [a]		
	RR	95% CI [b]		RR	95% CI [b]	
1: Relocation to temporary housing						
Natural Indirect Effect (via ceased or started group participation)	0.59	0.31	0.93	0.61	0.39	0.89
Natural Direct Effect (of relocation)	3.88	1.89	8.09	3.75	1.61	6.43
Total Effect	2.28	1.35	3.83	2.28	1.29	3.82
2: Relocation to other types of housing						
Natural Indirect Effect (via ceased or started group participation)	0.98	0.62	1.89	1.16	0.73	2.36
Natural Direct Effect (of relocation)	1.60	0.61	3.04	1.36	0.45	2.64
Total Effect	1.58	0.90	2.68	1.58	0.94	2.74

Abbreviations: NIE, the natural indirect effect; NDE, the natural direct effect; TE, the total effect; MDE, major depressive episodes; RR, relative risk; CI, Confidence Interval; MICE, multiple imputation by chained equation

NOTE: Adjusted for the baseline covariates of gender, age, equivalent household income (< 200 million yen: low income), years of education (≤ 9 years of compulsory education indicated low education), lived alone or not, had an illness or not, had a job or not, with group participation or not, depressive symptoms, standardized population density (originally, person/km^2) and standardized area slope (originally, %), and disaster damage in 2016 such as housing damage, and farmland damage

[a] Reference for M1 is "started or sustained," reference for M2 is "ceased or sustained"

[b] Bootstrapped 1,000 times, 95% CI displays bias-corrected Confidence Interval

Dataset: Imputed dataset by MICE (m=20), including an outcome (MDE), an exposure, a mediator, and covariates as imputed variables

Table 6: Natural Indirect Effects, Natural Direct Effects, and Total Effects of the Relocation on Post-traumatic Stress Disorder Symptoms via a Single Mediator (Ceased or Started Group Participation) by Types of Relocation: Mediation Analysis by Inverse Odds Weight from Inverse Odds Ratio-Weighted Methods Using Poisson Regression with Multiple Imputation by Chained Equation (n = 828), Mifune, Japan, 2013–2016

	PTSD symptoms					
	M1: ceased group participation [a]			M2: started group participation [a]		
	RR	95% CI [b]		RR	95% CI [b]	
1: Relocation to temporary housing						
Natural Indirect Effect (via ceased or started group participation)	0.70	0.42	1.25	0.71	0.44	1.17
Natural Direct Effect (of relocation)	2.02	0.87	3.72	2.00	0.86	3.38
Total Effect	1.41	0.86	2.17	1.41	0.90	2.16
2: Relocation to other types of housing						
Natural Indirect Effect (via ceased or started group participation)	0.96	0.58	1.32	1.25	0.93	2.13
Natural Direct Effect (of relocation)	1.56	0.87	2.76	1.21	0.51	1.93
Total Effect	1.50	1.00	2.22	1.50	0.97	2.17

Abbreviations: NIE, the natural indirect effect; NDE, the natural direct effect; TE, the total effect; PTSD, post-traumatic stress disorder; RR, relative risk; CI, Confidence Interval; MICE, multiple imputation by chained equation

NOTE: Adjusted for the baseline covariates of gender, age, equivalent household income (< 200 million yen: low income), years of education (≤ 9 years of compulsory education indicated low education), lived alone or not, had an illness or not, had a job or not, with group participation or not, depressive symptoms, standardized population density (originally, person/km^2) and standardized area slope (originally, %), and disaster damage in 2016 such as housing damage, and farmland damage

[a] Reference for M1 is "started or sustained," reference for M2 is "ceased or sustained"

[b] Bootstrapped 1,000 times, 95% CI displays bias-corrected Confidence Interval

Dataset: Imputed dataset by MICE (m=20), including an outcome (PTSD symptoms), an exposure, a mediator, and covariates as imputed variables

Table 7: Natural Indirect Effects, Natural Direct Effects, and Total Effects of the Relocation on Depression Measured by 15-item Geriatric Depression Scale via the Mediator of Renewed (Ceased or Started) Group Participation by Types of Relocation: Mediation Analysis by Inverse Odds Weight from Inverse Odds Ratio-Weighted Methods Using Poisson Regression with Multiple Imputation by Chained Equation (n = 828), Mifune, Japan, 2013–2016

	Depression (GDS ≥ 5)		
	RR	95% CI [a]	
1: Relocation to temporary housing			
Natural Indirect Effect (via renewed group participation)	0.80	0.49	1.24
Natural Direct Effect (of relocation)	2.09	1.15	3.33
Total Effect	1.66	1.19	2.41
2: Relocation to other types of housing			
Natural Indirect Effect (via renewed group participation)	0.94	0.69	1.33
Natural Direct Effect (of relocation)	1.80	0.97	3.28
Total Effect	1.69	1.10	2.80

Abbreviations: NIE, the natural indirect effect; NDE, the natural direct effect; TE, the total effect; GDS, 15-item Geriatric Depression Scale; RR, relative risk; CI, Confidence Interval; MICE, multiple imputation by chained equation

NOTE: Adjusted for the baseline covariates of gender, age, equivalent household income (< 200 million yen: low income), years of education (≤ 9 years of compulsory education indicated low education), lived alone or not, had an illness or not, had a job or not, with group participation or not, depressive symptoms, standardized population density (originally, person/km^2) and standardized area slope (originally, %), and disaster damage in 2016 such as housing damage, and farmland damage

[a] Bootstrapped 1,000 times, 95% CI displays bias-corrected Confidence Interval

Dataset: Imputed dataset by MICE (m=20), including an outcome of depression (GDS ≥ 5), an exposure, a mediator, and covariates as imputed variables

5. DISCUSSION

Our results showed that relocation to temporary housing may directly enhance the risk of MDE, but renewals of group participation after the 2016 Kumamoto earthquake, regardless of ceasing or starting, may indirectly lower the risk of MDE for those who relocated to temporary housing. On the other hand, relocation to other types of housing showed no clear direct or indirect effects estimates on MDE. Both types of relocation showed no clear associations with PTSD symptoms. Against the hypotheses stated in Section 2, not all disaster relocation was directly associated with mental health issues such as MDE or PTSD symptoms, and changes in or renewals of group participation were not stressors for disaster-affected older adults. Rather, for those who relocated to temporary housing, renewals of group participation served as the stress relievers against MDE. We could not compare the importance of the mediators between different types of housing, as no clear indirect effects were observed for those who relocated to other types of housing. Moreover, relocation to temporary housing was not associated with started group participation, though relocation to other types of housing was associated with ceased group participation. Thus, our results only indicated that the mediation effects may differ according to types of housing. We need to consider what was related to the contrasting results between temporary housing and other types of housing.

As for relocation to temporary housing and MDE, our results were consistent with those of previous studies that claimed that relocation to temporary housing after the Great East Japan Earthquake of 2011 was associated with an increased risk of depression [41, 42]. Utilizing causal mediation analysis and longitudinal data comparing relocated and non-relocated people, we reinforced the findings of a pre-existing cross-sectional study of relocated people after the Great East Japan Earthquake of 2011 which reported that group participation was a more important factor against depression for those who relocated to temporary housing compared to those who relocated to rented housing [51]. As for possible explanations for renewals of group participation that served as stress relievers against MDE in contrast to the hypotheses, both the group relocation policy and the socio-physical environment of temporary housing built in accordance with "Kumamoto Type Default" [76] could be factors for mitigating depression risks via renewals of group participation. As with the prefectural-level administrative efforts, temporary housing was built following the standards of "Kumamoto Type Default" [76], which designated public gathering places at temporary housing complexes, guided by the "Minna No Ie" project at the time of the Great East Japan Earthquake of 2011[77]. Public gathering places could be used not only for group activities or meetings for housing improvement but also for daily interactions or talking among residents [76]. Similarly, in Mifune Town after the 2016 Kumamoto earthquake, a group

relocation policy to temporary housing was adopted, and public gathering places were opened near them. For residents, the experience of group relocation and the socio-physical environment of temporary housing may have influenced their potential needs to change their group participation. This may have resulted in the renewal or optimization of their social ties as those who wished to belong to a group may have found a new one, while those who felt burdened with group membership or activities may have chosen not to participate after the relocation [119, 120]. The latter may have been protected by the temporary housing environment. For example, in a neighborhood where people lived near each other and public gathering spaces were accessible, daily social interactions might have occurred and social support would be available through anticipated social ties (such as connections with acquaintances in the group relocation) or unanticipated social ties (such as connections with new people) [56, 58, 78]. These benefits may not be exclusive to outsiders of the groups, unlike general concerns [119] and residents may obtain the benefits without compulsory membership. Therefore, some residents in temporary housing who felt uneasy about participating in social groups may choose not to participate without the concern of losing social interactions.

On the other hand, relocation to other types of housing was not associated with MDE, which is consistent with previous studies [41, 42]. A potential explanation may be that some people who relocated to other types of housing, such as new private housing, might be

more flexible at housing selection [38, 39], which poses lower psychological burdens compared to those who relocated to temporary housing [121]. A possible reason for the lack of clear natural direct or indirect effects estimates of any type of relocation on PTSD symptoms could be that PTSD is influenced more by acute stressors immediately after disasters than secondary stressors [2, 4, 6, 10].

This study made use of unique pre/post-disaster dataset to clarify the mediator between relocation to temporary housing and the onset of MDE. To the best of our knowledge, this is the first longitudinal study to elucidate that renewal of group participation may mediate and alleviate the increased risks of MDE after relocation to temporary housing. Overcoming restrictions of the traditional approaches or other counterfactual-based approaches of mediation analyses, we utilized the advantages of causal mediation analysis by the IORW method [107, 108] to derive the mediation effects for the counterfactual-based approach: flexibilities of the model or variable selection (i.e., Poisson regressions or binary outcomes could be used), and inverse odds weighting for adjusting baseline covariates and allowing exposure-mediator interactions [106, 112, 122]. However, this study has several limitations. First, although we hypothesized that relocation, changes in group participation, and onsets of mental health issues occurred sequentially, the latter two were measured at the same time point due to data restriction. Thus, the existence of reverse causality cannot be

ruled out. Second, we could not distinguish between the effects of the physical and social environments of housing due to restrictions on the data. Thus, the types of relocation (relocation to temporary housing vs. other types of housing) may reflect both the differences between social environments (group vs. individual relocation) and built environments (types of housing). Alternatively, the types of relocation may also reflect the differences in the availability of services for daily lives or other regional characteristics, though we could not distinguish this due to lack of the measurements. Third, the dataset may be affected by selective attrition of depressed people and the effect estimates on mental health may be underestimated due to selection bias [123], although our results showed the clear effect estimates of relocation to temporary housing on MDE. Alternatively, compared to participants, non-participants who were lost to follow-up at the second wave, may be more likely to be 75 years or over, have a low education, live alone, have an illness, and have no group participation at baseline (Table 2). As the target population of JAGES is limited to functionally independent adults of ages 65 or over, those who received certification of long-term care needs between the first and second waves were not included in the second wave. Therefore, those who were socio-economically disadvantaged or had health problems may have been selectively lost to follow-up. Fourth, although previous studies indicated gender differences in the association of group participation with mental health [79, 80], in this study, mediation analysis stratified by

gender did not converge, possibly due to the small sub-sample sizes. Even though we imputed the variables via MICE to utilize the entire available data of respondents, the overall sample size may have been small, since the estimates still had large standard errors and the efficiencies of the estimates were not high in this study. In addition, due to the small sample size owing to missing values, we could not conduct complete case analyses. Fifth, for our causal mediation analyses, we could not calculate the proportion mediated measure (i.e., the proportion of the indirect effect to the total effect) [106], which could have been used to compare the importance of mediators against the total effects by types of housing. It should be noted that the use of the proportion mediated measure is desirable only when the directionalities of the estimates of the indirect effect and the total effect are the same [106]. In our results, the calculation of the proportion mediated was not appropriate (even in the result of the clear natural indirect effect of relocation to temporary housing and MDE via renewed group participation), due to the opposite directionality of the natural indirect effect estimate and the total effect estimate. Thus, we could not make full use of advantages of the causal mediation analysis. Sixth, the possibility of the existence of unmeasured confounders among the exposure, the mediator, and the outcomes cannot be denied, even though the time intervals between these variables were assumed to be short (within seven months). Specifically, if there are unmeasured mediator-outcome confounders, the effect estimates would be biased due to

collider bias [117]. Seventh, as mental health outcomes in this study were not based on diagnosis and measured by screening tools instead of interviews, the prevalence may be overestimated, including those who did not need mental health services in practice [3]. In this study, the overall prevalence of PTSD symptoms was 22.1% (Table 1), but in the literature review, the prevalence of PTSD after natural disasters was 5–10% [11]. Eighth, as the results of mediation analyses in this study were derived from strong assumptions and a small number of participants, the reproducibility of the mediation effect should be examined with caution. To confirm the robustness of the results, reinforcement of the study design is needed, such as utilizing three waves of data and larger samples. Moreover, the measurement of the mediators needs improvement. For example, the measurement of changes in group participation in this study may not capture temporal gathering at temporary housing, such as meetings for housing improvement and spontaneous daily interactions or talks among residents [76]. These activities may have reinforced social ties with acquaintances [56, 58] owing to group relocation or new neighbors, [78] and may have had an uncaptured mediation effect between relocation and mental health issues. Ninth, the socio-economic characteristics of those who relocated to temporary housing and those who relocated to other types of housing may differ, although we tried to adjust the difference by inverse odds weighting in the IORW method. According to Table 1, compared to those who relocated to other types of housing, those who relocated to temporary

may be more likely to be of age 75 or over, have low income, have low education, have illness, and have depression at baseline. Therefore, it could be assumed that socio-economically disadvantaged people may have selectively relocated to temporary housing rather than other types, such as private housing.

Future studies are needed to address several points not included in this study. First, we only tested the pre/post-disaster changes in belongingness to any social group as a mediator, but considering changes in the frequency and the variety of group participation (such as changes in the number and the type of groups to which each participant belongs) is also meaningful [124]. Second, further research is needed regarding the willingness to join social groups (specifically for those who resigned from groups after disasters) to confirm the results of this study. Third, more investigation is needed on exactly which socio-physical environmental characteristics of housing could protect disaster survivors from mental health issues. Fourth, the long-term direct and indirect associations between relocation and mental health should be investigated. As was suggested in this study, temporary housing resulted in the optimization of group participation and social relationships of the residents. However, in the long-term, these people have to move out, which may change their social relationships again. In contrast to those who relocated to temporary housing, those who relocated to other types of housing, specifically those who rebuilt their private housing, might not have access

to social interaction or supportive environments such as public gathering places in temporary housing, and disaster relief services to those people are known to be inadequate. Careful monitoring of mental health status is needed in the long term. Additionally, the duration of the long-term impact of relocation should be monitored, even though an existing study revealed that it no longer affected depression 5.5 years later [42]. This is because some people affected by disasters may experience a delayed onset of PTSD or depression [2, 21-23].

This study has policy implications that the administrative efforts by Mifune Town after the 2016 Kumamoto earthquake (such as group relocation policy to temporary housing and opening public gathering places in accessible distances to prevent social isolation among the relocated people) may have contributed to the mitigation of psychological burdens in temporary housing. The socio-physical environments of temporary housing in Mifune might have been suitable for renewing social ties among older adults: those who were seeking a group could find a new group, while those who felt burdened by participating in groups had the option not to participate [119, 120]. Even if some of them resigned from their former groups, they may have been able to continue their daily social interactions with new people or acquaintances from their pre-disaster communities moved by group relocation, since people lived nearby and public gathering places were accessible. Therefore, I recommend adopting group relocation policies and optimizing socio-physical environments of housing such as

setting up public gathering places so that disaster-affected people may have options to participate in group activities and keep social ties with others even without participating in groups. These efforts could create opportunities for social interactions and supportive environments that may reduce the psychological burdens of stressors for those affected by natural disasters and protect their mental health.

6. CONCLUSION

This paper suggests that disaster-related relocation to temporary housing had a negative impact on post-disaster severe mental health issues, but this could be attenuated via changes in group participation (one of the structural aspects of social relationships), in terms of renewal of group participation regardless of ceasing or starting. Although further investigations are needed, the risk attenuation brought on by changes in group participation may be linked to the optimization of social relationships due to relocation to temporary housing.

While group participation could be an intervention target for protecting the mental health of disaster affected older adults from the negative impacts of disaster-related relocation, respecting the will of residents who do not wish to participate in groups may also be meaningful depending on the type of relocation. The renewal or optimization of social ties

and reduced psychological burdens may be attributed to the group relocation policy and the setting of temporary housing (e.g., public gathering places).

ETHICS APPROVAL

The JAGES was approved by the Ethics Committee at the National Center for Geriatrics and Gerontology (992), at Chiba University, Faculty of Medicine (2493), at the University of Tokyo, Faculty of Medicine (10555), and at Kyoto University, Graduate School and Faculty of Medicine (R3153).

Written informed consent was obtained from voluntary return of the questionnaire. The ethics committees approved the use of the assumed consent upon the return of the questionnaire.

Conflicts of interest: none declared.

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