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IRVINE

Understanding Earthquake Risk Perception and Preparedness Among Older Adults in Japan

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Public Health

by

Mihoka Fukurai

s

Dissertation Committee:
Professor Lisa Grant Ludwig, Chair
Professor Oladele Ogunseitan
Professor Jae Hong Kim

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DEDICATION

To

The Earth.
Thank you for making an environment with earthquakes and people to exist.
If not for you, I don't know what I would have studied.

Oh, and to all future-old-people.
For someday you might want to care about my research.
Maybe.

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Well. What I learned from my PhD is that everything will be ok. And if not, we're going to die anyway. Look at yourself from the perspective of Earth—each of us, we're pretty insignificant in the grand scheme of things. But that allows for curiosity, for because we are insignificant, we are free to explore (wow, the PhD revived a poetic spirit in me).

Haiku:
Oh! a PhD/have I dreamt a different life?/Hoped I'd be a plant.

VITA

Mihoka Fukurai

2017 Bachelor of Science in Human Development (BS)
Bachelor of Arts in Japanese Language (BA)
Minor in Psychology
University of California, Davis

2020 Master of Public Health (MPH)
Certificate: Aging and Society
Department of Sociomedical Sciences
Columbia University, Mailman School of Public Health

2026 Doctor of Philosophy in Public Health (PhD)
Department of Population Health & Disease Prevention
University of California, Irvine, Wen School of Population & Public Health

FIELD OF STUDY

Public Health

PUBLICATIONS

Peer-reviewed Publications:

Fukurai, M., & Grant Ludwig, L. (2025). Older Adults, Loneliness, and Earthquake Disaster Preparedness in Japan. *Disaster Medicine and Public Health Preparedness,* 19, e356. doi:10.1017/dmp.2025.10273

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Casey, J. A., **Fukurai, M.,** Hernández, D., Balsari, S., & Kiang, M. V. (2020). Power outages and community health: a narrative review. *Current environmental health reports*, 7, 371-383.

Meyer, O., **Fukurai, M**., Ho, J., Limtiaco, P., Nguyen, H., Dang, J., Zane, N. and Hinton, L. (2018). Dementia caregiver intervention development and adaptation in the Vietnamese American community: A qualitative study. *Dementia*.

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PRESENTATIONS:

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ABSTRACT OF THE DISSERTATION

Understanding Earthquake Risk Perception and Preparedness Among Older Adults in Japan

by
Mihoka Fukurai
Doctor of Philosophy in Public Health
University of California, Irvine, 2026
Professor Lisa Grant Ludwig, Chair

Natural disasters disproportionately affect older adult populations, who consistently account for a majority of disaster-related mortality. While prior research has emphasized the role of risk perception in motivating preparedness behaviors, less attention has been given to how psychosocial and structural factors shape these processes among aging populations. This dissertation addresses this gap by examining how risk perception, loneliness, and structural vulnerability interact to influence disaster preparedness among older adults in Japan.

Guided by the Protective Action Decision Model, this research extends existing theoretical frameworks through the development of the Japanese Older Adult Preparedness Model (JOAPM), which integrates psychosocial and structural dimensions into traditional models of protective action. This approach conceptualizes preparedness as an emergent process shaped not only by cognitive evaluation, but also by social relationships and environmental constraints.

This dissertation consists of three empirical studies. The first examines changes in risk perception and preparedness behaviors before and after the 2011 Tōhoku Earthquake and Tsunami using nationally representative survey data. Findings indicate that disaster experience significantly increases risk perception and is associated with changes in preparedness behaviors, including insurance uptake. The second study investigates loneliness as a psychosocial determinant of preparedness among older adults. Results demonstrate that loneliness is

negatively associated with preparedness, while also exhibiting a small indirect relationship through increased risk perception. The third study examines structural vulnerability, focusing on mobility limitations and disability. Contrary to common assumptions, physical limitations alone do not fully explain preparedness behaviors; rather, broader social and infrastructural contexts play a more significant role.

Together, these findings challenge the assumption that increasing risk perception alone is sufficient to improve preparedness. Instead, they demonstrate that preparedness is shaped by the interaction of psychological, social, and structural factors that influence both perception and the ability to act. By integrating these dimensions, this dissertation advances a more comprehensive understanding of disaster preparedness among older adults and provides a framework for developing more targeted and equitable disaster risk reduction strategies.

WC: 322

CHAPTER I:

INTRODUCTION

Natural disasters have increased in frequency and impact in recent decades, with disproportionate consequences for older adult populations [1–5]. Across a range of hazards, including earthquakes, heatwaves, and hurricanes, individuals aged 65 and older consistently account for the majority of disaster-related mortality [6–8]. This reflects not only age-related physical vulnerability, but also a complex interplay of social, economic, and psychological factors that shape preparedness and response behaviors towards risk.

Older adults are a heterogeneous population, characterized by wide variation in physical ability, cognitive function, financial stability, and social support [1,3,9–11]. Despite this diversity, disaster preparedness policies and interventions often rely on generalized assumptions about aging populations, frequently targeting a "typical" older adult living independently with access to stable support systems [12–15]. Such assumptions overlook critical dimensions of vulnerability that may significantly influence disaster outcomes.

The devastating impacts of these dynamics became clear during the 2011 Tōhoku Earthquake and Tsunami, one of the most significant disasters in modern Japanese history. Over 80% of direct earthquake and tsunami-related fatalities occurred among individuals aged 65 and older [16]. The actual death toll may be substantially higher when including those who died from excess mortality among older adults caused by indirect factors, such as displacement, disruptions to care systems, and declines in physical and mental health after the disaster [17–20]. These outcomes emphasize how social vulnerability and aging-related decline in abilities influence disaster risk that reaches far beyond immediate exposure to hazards.

Older Adult Vulnerabilities

Historical evidence from other disasters further reinforces this pattern. For example, during the 1995 Chicago Heat Wave, older adults living alone in urban environments experienced significantly higher mortality rates, often due to limited mobility, social isolation, and lack of access to cooling resources [21]. Such cases illustrate that vulnerability among older adults is not just due to hazard intensity but is deeply embedded in broader social and environmental contexts.

A well-known hazard, such as Hurricane Katrina, also highlights these vulnerabilities. During Hurricane Katrina, older adults experienced significantly higher mortality compared to younger populations [22–24]. Estimates suggest that nearly 70% of those who died were aged 60 or older, despite representing a much smaller proportion of the population [25]. Many of these deaths occurred among individuals with limited mobility, chronic health conditions, or those residing in long-term care facilities [26,27]. The disaster exposed critical failures in evacuation planning and social support systems, particularly for older adults who were unable to evacuate independently or lacked access to transportation. In some cases, individuals remained in place due to physical limitations or reliance on caregivers and institutional systems that ultimately failed. These outcomes highlight how structural vulnerability, rather than hazard exposure alone, can determine disaster outcomes.

Similar patterns were observed following the 2011 Christchurch Earthquake. While mortality in Christchurch was lower than in larger-scale disasters, such as the Haiti Earthquake and the following Tōhoku Earthquake, older adults experienced disproportionate impacts during the recovery phase. Research indicates that older individuals faced greater challenges related to

displacement, housing instability, and access to services following the earthquake [28–30]. In particular, older adults were more likely to experience prolonged disruption due to limited financial resources, reduced mobility, and dependence on local social networks that were disrupted by the disaster. These findings emphasize that vulnerability among older adults is not limited to immediate mortality but also extends into long-term recovery processes [31].

More recent wildfires in California, including those affecting communities such as Pacific Palisades from 2024 to 2025, reveal the disproportionate risks faced by older adults. Although wildfire-related mortality may be lower than in large-scale disasters such as hurricanes or tsunamis, older adults remain particularly vulnerable due to mobility limitations, chronic health conditions, and heightened sensitivity to smoke exposure [1,32,33]. Wildfire evacuations often require rapid decision-making and access to transportation, resources that may not be readily available to older individuals. Furthermore, the prolonged nature of wildfire events, like extended periods of poor air quality and displacement, can exacerbate existing health conditions and increase long-term vulnerability. These challenges highlight that, even in high-resource environments, older adults face structural and environmental barriers that limit their ability to respond effectively to evolving disaster conditions.

Across disasters, including earthquakes, hurricanes, heatwaves, and wildfires, a similar pattern emerges: older adults are disproportionately affected not only due to physical vulnerability, but because of the social, structural, and environmental conditions that shape their ability to prepare for, respond to, and recover from hazard events.

Risk Perception and Preparedness

In addition to these structural and social factors, psychological processes play a critical role in shaping preparedness. Risk perception is widely recognized as a central driver of disaster preparedness behavior, influencing how individuals interpret hazards and engage in protective actions [34–36]. While a substantial body of literature supports the relationship between risk perception and preparedness, findings remain inconsistent regarding how risk perception is formed, maintained, and translated into action. Disaster experience has been shown to increase perceived risk; however, heightened perception does not always translate into sustained or adequate preparedness behavior [37,38]. These inconsistencies highlight critical gaps in understanding how individuals process risk information and act upon it [39,40].

Improving risk communication is therefore essential, particularly in the context of increasingly frequent and severe natural disasters associated with climate change. Preparedness is often framed in terms of immediate survival; however, its importance extends beyond the disaster event itself. Adequate preparedness can facilitate faster recovery, reduce long-term morbidity, and mitigate excess mortality following disasters [41,42]. Thus, understanding the mechanisms that drive preparedness behaviors has significant implications for both individual and public health outcomes.

The 2011 Tōhoku Earthquake and Tsunami further provides a critical case for examining gaps in risk perception. Despite Japan's extensive earthquake preparedness infrastructure and public education efforts, the disaster revealed a significant underestimation of tsunami risk, possibly influenced by a false tsunami warning two days before 3.11. Although a small proportion of deaths were directly attributable to the earthquake itself, the majority of fatalities resulted from the tsunami [16]. In many cases, individuals delayed evacuation, remaining in place

to address immediate damage from the earthquake, suggesting a misalignment between perceived and actual risk. This highlights the limitations of current risk communication strategies, which often rely on probabilistic information that may be difficult for individuals to interpret [40,43,44]. Moreover, there is limited evidence that traditional mass communication approaches alone are sufficient to increase preparedness behaviors.

In addition to cognitive processes, cultural and social contexts shape how risk is perceived and acted upon. Much of the existing literature is grounded in Western contexts, with limited attention to how these dynamics operate in East Asian settings. Japan presents a particularly compelling case due to its combination of advanced technological systems and evolving social structures. While often characterized as collectivist, contemporary Japanese society—particularly older adults—may experience increasing levels of social isolation, challenging assumptions about strong social cohesion [45,46].

These gaps point to the need for more comprehensive frameworks that integrate psychological, social, and structural dimensions of preparedness. This dissertation draws on the Protective Action Decision Model and extends it by developing the Japanese Older Adult Preparedness Model (JOAPM), which incorporates psychosocial factors such as loneliness alongside traditional determinants of behavior [47]. This approach recognizes that preparedness is not solely an individual cognitive process, but is shaped by dynamic interactions between lived experiences, social environments, and structural constraints.

Specifically, this dissertation examines how risk perception, loneliness, and structural vulnerability interact to influence preparedness behaviors among older adults in Japan. By integrating quantitative and qualitative approaches and leveraging data collected before and after

a major disaster, this research provides a nuanced understanding of how preparedness is constructed within the population, especially among aging populations. Ultimately, this work aims to inform more targeted, equitable, and context-sensitive disaster risk reduction strategies.

Theoretical Framework

This dissertation is guided by the Protective Action Decision Model (Lindell & Perry), which conceptualizes disaster preparedness as the outcome of a series of cognitive and social processes through which individuals interpret risk and evaluate protective actions [36,48]. According to PADM, individuals engage in a sequence of assessments, including threat perception, evaluation of protective action efficacy, and expectations of stakeholder responsibility, to determine whether and how to prepare for a hazard.

Within this framework, risk perception plays a central role in motivating protective behavior. Individuals must first perceive a threat as personally relevant and severe before engaging in preparedness actions. They must also believe that available protective measures, such as securing furniture, preparing emergency supplies, or identifying evacuation routes, are effective in reducing harm. Additionally, perceptions of institutional responsibility, particularly the role of government in disaster response, may influence individual motivation. For example, individuals who expect governmental protection may be less likely to engage in personal preparedness behaviors.

Importantly, these cognitive processes do not occur in isolation. PADM recognizes that decision-making is shaped by environmental and social contexts, including hazard exposure, social networks, and prior experience. In the context of Japan, where exposure to earthquakes is

widespread due to its location along a subduction zone, environmental cues and repeated hazard experience may influence both risk perception and preparedness behaviors. Social environments also play a critical role, as information, norms, and expectations are transmitted through family, community, and broader social networks.

However, while PADM provides a robust framework for understanding protective decision-making, it does not fully account for psychosocial factors that may be particularly salient among older adults. In particular, loneliness and social isolation, common yet often overlooked aspects of aging, may shape both how risk is perceived and the capacity to act upon that perception. For example, individuals experiencing loneliness may have reduced access to information, weaker social reinforcement of preparedness behaviors, and lower perceived self-efficacy in disaster contexts.

To address these limitations, this dissertation extends PADM by developing the Japanese Older Adult Preparedness Model (JOAPM). The JOAPM integrates psychosocial dimensions, particularly loneliness, alongside traditional PADM constructs and structural factors such as mobility, financial resources, and access to support systems. This expanded framework recognizes that preparedness is not solely a function of cognitive evaluation, but emerges from the interaction of psychological processes, social relationships, and structural constraints.

Within the JOAPM, individual characteristics—including age, sex, homeownership, disaster experience, and place attachment—interact with environmental and social contexts to shape key psychological processes such as risk perception, perceived efficacy, and expectations of institutional support. These processes, in turn, influence preparedness behaviors, including

actions such as obtaining earthquake insurance, preparing emergency supplies, and identifying evacuation strategies.

By integrating psychosocial and structural dimensions into an established behavioral framework, the JOAPM provides a more comprehensive approach to understanding disaster preparedness among older adults. This model allows for a deeper examination of how vulnerability is constructed and experienced, and offers a foundation for developing more targeted and equitable disaster risk reduction strategies. In doing so, this dissertation shifts the focus from whether individuals *choose* to prepare to whether they are *able* to prepare within the constraints of their social and structural environments.

Each of these dimensions is discussed in the following chapters, as Chapter II examines whether a destructive earthquake and tsunami disaster influences risk perception and changes preparedness behaviors in the Japanese population. Using a pre- and post-Tohoku earthquake and tsunami disaster attitude survey administered by the government of Japan, we investigate whether risk perception and behavior differ between national sentiment before and after the disaster. The 2011 Tohoku disaster is the second most destructive earthquake to affect the Japanese population, with the last large earthquake being the 1995 Kobe Hanshin Earthquake, which resulted in about 5,500 deaths and 41,000 injuries[49–51].

Chapter III investigates how psychosocial factors such as loneliness may affect risk perception and preparedness behavior. We explore a new framework that incorporates psychosocial factors and their effects on behavior in older adults. As noted in prior research, affect, such as sadness, does not lead to behavior change as much as intense optimism or negativity. Chapter IV examines the Japanese community-dwelling older adult population and

those with mobility difficulties. In the literature, there has been consistent evidence that those who are disabled are less prepared for natural hazards. We investigate whether this holds in a country that has undergone policy changes regarding disaster preparedness following the 2011 Tohoku disaster. Chapter V provides a synthesis of findings from published papers in Chapters II-IV and discusses their implications.

CHAPTER II:

Risk Perception to Preparedness: 2011 Pre- and Post-Tohoku Japan Earthquake

ABSTRACT

Natural hazards are ubiquitous, and preparedness and mitigation are essential to reducing morbidity and mortality. This study examines Japan's 2011 M 9.1 (USGS) Tōhoku Earthquake and its effect on insurance uptake and risk perception. Individual characteristics, including age, biological sex, income, area of residence relative to the disaster, and homeownership, are known to influence risk perception and insurance uptake. The results of this study demonstrate that risk perception and insurance uptake increased after the Tōhoku Earthquake. The likelihood of insurance uptake seems unaffected by income level post-disaster, while before the earthquake, income was a significant factor in enrolling in insurance. These findings have significant implications for enhancing preparedness measures through earthquake insurance. The observed increase in risk perception and insurance uptake following the Tōhoku Earthquake emphasizes how exposure to disasters shapes individuals' perceptions of risk and their willingness to take proactive measures. These results suggest that witnessing a major disaster can heighten risk perception and insurance uptake. Alternatively, personal disaster experience may attenuate risk perception and diminish preparedness behaviors. This necessitates further research into natural hazards, risk perception, and the ramifications of experiencing or witnessing such disasters.

Keywords:

Risk perception, Tōhoku Earthquake, Tsunami, Insurance, Protective behavior.

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1. Introduction

Since the 1970s, the world has experienced an overall increase in disasters, including droughts, extreme weather, volcanic activity, and earthquakes, among other manufactured technological disasters [52]. The magnitude 9.1 Tōhoku Earthquake of 2011 caused a tsunami and subsequent nuclear power plant meltdown in Japan (see Fig 1). The combination of disasters cost over 18,000 lives and missing persons. The Tōhoku Earthquake is known as modern history's most severe complex disaster [53]. The detrimental effects of the earthquake have been long-lasting, and some have experienced continuous adverse effects for over a decade as people relocated, changed occupations, and are still experiencing fear and discrimination from the impact of radiation.

In most natural disasters, many causes of death can be attributed to people's behaviors. In the 2011 Tōhoku Earthquake, individuals underestimated the tsunami threat, stayed home or returned, and faced the highest fatalities. The threat of the tsunami was underestimated and the people felt safe enough to remain home, where the highest number of fatalities occurred [54]. The tsunami inundation area was vastly underestimated, and the nuclear power plant meltdown was an unexpected consequence that followed the tsunami caused by the six-minute-long earthquake. Researchers mostly agree that risk perception affects preparedness [36,55–58]. With effective risk communication, one should be able to encourage ample preparedness behaviors. Yet, there has not been concrete evidence that informing the public about disaster risks through the main media channels will increase risk perception and household preparedness [59]. Many variables may affect perceptions of risk, which tend to differ in every disaster and population. Some variables include demographics of the population, types of disasters, public infrastructure, and culture, which obscures the understanding of how risks are interpreted and lead to preparedness behaviors.

Earthquake risk is especially difficult to evaluate and comprehend. A lack of technology for predicting earthquakes leads people to interpret the risks of earthquakes on their own, frequently informed by previous experiences or hearsay. Earthquake hazards and risks are usually communicated through probabilities, which are difficult to interpret [43,60,61]. In addition, it is uncertain whether communicating a natural disaster risk as a probability effectively raises risk perception and preparedness [59,61].

Individual characteristics such as gender, age, and homeownership also affect risk perception and preparedness behaviors [36]. Another characteristic that may influence risk perception is a personal experience of disaster-related loss, area, and proximity to a disaster [62]. The most recent earthquake to result in widespread fatalities in Japan before the 2011 Tōhoku Earthquake was the 1995 January earthquake in South Hyogo. Is 16 years enough time to forget the devastating effects of an earthquake? This question arises considering the February 2010 Central Chile Earthquake, which triggered a tsunami striking the Japanese coast hours after the seismic event. Although residents of the coastal regions of Miyagi and Iwate evacuated in 2010, the tsunami inflicted minimal damage. Prior to that, the Miyagi area experienced the Minamisanriku earthquake and tsunami in 1933, which caused 3,000 deaths. Studies show that memory of past experiences influences risk perception and behaviors [62]. Over time, the memory of the disaster fades, and risk perception diminishes [63]. How can memory affect risk perception and preparedness measures before and after the 2011 Tōhoku Earthquake? Populations that have not experienced or are distant geographically from a disaster exhibit higher risk perceptions and exaggerated anxiety regarding the potential ramifications of natural hazards [64,65]. There is also evidence that descriptive and experiential information gives rise to markedly distinct risk

perception, where description leads to overestimating the occurrence of adverse rare events. In contrast, experience facilitates underestimating rare events [66,67].

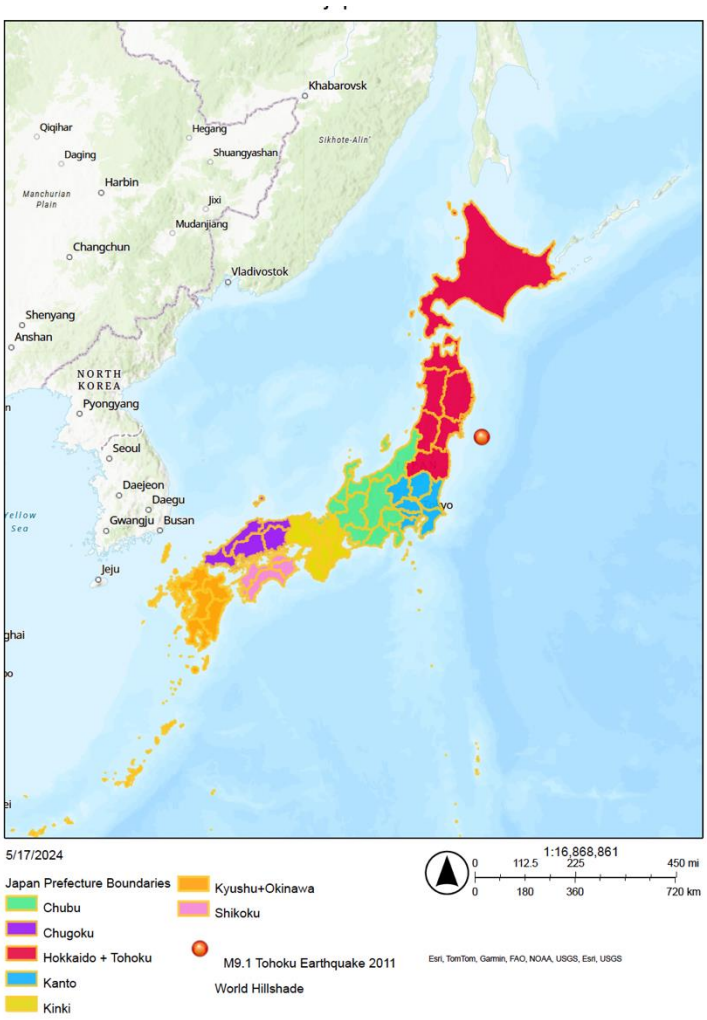

Figure 1: 7 Regions of Japan categorized in this paper and Epicenter of the Tōhoku Earthquake

While consensus remains elusive regarding the relationship between preparedness efforts and the probability of mortality or morbidity across different demographic cohorts in the context of natural disasters, preparedness extends beyond survival and injury prevention. Empirical evidence suggests that natural disasters give rise to significant mental distress and health complications in their aftermath. Effective preparedness measures enhance the likelihood of a speedy recovery, mitigating psychological distress and reducing the onset or triggering of other medical conditions among older adults. Preparedness and mitigation help alleviate the strain on community resources post-disaster, mitigating excess deaths [36,68–71]. One strategy to mitigate the effects of natural disasters is to enroll in insurance. In the Tokyo Metropolitan area, over 35% of the households purchased earthquake insurance in 2020, an area with a 70% chance of a large earthquake in the next 30 years [72]. Insurance can aid recovery

efforts by supporting individuals and businesses financially as people recover from destructive events [73–75].

This study investigates the impact of the Tōhoku Earthquake on risk perception and insurance enrollment. It explores how exposure to the earthquake influenced risk perception and insurance registration. The study posed several questions: Is risk perception a predictor of insurance uptake? Did exposure to the Tōhoku Earthquake heighten risk perception? Did exposure to the Tōhoku Earthquake increase insurance enrollment? Lastly, what individual characteristics most heavily predict insurance uptake and risk perception?

1.1 Protective Action Decision Model:

Lindell and Perry's Protective Action Decision Model (PADM) [36] emphasizes the influence of the social, environmental, and cultural context on shaping individuals' threat perceptions, consequently leading to adjustments in preparedness actions (Figure 2).

The social, environmental, and cultural contexts encompass variables ranging from modes of information acquisition to personal characteristics such as age and gender. This collection of variables collectively constructs the social and environmental backdrop of an individual's risk

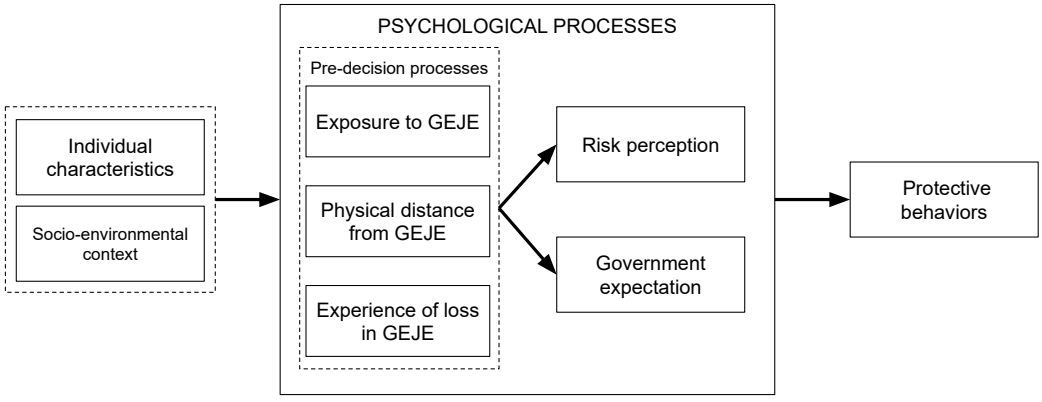

Figure 2: Simplified Lindell and Perry's PADM physical distance from the Great Eastern Japan Earthquake epicenter.

assessment and decision-making processes. The information gleaned from these socio-

environmental and cultural contexts shapes the decision-making trajectory, ultimately culminating in an informed subjective risk and threat evaluation.

Three psychological processes precede protective behaviors: pre-decisional processes, threat perceptions and stakeholder perceptions, and protective action decision-making. The variables in this study fit into the pre-decisional processes, threat perception, and stakeholder perceptions. In the 2012 PADM, the pre-decisional processes include exposure to information that influences the formation of threat and stakeholder perceptions. In this study, previous exposure to the Tōhoku Earthquake, distance from the Tōhoku Earthquake, and loss experience in the Tōhoku Earthquake are hypothesized to affect risk and stakeholder perceptions. Some literature asserts that experience informs future risk perception. Subsequently, this perceived level of risk serves as a determinant, guiding appropriate behavioral responses, which include preparedness. Stakeholder perception also affects protective action decisions. Lindell and Perry explain stakeholder perceptions as social stakeholders' power over the population's decision to partake in protective behaviors [36]. French and Raven categorize the perceived responsibility of the federal government within the psychological processes involved in adopting protective behaviors. The federal government's expectation to aid in coping with earthquakes influenced respondents' inclination to engage in seismic hazard adjustment behaviors [76]. The model was applied to evaluate the impact of the March 2011 Northern Japan Triple Disaster (Tōhoku Earthquake plus tsunami and nuclear power plant accident) on risk perception and preparedness behaviors.

2. Materials and Methods

2.1 Participants and period

The Tōhoku Earthquake occurred on March 11, 2011, and was immediately followed by a tsunami that affected much of the eastern coast of Japan. The earthquake shook the Japanese population from Central to Northern Eastern Japan. The Government of Japan surveyed participants before and after the disaster. The survey targeted people between the ages of 20 and 60 in Japan. The Government of Japan and the Economic and Social Research Institute distributed and collected data via the web in 2011 regarding questions related to natural hazards. One dataset was collected January 6-7, 2011 (n=2640), two months before the Tōhoku Earthquake. The second dataset is from November 2011 (n=3552), collected on November 5, 2011, 9 months post-disaster.

2.2 Measure

Both surveys inquire about respondents' demographic information, views on risk, household preparedness, and disaster management, among many other variables. The PADM by Lindell and Perry states that individual characteristics affect psychological processes, which can be broken down into two levels. The first level is the pre-decisional processes, which include exposure to the Tōhoku Earthquake, physical distance from the disaster, and experience with the disaster. These variables affect the next level of decisional processes comprised of risk perception and attitudes towards government, which are hypothesized to be the core predictors of preparedness behavior, measured through insurance enrollment, in this study.

In the pre-decisional processes, exposure to the disaster is represented by a binary yes/no. Seven areas in Japan represent the physical distance from the disaster, and the disaster experience is asked in the post-Tōhoku Earthquake survey in November.

The second level of the psychological process includes risk perception and attitudes toward the government. The variable used as perceived risk is an average of 4 questions measured by a 5-level Likert scale ranging from very unlikely to very likely. Strongly agree to be 1, to strongly disagree with a score of 5. The statements include, "There will be a natural disaster big enough to destroy Japan in the future." Other risk perception questions are "the probability that the next generation will experience a larger disaster" and "the next generation will struggle more with natural disasters." A composite risk score is calculated by averaging the risk perception score across the four questions.

The variable for attitudes toward government was an average score across four questions. The response measure was a Likert scale ranging from 1, the government should take full responsibility, and civilians should not be involved at all, to 5, the civilians should take full responsibility, and the government should not be involved at all (see Table 4). As the score increases, the less one believes the government should be involved. Hierarchical linear regression was conducted to observe the relationship between government risk perception by taking the mean score of the four government expectations.

The experience questions in the post-Tōhoku Earthquake survey asked ten questions (see Appendix 1). A three-level multiple choice question assessed the experience of loss in the Tōhoku Earthquake (1 does not apply to me at all; 2 somewhat applies to me; 3 applies to me). Ten questions were asked about their experience with the disaster (shown in Appendix 1).

The main response variable, the preparedness variable, is "I have earthquake insurance," answered with a binary "yes" or "no." Individual characteristics considered are marital status, the existence of offspring, income, homeownership, area of residence, biological sex, and age.

2.3 Procedure

The dataset reflects disaster attitudes, including risk perception and preparedness, focusing on earthquakes as a disaster. The post-disaster survey distributed in November had additional questions to reveal more specific experiences regarding the Tōhoku Earthquake.

The analysis was conducted using the data sets from the Social Science Japan Data Archive (SSJDA) on disaster attitudes at two time points in 2011. The PADM [36] guides the analysis of how the 2011 Tōhoku Earthquake affected attitudes, perspectives, and decisions. The dataset is publicly available through Tokyo University's Data Archive (https://ssjda.iss.u-todkyo.ac.jp/).

2.4 Statistical analysis:

Bivariate analyses were conducted using t- and chi-square tests to explore the relationship between protective behavior, risk perception, various demographic variables, and exposure to the 2011 Tōhoku Earthquake and tsunami. A hierarchical multivariate logistic regression was fitted to assess the relationships between individual characteristics, experience, stakeholder perceptions, risk perception, and the likelihood of purchasing insurance. For the hierarchical regression, six individual characteristics (age, gender, income, having children/grandchildren, area of residence, marital status, and homeownership) were entered in the first block. Risk perception and government perception were entered in the second block. A backward stepwise regression was used to eliminate variables.

First, the relationship between exposure to earthquakes and risk perception is tested. It is hypothesized that exposure to a large disaster will change the perception of the risk of future earthquakes. Additionally, the relationship between exposure to the disaster and the uptake of earthquake insurance is examined by testing whether there is a significant change in insurance enrollment between the pre-disaster group and the exposed group. The relationship between

future risk perception and insurance uptake was also examined. We expected a significant positive relationship between future risk perception and insurance enrollment.

If a significant difference was observed between the exposed and unexposed population, the variables were assessed independently based on their exposure to the disaster.

All statistical analyses were conducted using SPSS Version 29.

2.5 Ethics statement

The University of California, Irvine Institutional Review Board (IRB) in Human Subject Research approved all analyses of this paper.

2.6 Limitations in the Methodology

The survey participants are self-selected from a pool of registered subjects. They were randomly selected to reflect the population of each area, considering income and age. The population surveyed is representative of the population in each of Japan's seven regions: Hokkaidō and Tōhoku, Kantō, Chūbu, Kinki, Chūgoku, Shikoku, and Kyūshu and Okinawa (Figure 1). Representation of the data is limited as the survey was administered via the web, which may skew the results due to the ability to use computers and the disaster information provided by the internet.

3. Results

Table 1: Demographics separated by pre- and post-Tōhoku earthquake

	January 2011			**November 2011**		
	Mean	Count	%	Mean	Count	%
Age	40	2640		40	3552	
Sex						

Male		1320	50%		1768	49.8%
Female		1320	50%		1784	50.2%
Income						
Below 3,000,000 yen		539	20.4%		774	21.8%
3 million to 6 million yen		927	35.1%		1311	36.9%
6 million to 9 million yen		647	24.5%		845	23.8%
9 million to 12 million yen		316	12.0%		385	10.8%
12 million to 15 million yen		116	4.4%		144	4.1%
15 million yen and above		95	3.6%		93	2.6%
Area						
Hokkaidō+Tōhoku		226	8.6%		327	9.2%
Kantō		1130	42.8%		1550	43.6%
Chūbu		404	15.3%		558	15.7%
Kinki		527	20.0%		627	17.7%
Chūgoku		113	4.3%		167	4.7%
Shikoku		54	2.0%		65	1.8%
Kyūshū + Okinawa		186	7.0%		258	7.3%
Have children or grandchildren						
Yes		1083	41.0%		1575	44.3%
No		1557	59.0%		1977	55.7%
Marriage status						
Single		1062	40.2%		1383	38.9%
Married		1464	55.5%		1966	55.3%
Divorced/widowed		114	4.3%		203	5.7%
Home ownership						
Rent		869	32.9%		1192	33.6%
Own single standing house		1232	46.7%		1625	45.7%
Own apartment unit		448	17.0%		622	17.5%
Other		91	3.4%		113	3.2%
Have earthquake insurance						
Yes		767	29.1%		1213	34.1%
No		1873	70.9%		2339	65.9%

3.1 Demographic and other characteristics

Table 1 lists the demographic characteristics. There were 6,192 total respondents combining two datasets, 2640 before the Tōhoku Earthquake and 3552 after. The pre-disaster dataset had equal numbers of male and female respondents, and the post-disaster had slightly more female respondents (50.2%). Over half the respondents owned their living arrangements pre- Tōhoku

Earthquake (63.7%) and post- Tōhoku Earthquake (63.2%). Less than half the respondents had children or grandchildren (41% pre-disaster; post-disaster: 44.3%). The marital status was similar in both pre-and post- Tōhoku Earthquake, with more than half the respondents being married (pre: 55.5%; post: 55.7%).

3.2 Risk perception and insurance uptake and exposure to the Tōhoku Earthquake

3.2.1: Exposure to Tōhoku Earthquake *and Risk Perception:*

An independent two-sample t-test analysis shows a significant increase in average future risk perception post-disaster compared to the pre-disaster population ($t = 11.377$, $p<0.001$).

3.2.2: Exposure to Tōhoku Earthquake *and Insurance Enrollment:*

In a bivariate analysis using the combined dataset, a higher proportion of the post-disaster population had enrolled in earthquake insurance than the population pre-disaster (34% post-disaster vs. 29%. Pre-disaster, $X^2= 18.09$ $p<0.001$).

In multivariable logistic regression, after taking into account children, sex, marital status, homeownership, income, and age, the people who answered the survey after the earthquake had 1.26 times higher rate of earthquake insurance enrollment when compared to people who have not yet been exposed to the disaster (Table 2).

Table 2: Multivariate hierarchical backward selection logistic regression predicting odds of insurance enrollment in combined dataset with both pre and post disaster data

	B	S.E.	Wald	Sig.	OR	95% C.I.for OR	
						Lower	Upper
Hokkaidō+Tōhoku			15.448	0.017			
Kanto	0.04	0.11	0.131	0.718	1.04	0.839	1.29
Chūbu	0.178	0.121	2.146	0.143	1.195	0.942	1.516
Kinki	-0.129	0.12	1.153	0.283	0.879	0.694	1.112
Chūgoku	-0.14	0.171	0.668	0.414	0.87	0.622	1.215
Shikoku	0.432	0.221	3.816	0.051	1.54	0.999	2.376
Kyūshū + Okinawa	0.045	0.148	0.094	0.759	1.046	0.783	1.398
age	0.008	0.003	6.749	0.009	1.008	1.002	1.014
Female	-0.089	0.059	2.278	0.131	0.915	0.815	1.027
Have Kids/Grandchildren	0.005	0.08	0.004	0.949	1.005	0.859	1.176
Single			55.912	<.001			
Married	0.677	0.092	54.182	<.001	1.967	1.643	2.355
Divorce/Widowed	0.713	0.149	22.887	<.001	2.04	1.523	2.731
Annual income	0.147	0.025	35.035	<.001	1.158	1.103	1.215
Rent			294.221	<.001			
Own standalone house	1.041	0.077	184.303	<.001	2.833	2.438	3.293
Own an apartment unit	1.419	0.09	247.358	<.001	4.134	3.464	4.934
Other	-0.042	0.209	0.041	0.84	0.959	0.637	1.443
After the GEJE	0.232	0.06	15.034	<.001	1.261	1.122	1.418
Mean of Risk perception	-0.204	0.047	18.597	<.001	0.816	0.744	0.895
Constant	-2.396	0.219	119.391	<.001	0.091		
Variables entered step 1. Area of residence, Age, Sex (binomial), Have Children or Grandchildren (binomial), Marital Status, Annual income, Home ownership status, Variable(s) entered on step 2: Before and after the Tōhoku Earthquake, mean risk perception.							

3.3 Association between Future Risk Perception and Insurance Enrollment at two different

3.3.1 Before the Tōhoku Earthquake

Wald backward selection regression was performed on two separate pre- and post-disaster datasets to test whether risk perception significantly contributes to the odds of insurance uptake

at different time points. Prior to the Tōhoku Earthquake, leaving all other variables constant, a one-point increase in risk perception increased 1.25 times the likelihood of insurance uptake (See Table 3).

3.3.2 After the Tōhoku Earthquake

In testing whether risk perception and insurance uptake post-disaster in November, risk perception and insurance uptake were independent (See Table 3).

3.4 Supplemental analysis:

3.4.1 Relationship between individual characteristics and insurance enrollment divided into pre- and post- Tōhoku Earthquake datasets:

Table 3: Pre-and Post -variables contributing to odds of insurance enrollment in hierarchical Backward stepwise regression.

	January 2011 data					***November 2011 data***			
	Sig.	OR		95% C.I.		Sig.	OR	95% C.I.	
				Lower	Upper			Lower	Upper
Hokkaidō+Tōhoku	0.009				1.097	-	-	-	-
Kanto	0.843	1.036		0.732	1.465	-	-	-	-
Chūbu	0.242	1.256		0.857	1.842	-	-	-	-
Kinki	0.221	0.789		0.541	1.152	-	-	-	-
Chūgoku	0.84	1.055		0.626	1.779	-	-	-	-
Shikoku	0.012	2.284		1.195	4.367	-	-	-	-
Kyūshū + Okinawa	0.878	0.964		0.604	1.538	-	-	-	-
Below 3,000,000 yen	<.001					0.003			
3 million to 6 million yen	0.004	1.543		1.145	2.079	0.358	1.111	0.888	1.391
6 million to 9 million yen	<.001	2.08		1.521	2.845	0.023	1.323	1.04	1.683
9 million to 12 million yen	<.001	2.154		1.503	3.085	0.001	1.607	1.208	2.136
12 million to 15 million yen	<.001	2.29		1.432	3.664	0.012	1.66	1.118	2.464

15 million yen and above	<.001	2.585		1.562	4.278	0.082	1.521	0.949	2.44
Single	<.001					<.001			
Married	<.001	2.107		1.717	2.585	<.001	1.83	1.513	2.213
Divorce/Widowed	0.019	1.75		1.095	2.798	<.001	2.189	1.552	3.087
Rent	<.001					<.001			
Own standalone house	<.001	2.365		1.877	2.98	<.001	3.182	2.627	3.855
Own an apartment unit	<.001	3.701		2.813	4.869	<.001	4.438	3.528	5.581
Other	0.245	1.408		0.79	2.507	0.258	0.712	0.395	1.283
Mean of risk variables	<.001	0.751		0.652	0.866	0.031	0.875	0.774	0.988
Constant	<.001	0.136				<.001	0.108		
	a. Variable(s) entered on step 1: sex, age, area, Income, marital status, having children/grandchildren, homeownership, mean of risk perception.								

Many demographic variables suggest the likelihood of purchasing earthquake insurance before and after the Tōhoku Earthquake. A Wald backward selection logistic regression was conducted to find variables contributing to insurance enrollment separately before and after the disaster. Before the disaster, many individual factors significantly contributed to the odds of buying insurance. Keeping all other variables constant, individuals in most income brackets differed significantly in the likelihood of insurance enrollment status compared to the lowest income bracket before the disaster ($p<0.001$). The likelihood of insurance enrollment increased as income increased.

However, after the disaster, the rate of insurance uptake in none of the income brackets was significantly different from that in the lowest income bracket (See Table 3).

Compared to single individuals, married or widowed people had a significantly higher rate of enrolling in earthquake insurance post-disaster. In comparison, in the pre-disaster context, only married people had a significantly higher likelihood of purchasing insurance than single individuals. Owning homes or apartments increased the likelihood of insurance uptake compared to renters in pre- and post-Tōhoku Earthquake populations.

3.4.2 Relationship between individual characteristics and average risk perception divided into pre- and post-Tōhoku Earthquake datasets:

Splitting the data into pre- and post-Tōhoku Earthquake, the linear regression showed that risk perception was significantly higher in females than in males in both pre-Tōhoku Earthquake (t=-5.623; p<.001) and post-Tōhoku Earthquake (t=-5.266; p<.001).

3.4.3 Government Expectation, Risk, and Insurance

Before the Tōhoku Earthquake, the less people believed that the government should be involved, the lower the risk perception (t=11.225, p<0.001). In November, similar trends were found (t= 11.618, p<0.001). In both pre- and post-disaster, the government's expectation of support did not affect the likelihood of insurance enrollment (OR=1.068, p=0.314; OR=1.087, p=0.217).

Table 4: Government expectations in January and November, and the effect on insurance uptake

	JAN 2011					**NOV 2011**				
	B	Sig.	Exp(B)	95% C.I.for EXP(B)		B	Sig.	Exp(B)	95% C.I.for EXP(B)	
The administration's participation in strengthening of life-lines in towns through retrofit construction	-0.095	0.115	0.91	0.809	1.023	-0.058	0.108	0.943	0.879	1.013
The administration's participation in retrofitting private buildings	-0.011	0.829	0.989	0.891	1.097	0.017	0.729	1.017	0.925	1.118
The administration's participation in supplying emergency supplies.	0.045	0.453	1.046	0.931	1.174	-0.034	0.452	0.967	0.886	1.055
The administration's participation in retrofitting private buildings	-0.028	0.67	0.973	0.856	1.105	0.144	<.001	1.155	1.063	1.255
Constant	-0.71	<.001	0.492			-0.901	<.001	0.406		

3.4.4 Direct Experience of Loss and Fear Due to Tōhoku Earthquake

Table 5: Experiences' effect on insurance uptake and risk perception

	Odds of buying insurance			**95% C.I.for EXP(B)**		**Risk perception**		**95.0% C.I. for B**	
	B	Sig.	Exp(B)	Lower	Upper	B	Sig.	Lower	Upper
I felt endangered by the quake	-0.029	0.62	0.972	0.867	1.089	-0.067	<.001	-0.1	-0.034
I could not go home after the quake	0.007	0.91	1.007	0.898	1.129	0.061	<.001	0.027	0.094
I could not contact family and/or friends after the quake	0.085	0.131	1.089	0.975	1.215	-0.056	<.001	-0.088	-0.024
The disruption in life line (electricity, gas, water etc) and lack of supplies affected my daily life due to the quake	-0.001	0.987	0.999	0.879	1.135	-0.03	0.117	-0.067	0.007
I had to live in evacuation centers or temporary housing after the quake	-0.216	0.098	0.806	0.624	1.04	0.06	0.101	-0.012	0.133
Homes, cars, and other assets were damaged due to the quake	0.097	0.372	1.102	0.891	1.363	0.019	0.561	-0.044	0.081
Family and/or friends died due to the quake and related disasters	0.065	0.668	1.067	0.794	1.434	0.122	0.006	0.035	0.209
Family and/or friends lived in long-term temporary housing and evacuation centers	0.039	0.75	1.04	0.817	1.325	-0.082	0.024	-0.153	-0.011
My hometown was affected by the disaster and I am heart broken	-0.029	0.725	0.971	0.826	1.142	-0.013	0.591	-0.06	0.034
Due to the earthquake, the available jobs suddenly decreased	0.013	0.854	1.014	0.878	1.17	-0.057	0.008	-0.099	-0.015
Constant	-0.731	<.001	0.482			2.171	<.001	2.089	2.252
Risk perception: 1 is high, 5 low threat perception; negative coefficient suggests higher risk perception									

After conducting linear regression of experience and risk perception in the post-disaster population, the analysis showed that those who felt endangered by the shaking, those who couldn't go home, and those whose friends and family were missing had a significant relationship with risk perception. Those who experienced difficulty going home immediately after the quake had lower risk perception than those who could,

while those who felt endangered by the Tōhoku Earthquake or had friends and family missing had significantly higher risk perception than those who did not. In a logistic regression between negative experiences due to the disaster and insurance uptake, all loss experienced variables were

independent of insurance uptake (>0.001) (see Table 5).

4. Discussion

This study compared pre- and post-Tōhoku Earthquake exposure, risk perception, and preparedness behaviors. Different variables informed risk perception and insurance uptake in pre-and post-Tōhoku earthquake surveys.

4.1 Experience/witnessing a large-scale disaster, risk perception, and insurance enrollment.

A notable finding of this study was the adoption of insurance in the aftermath of the disaster. While income seemed to be a significant factor in the likelihood of buying insurance before the Tōhoku Earthquake, the findings pre-disaster contrasted with the population surveyed in November in the aftermath of the disaster. Income level did not significantly impact insurance adoption after the disaster. Notably, no statistically significant variances were observed in insurance enrollment between the lowest income stratum and any other income categories in November, six months after the earthquake, tsunami, and nuclear power plant disaster. These findings suggest that exposure to a major calamity, such as the Tōhoku Earthquake, may motivate individuals to consider insurance coverage regardless of household income.
This supports Lindell and Perry's 2012 PADM claim that protective behavior is not independent of risk perception [36].

4.2 Geographic distance from disaster, risk perception, and insurance

Proximity to disasters and hazards should increase risk perception, according to Lindell and Perry's PADM. Studies involving nuclear powerplant risk perception increase as the distance from the powerplant decreases [77]. Several studies regarding hurricane risk perception show proximity and geographic location are predictors of risk perception [78] [79]. Geographic

vulnerability is also known to be associated with taking protective actions in the face of a hurricane [80]. Nevertheless, neither geographical disparities nor distances from the Tōhoku Earthquake influenced risk perception or insurance enrollment in this study, in contrast to findings in several similar studies [81]. Experience and proximity to large disasters seemed independent concerning risk perception. Areas in Japan that have experienced large-scale disasters do not have a heightened risk perception. Before the 2011 Tōhoku Earthquake, the largest earthquake was in Niigata prefecture, categorized in the "Kantō" region, in 2006. Neither Kantō in the pre-disaster nor Tōhoku post-disaster showed a significantly increased level of risk perception compared to other regions in Japan.

However, these outcomes mirror those revealed in a prior investigation exploring flood risk, preparedness, and other climate change-related hazards [64,65]. The area of residence did not contribute to insurance uptake. In a pre- or post-disaster environment, we hypothesized that the most affected area would increase insurance uptake, which was not observed in this dataset.

4.3 Temporal distance and risk perception

Before the Tōhoku Earthquake, the most recent significant earthquake with a substantial death toll was the South Hyogo (also known as the Great Hanshin) Earthquake in January 1995 in the Kansai area. It measured a 7.2 magnitude and killed over 6,000 individuals [51]. Between 1995 and 2011, there were very few earthquake-related deaths. Few papers report results from studies of risk perception over time. The PADM supports the idea that the memory of past experiences influences risk perception. One study of the aftermath of Hurricane Katrina asked the victims about their subjective risk perception of a hurricane happening in the next year at 2-time points: immediately after Hurricane Katrina (time 1) and a year after Katrina (time 2) [62,64,65]. They found

that when comparing time one and time two, the subjective risk did not change. Even after informational lessons about hurricanes, explaining that devastating hurricanes are rare, the information did not change the perception between the 2-time points. Most participants did not reevaluate their initial high-risk assessment. The level of fear and perceived risk did not change the mental hardships that come with disasters. Mental illnesses caused by Katrina did not diminish even seven months longer after the disaster. Mental illnesses were far more significant in those with lower SES, with over 30% of residents experiencing post-traumatic stress symptoms [82].

Although one year did not change risk perception in Katrina's case, risk perception may start to fade after decades or generations. Communities create folk tales and often pass down historical occurrences through oral traditions. Floodplains, collective memory, and settlement locations were studied using records from 1293 in Central Europe. Looking at resettlement patterns after devastating floods that forced communities to build away from floodplains, the first generation after those who experienced the flood stayed away. After two post-flood generations, communities resettled in floodplains despite the risks of devastating floods [63]. This shines a light on the relatively short-lived risk perceptions passed down through generations, affecting only one generation after those who experienced floods to take natural disaster mitigating behaviors, then seemingly forgetting about the risk of floods.

4.4 Individual direct Experience, risk perception, and insurance.

Additional individual characteristics may influence risk perceptions, disaster-related losses, and the degree of trust in information concerning the risk of such losses. Notably, in this dataset, individuals who perceived themselves to be in jeopardy during the Tōhoku Earthquake, those

who were unable to return home immediately following the disaster, and those who experienced difficulties in establishing contact with family members or friends in the immediate aftermath exhibited significant effects in risk perceptions. Contrary to expectations, individuals who experienced a heightened sense of self-danger during the Tōhoku Earthquake and encountered difficulties immediately contacting loved ones in the disaster's aftermath demonstrated significantly lower risk perception. Conversely, those unable to return home promptly following the Tōhoku Earthquake event exhibited heightened risk perception. However, the literature regarding personal experience and risk perception is discrepant. Although risk perception was heightened through some experience, this analysis observed that personal experience of loss resulting from the disaster did not reveal a statistically significant increase in the likelihood of purchasing earthquake insurance, contrary to the logic supported by the PADM.

There has been conflicting evidence on how disaster experience affects individuals' risk perception [66,67,83]. Some literature supports that experiencing a climate change-related disaster increases the risk perception for climate change [84]. A study in Greece showed that direct experience with disasters increased environmental sensitivity, increasing risk perception in the population. However, people do not frequently experience large-scale disasters but use information and descriptions of hazards to inform their perception of risk and behaviors. It has been observed in psychological studies that the *description* of a rare negative experience will lead an individual to overestimate the perception of risk, while *experiencing* rare negative experiences leads to underestimating risk [66]. This paradox further obscures the formation and maintenance of risk perception aiming to increase preparedness behaviors.

4.5 Gender differences, having children or grandchildren, risk perception, and insurance.

Interestingly, sex was not a significant predictor of insurance uptake in this study. In previous literature, gender is observed to be a strong predictor of risk perception. Previous literature supports that females are more risk-averse than males in financial risk-taking [85].

There is evidence that mothers are more concerned about low-dose exposure to radiation after the Fukushima meltdown when compared to fathers. Anxiety was twice as high in mothers living in Fukushima compared to fathers living in Fukushima. Fathers, instead, reported milder forms of anxiety. This was a study that compared the gender differences in parents and anxiety.

Another surprising factor was that having children did 。lkj

4.6 Limitations

It is important to note that enrolling in insurance is not the most effective protective measure in the case of an earthquake and its related consequences [86]. There may be limitations in experience that influence insurance uptake. Those with direct experiences may have lost property, homes, and family members, none of which can be improved by purchasing insurance after the disaster.

The areas were too broadly grouped together.

Also, this dataset did not include older adults, a significant portion of the Japanese Population. Given their vulnerability, it is imperative that we study this demographic to mitigate injuries and fatalities resulting from natural hazards. The findings in this study must consider the data's limitations.

4.7 Future direction:

Future studies should explore optimism bias and its influence on threat perception and protective action. In this study, experiencing loss or fear of earthquakes did not consistently correlate with increased risk perception or enrollment in earthquake insurance. The PADM posits that

experiencing hazards heightens risk perception, thereby heightening the likelihood of adopting protective behaviors [36]. Government reliance, trust, and expectations also shape protective behavior, as the PADM outlines. The dataset used in this study questions the perceptions of the government on disaster preparation and recovery expectations rather than their opinion of governmental trustworthiness. Exploring trust in the government could offer valuable insights into individual preparedness measures in Japan.

The recent M7.5 earthquake and tsunami on the Noto Peninsula in January 2024, resulting in over 200 fatalities and 13,000 displaced people, serve as a reminder of the 2011 Tōhoku Earthquake [87]. Television programs and annual events commemorating March 11 keep the memory of the Tōhoku Earthquake vivid in the Japanese population's consciousness. Experiencing two tsunamis and earthquakes within 15 years may maintain the perception of earthquake and tsunami threats, making the Japanese population more inclined to participate in seismic hazard preparedness.

Furthermore, it is crucial to study the older population, given their susceptibility to mobility issues that hinder evacuation and other self-protective measures. With the expected Great Kantō earthquake looming, including the older population in disaster planning is vital.

In addition to older adults, disparities in resources between urban and rural areas in Japan pose challenges. Access to healthcare, for instance, varies significantly between these regions, complicating efforts to prevent morbidity in the aftermath of disasters. Studying the needs of rural and urban populations could ensure comprehensive disaster preparedness [88].

5. Conclusion

This study examines the 2011 Tōhoku Earthquake and its aftermath and attempts to clarify the relationship between disaster experiences, individual characteristics, risk perception, and

insurance uptake. The findings reveal a notable increase in risk perception and insurance enrollment following the Tōhoku Earthquake disaster. In the post-disaster context, results suggest that financial status did not affect the odds of buying insurance, implying the recognition of the significance of seismic insurance among individuals of all socio-economic backgrounds after witnessing a large-scale disaster.

These results have significant implications for enhancing preparedness measures. The observed surge in threat perception and insurance uptake emphasizes the importance of exposure to disasters in shaping individuals' perceptions of risk and motivating proactive measures. However, it is crucial to acknowledge that personal disaster experiences may also lead to diminished risk perception and preparedness behaviors, highlighting the need for further research into these phenomena. Moving forward, efforts to improve disaster preparedness should consider the many variables influencing risk perception and insurance uptake, including individual characteristics and the dynamics of disaster experiences. By gaining a deeper understanding of these factors, policymakers and stakeholders can develop more effective strategies for enhancing community resilience and mitigating the impacts of natural hazards.

CHAPTER III:

Older Adults, Loneliness, and Earthquake Disaster Preparedness in Japan

Abstract:

Objective: This study explores how loneliness affects earthquake risk perception and preparedness behaviors among older adults in Japan. Aging is often accompanied by increased vulnerability to natural disasters, and loneliness is hypothesized to compromise effective preparedness. Using the Japanese Older Adult Preparedness Model (JOAPM), which integrates the Protective Action Decision Model (PADM) and cultural context, we examine how loneliness influences both perceived earthquake risk and protective behaviors.

Methods: An online survey conducted in April 2024 gathered responses from adults aged 55 and older across four earthquake-prone Japanese prefectures. Measures included demographics, disaster experience, loneliness (UCLA Loneliness Scale), risk perception, and preparedness actions such as household adjustments. Regression and mediation analyses assessed the direct and indirect effects of loneliness on preparedness.

Results: Findings show that loneliness has a significant negative direct effect on disaster preparedness. However, it also slightly increases risk perception, which in turn is positively related to preparedness behaviors, suggesting a modest indirect pathway. Overall, the direct negative effect of loneliness outweighs the indirect benefit.

Conclusion: The results highlight the complex role of psychosocial factors in disaster readiness, suggesting that interventions should address information dissemination, self-efficacy, and the emotional isolation experienced by older adults in high-risk areas.

Keywords: Older Adult, Risk Perception, Earthquake, Preparedness Behaviors

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1. Introduction

With the development of modern medicine and the decrease in infectious diseases, people are living longer, yet are plagued with a variety of chronic diseases and disabilities[89]. In the Global North, there is a trend of decreasing birthrate, an increasing number of older adults, and a growing number of natural disasters worldwide[90]. With longer lives, many older adults enjoy independent living in their communities and homes. Yet, with older age, loneliness increases as adult children move away, friends and family pass, and one may experience decreased bodily functionality, resulting in diminished social interaction[91].

Loneliness affects an individual in many different spheres of life. In 1990, Chicago experienced a prolonged heat wave affecting the whole city and its residents. The heat wave effectively killed many older adults living alone and experiencing social isolation.[92] In recent years, loneliness has been labeled as an epidemic, having a significant impact on human health and dictating health outcomes.[93] Loneliness can both exacerbate and increase vulnerability in natural disasters.[94,95] Older adults and people with disabilities are usually more at risk than able-bodied populations in natural disaster contexts. Older individuals face a higher likelihood of developing adverse mental illnesses and suffer from depression at an increased rate.[96] Physically disabled individuals and those with chronic illnesses often struggle to manage their symptoms in the chaotic environment. Medication supply tends to be a challenge in disaster contexts, for people rarely evacuate with a comprehensive set of their medications or information on their medications.[24] This can cause complications, making continued treatments for illnesses and disabilities more difficult, and making preparedness an essential step in hazard-prone areas.[97] However, preparedness against disasters has been lower in older adult populations.[98] Prior research lacked a thorough

examination of the psychosocial impacts on older adults in disaster preparedness or risk perception, motivating our examination of this topic.

2. Background

2.1. Risk perception and loneliness

It is reasonably accepted in the literature that loneliness and its pervasiveness are public health concerns in many domains.[99] Loneliness among older adults is a greater health concern than in any other age group.[99] Older adults are generally more vulnerable due to increased loneliness and the health decline that comes with aging. Natural disasters introduce a layer of complications that may exacerbate the already high likelihood of loneliness and the health decline of aging. A study examining how social isolation affects risk perception found that those who experienced more social isolation had a more unrealistic risk perception than those who did not experience social isolation.[95]

2.2. Loneliness and protective behavior

Prior studies show a relationship between loneliness and protective behavior, although the literature is minimal. During the COVID-19 pandemic, it was observed that individuals who felt lonelier had less intention to engage in protective health behaviors.[100] The same paper noted a significant positive relation with purpose in life and engaging in protective behaviors. Meaning in life was also associated with experiencing less loneliness. Loneliness is also a risk factor in a disaster context. In 1990, Chicago experienced a prolonged heatwave that affected the entire city and its residents. The heat wave killed many older adults living alone.[21] In recent years, loneliness has been labeled as an epidemic, having a significant impact on human health and dictating health outcomes.[101] Loneliness can both exacerbate and increase vulnerability in natural disasters.[13]

2.3. Preparedness and Recovery

Preparedness is crucial for recovery and health in disaster contexts. Research has shown that individuals with better disaster preparedness tend to recover more quickly and experience fewer adverse health outcomes following disasters.[2,4,102] However, the relationship between loneliness, risk perception, and preparedness in the behaviors of older people remains understudied.

To understand this relationship, we surveyed Japanese adults in areas with high seismic risk to assess whether loneliness affects risk perception and preparedness behavior. This study is particularly relevant in the Global North, where older adults tend to be more independent than in the past, often living alone without the traditional family support structures.

2.4. Geographic and Environmental Factors

Many Japanese people live in coastal areas, which are particularly vulnerable to certain natural disasters, such as tsunamis and typhoons.[103] Despite the growing population of older adults in these regions, their specific needs are often not adequately considered in disaster planning and response.[104]

The environment, whether urban, suburban, or rural, also plays a significant role in experiences of loneliness and access to social support and other resources. Rural older adults may face unique challenges due to geographic isolation and limited access to services, whereas urban older adults may experience social isolation despite being physically proximate to others. [69,105,106]

2.5. Post-Disaster Changes

Following disasters, loneliness can increase, along with depression and lower social capital, as observed after Hurricane Katrina and the Gulf oil spill. The phases of post-disaster community relationships often follow patterns of initial solidarity or increased altruism, followed by a return to baseline.[107]

3. Model: Japanese Older Adult Preparedness Model (JOAPM)

The Japanese Older Adult Preparedness Model (JOAPM) draws from Lindell and Perry's Protective Action Decision Model (PADM) and emphasizes the influence of the social, environmental, and cultural context on shaping individuals' risk perceptions, consequently leading to adjustments in preparedness actions (Figure 3).[36] Expanding on the PADM, the JOAPM adds the psychosocial component as a product of demographic variables and a predictor of risk perception and subsequent preparedness behaviors. The societal experiences and positions of older adults are often unique and rely on psychosocial cues.[108] The JOAPM was mapped to explore how psychosocial elements, such as loneliness, affect the disaster perception and response of older adults, especially in Japan.

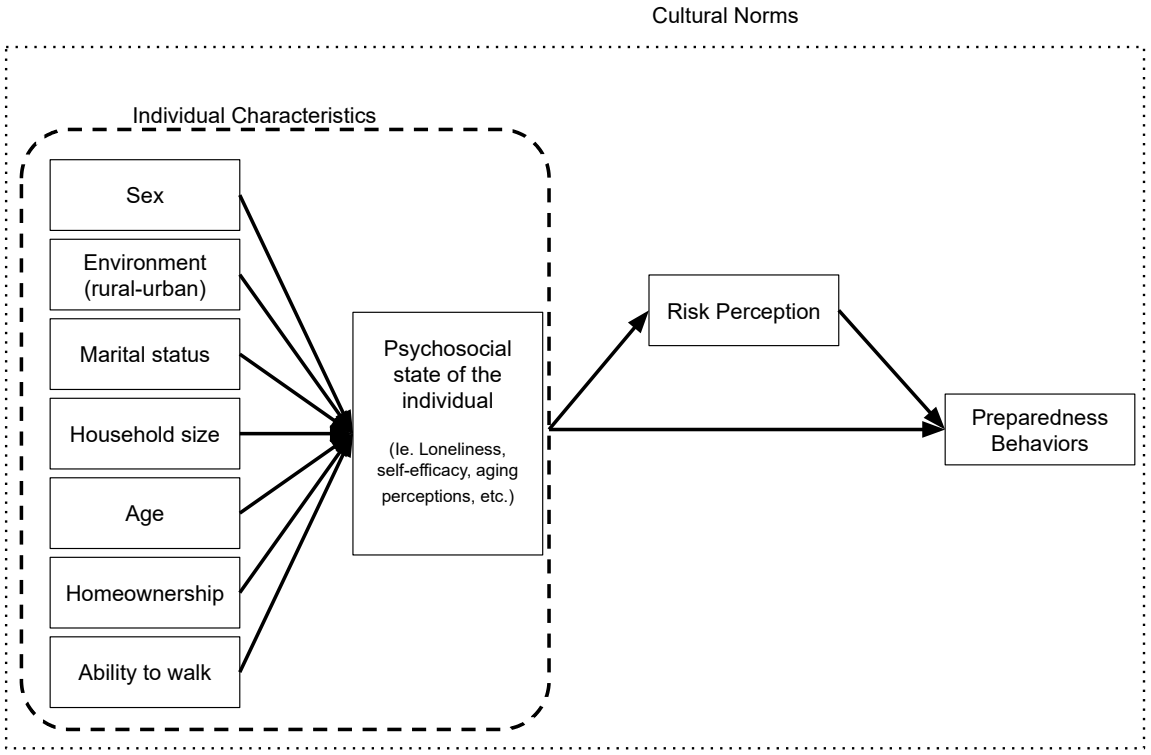

Figure 3: Japanese Older Adult Preparedness Model (JOAPM)

3.1. Demographic variables

Like the PADM, in the JOAPM, age, location of residence, marital status, and other individual characteristics inform the experience and risk perception, including exposure to information, attention, and comprehension, influencing the decision to engage in preparedness activities. However, in older adults, psychosocial variables, including but not limited to loneliness, self-efficacy, ageism, beliefs about aging, and changes in cognition and outlook, influence their views on risk perception and preparedness behaviors.

3.2. Psychosocial variable

Psychosocial components are essential in these risk appraisal and preparedness models, as older adults are more sensitive to their social and psychological environments.[109] Psychosocial factors have been shown to affect older adults in a variety of pathways. In this study, we focused on loneliness in older adults.

Social isolation and loneliness are linked to a range of adverse health outcomes, including depression and cognitive decline, both of which can impair risk perception and reduce individuals' capacity to prepare for natural hazards.[110] Loneliness also lowers resilience by depleting the psychological and emotional resources necessary to manage stress.

In contrast, healthy older adults often exhibit greater emotional resilience and tend to focus on positive emotional experiences, a phenomenon known as the positivity effect. While this adaptive strategy supports emotional well-being, it can also contribute to an optimism bias, where individuals underestimate their vulnerability or overestimate their ability to cope in the face of disaster.[108] Research has shown that even when presented with clear risk information, older adults may maintain unrealistic levels of optimism that can hinder preparedness efforts.[111,112] This is particularly true when optimism serves a mood-regulation function, choosing not to focus on unpleasant realities.[113]

However, this protective optimism is fragile. When social isolation and loneliness are present, they can disrupt access to emotionally meaningful activities and diminish the motivation to engage with risk-related information. These psychosocial stressors may contribute to feelings of helplessness or disengagement, thereby undermining both emotional resilience and practical disaster preparedness.

Further complicating the issue, loneliness negatively affects self-efficacy, one's belief in one's ability to manage challenges, which is a key predictor of disaster preparedness. High self-efficacy typically supports proactive behavior. However, in the context of loneliness, even those with high self-efficacy may fail to act. Isolation can dampen motivation, reduce perceived social support, and limit opportunities to access or share preparedness information, ultimately lowering an individual's confidence in their ability to prepare or respond effectively.[114–116]

When optimism bias and loneliness coexist, they can erode both emotional resilience and practical preparedness by reinforcing disengagement, avoidant coping, and a false sense of security. These psychosocial dynamics highlight the need to consider cognitive capacity, knowledge, and emotional and social context when assessing older adults' disaster readiness.

This study aims to better understand how loneliness affects risk perception and involvement in preparedness measures and how psychosocial states influence how older people relate to disasters. We examine demographic characteristics, including residence location (rural, suburban, or metropolitan), age, gender, etc., and their experience of loneliness. We then test the hypothesized direct relationship between loneliness and risk perception and preparedness.

3.3. Hypotheses

H1: Demographic characteristics affecting loneliness

a. A difference is observed in loneliness and different environments, with metropolitan areas experiencing higher loneliness in older individuals.
b. Older adults tend to be lonelier than younger older adults.
c. Females are more likely to experience loneliness.
d. Marital status is a protective factor for loneliness.
e. How many people they live with predicts loneliness; the more people they live with, the less lonely the individual.
f. Owning homes will reduce the likelihood of loneliness
g. Inability to walk unassisted increases loneliness.

H2: Loneliness directly influences protective behaviors negatively.

H3: Loneliness is also inversely related to risk perception. Higher loneliness is associated with lower risk perception.

H4: Risk perception is positively associated with preparedness. Higher the risk perception, the likelihood of partaking in preparedness increases.

H5: Risk perception mediates the relationship between loneliness and preparedness.

4. Materials and Methods

4.1. Participants and period

Study participants are Japanese. Japan is a rapidly aging country with one of the highest proportions of older adults worldwide.[117] With a higher proportion of older adults, protocols and methods for natural disaster preparedness must be adapted to meet the needs of older individuals, taking into account their disabilities, location of residence, social connectedness, and other factors.[22] Using the Survey Research Center in Japan, we recruited 1600 individuals from their representative pool of subjects. The survey targeted individuals over 55 years old living in four

eastern and southeastern prefectures: Tokyo, Kanagawa, Kochi, and Wakayama. The four prefectures were selected to observe rural-urban differences in older adults across various social structural environments with similar earthquake risks.

The survey was administered online in April 2024. Using the Yamane sampling method, 400 people were sampled from each prefecture. Notably, a large earthquake and tsunami hit Noto, Japan, on January 1st, 2024, killing just over 200 people, which may have affected risk perception and or protective behavior.

4.2. Measure

The surveys inquire about respondents' demographic information, views on risk, household preparedness, and loneliness, among other variables. The JOAPM, inspired by the PADM, follows the logic that individual characteristics influence psychosocial processes, such as loneliness in this study (see Figure 1). These variables affect risk perception, which is the core predictor of preparedness behavior. This study measures preparedness through the average number of preparedness actions taken.[118]

Loneliness is measured using the Abbreviated UCLA Loneliness Scale.[119] The scale uses seven items measured by a four-choice Likert Scale that ranges from 1, "I do not feel this way," to 4, "I feel like this often." The seven items ask questions such as, "I lack companionship" and "People are around me but not with me." The loneliness variable is transformed into one variable by averaging the seven items.

Risk perception is measured through the same set of questions that the government of Japan used in the pre- and post-Tohoku Earthquake and tsunami in 2011.[120] The questionnaire consists of four questions that measure the perception of the degree of an earthquake's effect. The items measuring risk perception include "I believe a very large earthquake that will devastate Japan is

likely in the future," or "the coming generations will experience more devastating disasters." The risk perception will be consolidated into a single variable by averaging the scores of the five items. This will allow us to compare with the 2011 Tohoku data.

The response variables are protective behaviors. One is the insurance enrollment, answered with a binary "yes" or "no." Another measure is household preparedness, assessed with a binary response ("yes" or "no") to six questions, including "measures taken to secure furniture" and "discussed disaster response and plans with family." The six items for household behaviors will be added to make a composite household preparedness score.

A simple mediation model assessed the relationship between risk perception and preparedness behaviors mediated by loneliness. This model identified Individual characteristics as covariates to isolate the relationship between loneliness, risk perception, and preparedness. Individual characteristics include residence location, marital status, homeownership, biological sex, household size, and age.

4.3. Procedure

The dataset reflects earthquake experiences and disaster attitudes, including risk perception and preparedness, with a focus on earthquakes as a disaster.

The Survey Research Center distributed the questionnaire to its survey population of over 3 million people, who are spatially representative of older adults (aged 55 and above) in four prefectures. The prefectures chosen—Tokyo, Kanagawa, Wakayama, and Kochi—were selected because they all face the Pacific Ocean, have similar earthquake and tsunami risks, and capture both rural and urban areas.

4.4. Statistical analysis

Bivariate analyses were conducted using t- and chi-square tests to explore the relationship between protective behavior, risk perception, various demographic variables, and loneliness. A one-way ANOVA was also employed to test the relationship between demographic variables and loneliness.

We employed Hayes' PROCESS Model 4 in SPSS to conduct the mediation analysis, using 5,000 bootstrap samples to generate 95% confidence intervals for the indirect effect. [104]

First, the relationship between loneliness, earthquakes, and risk perception is tested. It is hypothesized that loneliness will alter the perception of the risk of future earthquakes. Additionally, the relationship between loneliness and household earthquake preparedness is examined by testing whether there are significant changes in the number of protective behaviors practiced. The relationship between risk perception and protective behavior was also investigated. Then, the total effect of the mediation model was calculated to determine whether loneliness affects protective behavior through altering risk perceptions (See Figure 2).

All statistical analyses were conducted using SPSS Version 29.

4.5. Ethics Statement

The University of California, Irvine Institutional Review Board (IRB) in Human Subject Research approved all analyses of this paper.

4.6. Limitations in the Methodology

The survey participants were collected from a pool of registered subjects in Japan. They were randomly selected to reflect the population of each area, considering income and age. The population surveyed is representative of the older population in each prefecture. Representation of the data is limited as the survey was administered via the web, which may skew the results

due to the ability to use computers and the access to disaster information provided by the internet.

5. Result

The population of interest was aged between 55 and 79, with 400 individuals sampled from each region to ensure representation. In terms of residence, 576 individuals identified as living in an urban area, 323 in suburban areas, and 701 in rural areas. Regarding marital status, 203 were single, 1,134 were married, and 263 were widowed or divorced (See Table 6). The participants were asked about their participation in five preparedness activities, to which they either responded with a yes or a no. Over 85% of the participants had taken action in at least one preparedness behavior, and over half the participants had participated in 3 or more (See Table 7). A bivariate analysis revealed no statistically significant differences in loneliness between the areas. As expected, marital status revealed a significant difference ($F = 25.92$, $p < 0.001$) in loneliness, with singles reporting the highest level of loneliness and married couples reporting lower loneliness scores, on average. People who rented reported significantly higher levels of loneliness compared to those who owned their residences. Adults who lived with more than one person experienced less loneliness, on average (see Table 8).

Table 6: Demographic information

	N	%
Prefecture		
Tokyo	400	25.00%
Kanagawa	400	25.00%
Wakayama	400	25.00%
Kochi	400	25.00%
Gender		
Male	769	48.00%
Female	831	51.90%
Age		
55-59	374	23.40%

60-64	364	22.70%
65-69	329	20.50%
70-74	297	18.60%
75-79	236	14.70%
Residing environment		
Urban	576	36.00%
Suburban	323	20.20%
Rural	701	43.80%
Have trouble walking		
Yes	140	8.70%
No	1460	91.20%
How many people you live with		
0 (Alone)	289	18.10%
1	773	48.30%
2	312	19.50%
3	147	9.20%
4	53	3.30%
5+	26	1.60%
Marital status		
Single	203	12.70%
Married	1134	70.80%
Widowed/Divorced	263	16.40%
Living situation		
Rental	283	17.70%
Own House (Single standing)	986	61.60%
Own Apartment	331	20.70%

Conducting an ANOVA between different living environments —rural, suburban, and metropolitan areas —and loneliness, we found that living environments have minimal significance or effect on loneliness. A general trend of loneliness is increasing as the environment becomes more rural.

Table 7: Preparedness measures taken

	N	%
stockpiling food and water		
No	515	32.20%

Yes	1085	67.80%
knowledge of evacuation shelter		
No	397	24.80%
Yes	1203	75.10%
Have an emergency pack		
No	840	52.50%
Yes	760	47.50%
Discussion with family about emergency situations.		
No	830	51.80%
Yes	770	48.10%
Can help and rely on neighbors		
No	1160	72.50%
Yes	440	27.50%
sum of 5 prep activities		
0	188	11.70%
1	251	15.70%
2	287	17.90%
3	309	19.30%
4	319	19.90%
5	246	15.40%

Table 8:Average loneliness levels by household size

				95% Confidence Interval for Mean			
	N	**Mean**	**Std. Deviation**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
1	**289**	**16.54**	**5.267**	**15.93**	**17.15**	**7**	**28**
2	**773**	**14.63**	**4.771**	**14.30**	**14.97**	**7**	**28**
3	**312**	**14.84**	**4.638**	**14.32**	**15.35**	**7**	**28**
4	**147**	**15.56**	**4.953**	**14.75**	**16.37**	**7**	**28**
5	**53**	**14.45**	**4.721**	**13.15**	**15.75**	**7**	**26**
6+	**26**	**15.27**	**5.430**	**13.08**	**17.46**	**7**	**27**
Total	**1600**	**15.11**	**4.912**	**14.87**	**15.35**	**7**	**28**

Loneliness directly influences the number of protective actions taken. Loneliness has a direct, negative impact on preparedness: as loneliness increases, people take fewer preparedness actions (-0.0755, $p < 0.001$). Risk perception (0.2312, $p < 0.001$) has a more substantial influence on

preparedness activities than loneliness does. In other words, people who perceive higher risk tend to engage in more preparedness actions (see Figure 4).

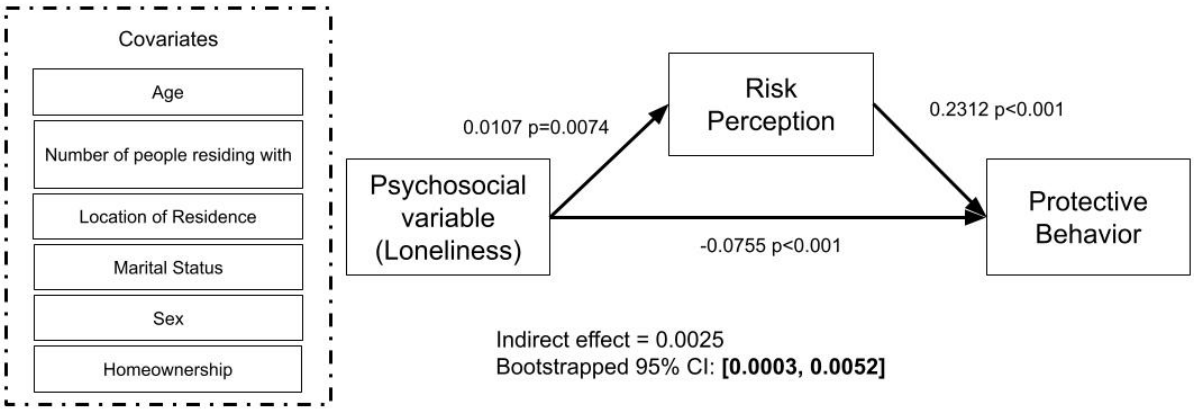

Figure 4: Mediation model of loneliness to protective action mediated by risk perception.

Analyzing the mediating role of risk perception between loneliness and protective behavior, we observed that loneliness does, in fact, slightly increase risk perception (0.0107, p = 0.0074). Since higher risk perception leads to more preparedness, loneliness indirectly increases preparedness by a small amount (0.0025).

6. Discussion

Consistent with our hypothesis, we found that loneliness is inversely associated with disaster preparedness. Individuals reporting higher levels of loneliness were less likely to engage in protective actions such as preparing emergency packs, securing furniture, or stockpiling supplies. While existing research on the relationship between loneliness and disaster preparedness is limited, this finding aligns with broader literature, suggesting that loneliness diminishes self-efficacy and is linked to lower participation in health-promoting and risk-reducing behaviors.[121] Loneliness may reduce one's motivation or confidence to engage in protective actions due to feelings of helplessness or a lack of perceived support.

Interestingly, our results show that loneliness is positively associated with risk perception, albeit weakly. This partially contradicts some prior findings that suggest socially isolated individuals tend to underestimate risks due to lower exposure to informal information networks.[95] However, other studies during the COVID-19 pandemic noted that loneliness was linked to heightened risk perceptions, mainly regarding financial or existential threats.[122] Loneliness may contribute to elevated anxiety, which may heighten sensitivity to environmental threats.

Despite this slight increase in risk perception, the indirect positive effect of loneliness via risk perception on preparedness was not as strong as the direct negative impact of loneliness on protective behaviors. This suggests that although lonelier individuals may feel more at risk, they remain less likely to translate this concern into preparedness actions—perhaps due to reduced self-efficacy, lack of motivation, or diminished social resources.[13,101] This dual pathway highlights the complexity of psychosocial influences in disaster contexts and contributes to the limited but growing literature on loneliness in emergency preparedness.[123,124]

These findings have theoretical implications for JOAPM. While the PADM emphasizes cognitive appraisal (e.g., risk perception) as a precursor to protective action, our results suggest that emotional and social variables, such as loneliness, may modify this pathway. Specifically, loneliness might shape risk perception but simultaneously inhibit behavioral follow-through. This disconnect emphasizes the need to expand preparedness models to incorporate psychosocial and affective dimensions more comprehensively, particularly among aging populations.

Our demographic findings offer additional insights. Contrary to some assumptions, no significant differences in loneliness were found across urban, suburban, and rural environments, although a slight trend indicated higher loneliness in rural areas. This supports previous research suggesting that relational factors such as marital status, cohabitation, and housing stability are stronger

predictors of loneliness than geographic context.[94,125] For example, married individuals and homeowners reported significantly lower loneliness scores, consistent with findings that social connection and residential security buffer against emotional distress.[126] With lower levels of loneliness, we found that the likelihood of individuals who partake in protective measures against earthquakes is higher.

Regarding risk perception and preparedness, gender and age emerged as significant predictors. Women and older individuals were more likely to take preparedness actions, which supports past research showing that women often engage more in health- and safety-related behaviors.[127,128, 102] However, these same demographic groups did not necessarily perceive higher levels of risk, suggesting that other mechanisms, such as social roles or cultural expectations, may influence preparedness behavior independently of risk perception.

Compared to the 2011 surveys administered to Japanese residents before and after the Tohoku earthquake, using the same items to measure risk perceptions, older adults generally tend to perceive higher risk compared to older individuals in this study. This data agrees with the existing literature, as older adults tend to perceive a higher risk. However, in January of 2024, there was a large earthquake and tsunami in Noto, affecting many older people. This could have affected older adults' risk assessment (See Table 9).

Table 9: Comparison of age groups' risk perception. Pre- and post-2011 Tohoku EQ and 2024 post-Noto

Average risk perception with scores from 1 (low risk) to 5 (high risk)					Japanese older risk perception avg Post-Noto 2024		
	Pre 2011 EQ		Post 2011 EQ		Age group	Mean	N
age group	Mean	N	Mean	N	55-59	3.8443	374
20-29	2.3189	660	2.0478	889	60-64	3.8777	364
30-39	2.2023	660	2.0723	889	65-69	3.8769	329
40-49	2.2155	660	2.0082	880	70-74	3.8434	297
50-59	2.1174	660	1.9804	894	75+	3.9195	236
Total	2.2135	2640	2.0272	3552	Total	3.8695	1600

These results have practical implications for the emergency preparedness, planning, and outreach of older adults. Disaster preparedness strategies must address emotional and social barriers, not just informational availability, as the PADM focuses on, in terms of social context. Interventions for older adults should include social support mechanisms, such as community buddy systems, facilitated family conversations, and outreach to individuals living alone. Preparedness messaging tailored to individuals experiencing loneliness may need to emphasize personal agency and achievable action steps, particularly in the absence of immediate social networks.[9,13] The cross-sectional design limits causal inference, and the online survey format may have biased the sample toward more digitally literate individuals who are possibly less isolated. Additionally, cultural variability in how loneliness, risk, and preparedness are experienced and reported may affect generalizability beyond Japan.[129] The reliance on self-reported measures increases the possibility of recall or social desirability bias.

7. Future Direction

Future research should explore alternative psychosocial mechanisms, such as purpose in life, trust in others, and perceived social capital, which may mediate the relationship between loneliness and preparedness.[100,130] Longitudinal studies would enable researchers to examine how these relationships evolve before and after disaster events and whether specific interventions, such as strengthening neighborhood ties or increasing social participation, can mitigate the loneliness-related preparedness gap. Another study could survey the populations of older adults across other countries with differing risk mitigation capacities, comparing their communication, understanding of risk, loneliness, and protective behaviors. For example, nations

in the Pacific Rim, such as the Western United States and the Southern hemisphere, face high risks of earthquakes.

Understanding how loneliness and related constructs like self-efficacy and optimism bias operate across different cultural contexts remains underexplored. Community values, social connectedness, and cultural narratives around self and responsibility all shape risk perception and preparedness in diverse ways. A culture's influence on the perception of loneliness can also influence group consciousness and political engagement. For example, literature has found that in a more collective society, a decision reached by trusted leaders will be a cue to action for behavior such as community-wide drills.[131] Meanwhile, individual agency and motivations tend to predict behaviors in a society that values individual decisions.[132]

Loneliness is also a factor that needs to be addressed pre- or post-disaster; we must value the needs of elderly individuals in general. In a society that values productivity and often measures the value of people by their individual contributions to society, it can be challenging to form relations and focus and allocate the already scarce resources to vulnerable populations.[50] A more significant challenge may be encouraging the shift in social attitudes towards the elderly and the value they can provide, particularly in terms of productivity.

8. Conclusion

This study is among the few empirical studies examining the relationship between aging, earthquake risk perception, and preparedness, with a specific focus on how psychosocial factors, such as loneliness, might affect behaviors. The findings reveal that loneliness has a complex impact on disaster preparedness among older adults, slightly increasing risk perception but significantly reducing the likelihood of taking protective actions.

As societies worldwide age and climate-related disasters become more frequent and severe, it is urgent to understand how emotional and social vulnerabilities may impact disaster readiness. Integrating psychosocial factors in emergency planning is not just a public health issue but also one of equity and resilience.

Future research must further explore the unique effects of loneliness to illuminate the complex relationship between experiencing old age, loneliness, self-efficacy, optimism bias, and information attainment. These factors are crucial in comprehensive disaster preparedness and could further enhance disaster preparedness in community-dwelling adults.

This study investigated the role of loneliness in shaping earthquake risk perception and preparedness behavior among older adults in Japan. We created the Japanese Older Adult Preparedness Model (JOAPM), which was informed by the Protective Action Decision Model (PADM) [28]. Our findings reveal a complex interplay between psychosocial and behavioral variables, with loneliness exerting both direct and indirect influences on preparedness actions through its relationship with risk perception.

CHAPTER IV:

Lessons Learned from the 2011 Tohoku Earthquake: Challenges and Innovations in Disability-Inclusive Infrastructure and Preparedness

Abstract

With Japan's rapidly aging population and high seismic events, understanding disaster preparedness among older adults is a critical component of inclusive disaster planning. This study investigates the relationship between walking disability and earthquake preparedness among 1,600 community-dwelling adults aged 55 and older in four high-risk prefectures (Tokyo, Kanagawa, Kochi, and Wakayama). Contrary to widely held assumptions, statistical analyses, including chi-square tests, multivariable regression, and mediation modeling, found no significant association between walking difficulty and either risk perception or the number of preparedness actions taken. Instead, preparedness was significantly influenced by contextual and infrastructural factors: individuals living in urban or suburban environments, in multi-person households, or owning homes were more likely to engage in protective measures such as stockpiling supplies, identifying evacuation shelters, and having emergency plans.

Risk perception was significantly correlated with preparedness ($p < .001$), yet it did not mediate the relationship between disability and readiness behaviors. These findings suggest that infrastructural access and social connectivity may outweigh individual physical limitations in predicting preparedness outcomes in high-risk prefectures in Japan. Japan's integrated approach, as stated in the Sendai Framework for Disaster Risk Reduction, including accessible building codes, community-wide drills, and multi-modal alert systems, may mitigate typical disparities seen in other countries. This research highlights the critical role of designing equitable

infrastructure and emergency protocols that enable older and mobility-limited individuals to participate fully in disaster preparedness. This paper informs both national and international applications for inclusive design, policy recommendations, and information and resource attainment for community-dwelling older adults in Japan. However, cultural differences could make implementing a similar intervention with similar results challenging.

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1. Introduction

Natural hazards often escape attention until a disaster occurs, leading to morbidity and casualties, along with homelessness and, at times, affecting the workforce. While catastrophic disasters seem rare, society assigns value to people based on their functionality, leaving individuals with disabilities and older adults marginalized in disaster planning. Issues like unawareness, rapid fire spread, and mismanagement did not provoke societal demands for improved disaster education for older adults. The 2011 Great East Japan Earthquake and Tsunami saw 89% of disaster-related deaths among adults over 65, highlighting the need for understanding their specialized requirements [133,134].

The intersection of aging and disability creates vulnerabilities that demand attention in disaster preparedness. Studies have consistently shown that older adults with disabilities face heightened risks during disasters due to multiple factors, including reduced mobility, chronic health conditions, mental health disruptions, and social isolation [135,136]. This vulnerability was evident during Hurricane Katrina, where 71% of those who died were over 60 years old, and during the 2011 Tohoku disaster, where evacuation challenges for disabled residents led to significantly higher mortality and morbidity rates [19].

Regardless of these known vulnerabilities, disaster preparedness often fails to address the needs of older adults and those with disabilities. Traditional preparedness recommendations may be impractical or insufficient for individuals with mobility limitations or other disabilities [31,137]. Furthermore, research suggests that standard emergency response protocols may not account for the complex needs of this population, particularly in terms of evacuation procedures and access to emergency services [138]. A literature review revealed that those needing help with daily activities were less likely to prepare for emergencies. Natural hazards also expose vulnerabilities

in healthy, independent older adults. Tools and communication methods neglect their perspectives and are often excluded from disaster planning. Awareness of disaster risk is lower among older adults, leading to unrealistic risk perceptions that impact preparedness. Additionally, optimism bias may hinder adequate preparation despite high risk perception [139,140]. Medical conditions or disabilities often serve as barriers to preparedness, worsening vulnerability. The 2011 Tohoku Earthquake and Tsunami highlighted these vulnerabilities. With the rapidly aging population and high exposure to natural hazards, Japan presents a unique context for researching older adult hazard risk perception and preparation. With one of the world's highest proportions of adults aged 65 and older (28.7% as of 2020), Japan's experience in disaster preparedness for older adults offers valuable insights for other aging countries (Cabinet Office, Government of Japan, 2020). Japan's approach to disaster preparedness, shaped by frequent natural hazards and a strong emphasis on community and neighborhood resilience, provides a crucial example for understanding how disability may influence preparedness behaviors among older adults [141].

This study examines the relationship between disability status, specifically walking difficulty, and disaster preparedness among older adults in Japan. By focusing on urban and rural areas with similar earthquake risks, we investigate how disability status influences risk perception and preparedness behaviors. Our research is guided by the Japanese Older Adult Preparedness Risk Model (JOAPM), informed by Lindell and Perry's Protective Action Decision Model (PADM), which provides a framework for understanding how individual characteristics and environmental factors influence preparedness decisions [36]. The findings from this study have important implications for understanding how disability status affects risk perception and preparedness behavior in older adults in Japan with a high likelihood of earthquakes—identifying effective

strategies for supporting vulnerable populations in disaster preparedness, informing policy development for inclusive disaster risk reduction and comparing and contrasting the United States' approach to disaster risk reduction in vulnerable populations, such as older adults.

Cases from the Tohoku earthquake and tsunami:

The 2011 Tohoku Earthquake and Tsunami disproportionately affected the older adult population, with 89.1% of disaster-related deaths occurring among people 65 and older. Disability significantly increased death rates, with disabled individuals dying at twice the rate of the general population. Over 14,000 elderly residents in care facilities were evacuated [19]. Evacuations of 27 nursing home residents by bus in Minamisanriku were trapped in floodwaters due to traffic and tsunami onset, leading to multiple fatalities. In Kesennuma, only half of 96 elderly residents were evacuated due to mobility and transport issues before the tsunami struck [142].

The disaster also disrupted healthcare, leading to a drastic increase in mortality risk among older adults with chronic conditions [143]. The elderly were disproportionately affected, with poor conditions in evacuation centers worsening their health. A study of 158 evacuees in Yamamoto Town found that many experienced rapid functional decline, with 38% reporting significant decreases in ADLs. Social isolation further aggravated the disasters' effects, where elderly individuals living alone were often not found for days post-disaster [19]. However, community ties sometimes led to identifying and rescuing isolated elderly residents. Overall, the disaster significantly impacted mortality rates among older adults.

1.2 Japanese Older Adult Preparedness Model (JOAPM)

The Japanese Older Adult Preparedness Model (JOAPM) draws from Lindell, and Perry's Protective Action Decision Model (PADM) and emphasizes the influence of the social,

environmental, and cultural context on shaping individuals' threat perceptions, consequently leading to adjustments in preparedness actions (Figure 1)[36].

The social, environmental, and cultural contexts encompass variables ranging from modes of information acquisition to personal characteristics such as age, ability, and location of residence. This collection of variables collectively constructs the social and environmental backdrop of an individual's risk assessment and decision-making processes. The information gleaned from these socio-environmental and cultural contexts shapes the decision-making trajectory, ultimately culminating in an informed subjective risk and threat evaluation in older adults.

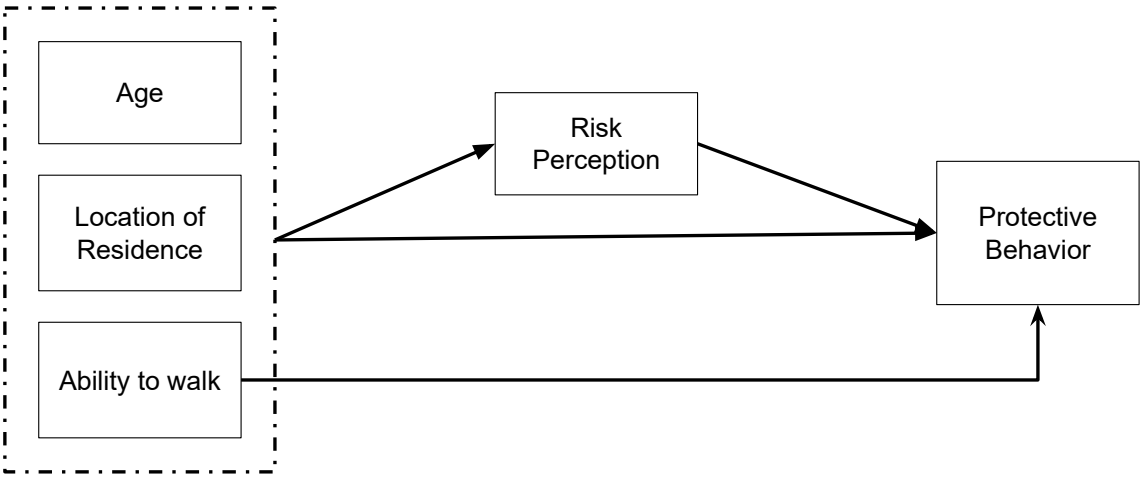

Figure 5: Simplified Japanese Older Adult Preparedness Model

In the JOAPM, age, location of residence, and ability to walk are hypothesized to affect risk perceptions. Subsequently, this perceived level of risk serves as a determinant, guiding an appropriate behavioral response. The model was applied to evaluate the perception of threat and protective behavior, which may be influenced by disability.

2. Materials and Methods

2.1 Participants and period

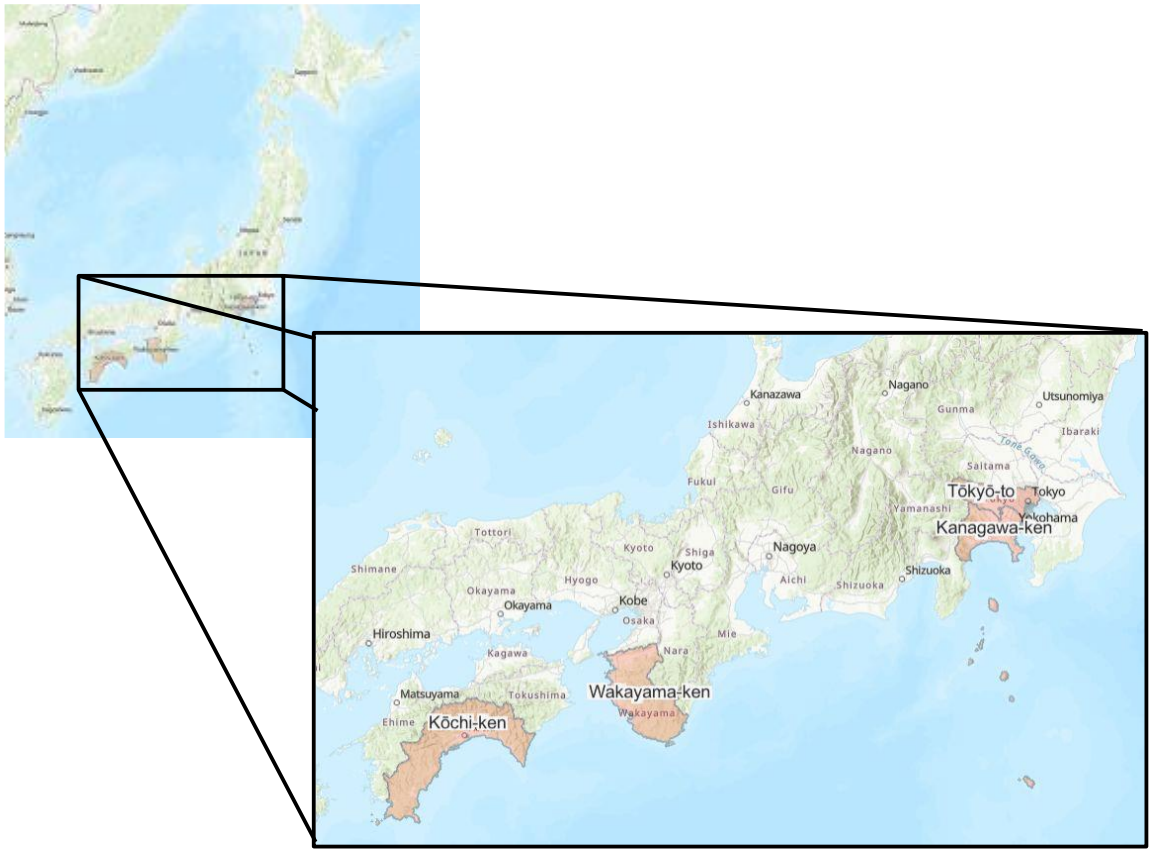

Figure 6: Map of prefectures sampled

Japan's aging population leads to urgent changes in disaster preparedness protocols for older adults, considering factors like disability and social connections. A survey focused on individuals over 55 in four prefectures—Tokyo, Kanagawa, Kochi, and Wakayama—was conducted online in April 2024, using the Yamane sampling method to select 400 participants from each area (see fig 2.). This study aimed to compare rural and urban responses to earthquake risks.

2.2 Measure

The surveys collect respondents' demographic information, risk views, hazard experiences, household preparedness, and disaster management data. The model indicates that individual characteristics influence psychological processes, categorized into two levels: pre-decisional

(age, location of residence, and walking difficulty). The decision-making process includes risk perception, a key predictor of preparedness behavior, measured by the number of preparedness actions taken.

The JOAPM outlines psychological processes, highlighting risk perception, which affects the adoption of protective behavior. Risk perception is evaluated using a questionnaire by Lindell and Prater, featuring five questions scored on a five-level Likert Scale. Scores are averaged for a consolidated risk perception variable [144]. The response variables include protective behaviors, such as household preparedness (binary response to five questions, including emergency pack readiness, family disaster discussions). Individual characteristics assessed include walking ability, residence location, and age.

2.3 Procedure

The dataset reflects earthquake experience and disaster attitudes, including risk perception and preparedness, focusing on earthquakes as a disaster. The Survey Research Center distributed the data to its survey population of over 3 million people, which spatially represents the population of older adults (over 55 years) in four prefectures. The prefectures chosen—Tokyo, Kanagawa, Wakayama, and Kochi—were selected because they all face the Pacific Ocean and have a similar earthquake risk, with over a 99% chance of a large earthquake occurring in the Nankai Trough in the next 30 years [44]. We sampled community-dwelling older adults, as they usually have limited access to resources and connectedness compared to adults in assisted living or specialized communities, which enhance social connectivity and foster a sense of community. We consciously chose community-dwelling older adults, as fewer support systems exist for this population, making isolation a more common phenomenon. The question we aimed to answer consisted of the effects of walking difficulty on disaster risk perception and preparedness of

those who live independently. The survey was then tested against the advisor of the survey company. An author translated the survey from English to Japanese and received feedback from another bilingual researcher, which was then tested against the advisor of the survey company.

2.4 Statistical analysis:

Bivariate analyses were conducted using t- and chi-square tests to explore the relationship between disability status, risk perception, and preparedness behaviors. We hypothesize that difficulty walking will be associated with higher risk perception but lower preparedness behaviors.

Multivariable logistic regression was conducted to assess the relationship between disability and the accomplishment of every protective measure to evaluate whether disability status is associated with certain protective activities. The protective action is a set of five questions: stockpiling food and water, knowing where their evacuation shelters were located, discussing an emergency evacuation plan with friends and family, having an emergency pack ready, and being able to rely on neighbors for assistance in the case of a disaster. We hypothesize that adults who have difficulty walking will have a lower likelihood of partaking in every activity but an even stronger negative relationship with being able to rely on neighbors to help during an earthquake. We used the PROCESS macro (Hayes, 2018) in SPSS 29 to test a mediation model (Model 4), with bootstrapping set at 5,000 samples to obtain 95% confidence intervals for the indirect effect. Using the PROCESS macro, we first assess the direct relationship between disability status and preparedness behavior and the association between disability status and risk perception separately. Then, the total effect of disability status on the number of preparedness activities was evaluated through risk perception as a mediator. We hypothesize that a direct association between difficulty walking and risk perception will have a positive relationship, linking

disability to a heightened risk perception. We hypothesize that disability will have a negative association with the number of preparedness levels, illustrating the difficulty of disabled individuals to partake in preparedness behaviors.

All statistical analyses were conducted using SPSS Version 29.

2.5 Ethics statement

The University of California, Irvine Institutional Review Board (IRB) in Human Subject Research approved all analyses of this paper.

2.6 Limitations in Methodology

The survey participants were self-selected from registered subjects and were recruited to reflect each area's population, considering income and age. Data is limited due to the online survey, which may skew results based on varying computer use and access to disaster information. While many disabilities exist, this study focused on mobility and independent navigation, not the only disability affecting preparedness efforts. We specifically focused on walking because mobility is crucial in evacuation, recovery, and preparedness.

3. Results

Table 10: Sample Demographics

	N	%
Prefecture		
Tokyo	400	25.00%
Kanagawa	400	25.00%
Wakayama	400	25.00%
Kochi	400	25.00%
Gender		
Male	769	48.00%
Female	831	51.90%
Age		
55-59	374	23.40%
60-64	364	22.70%

65-69	329	20.50%
70-74	297	18.60%
75-79	236	14.70%
Residing environment		
Urban	576	36.00%
Suburban	323	20.20%
Rural	701	43.80%
Have trouble walking		
Yes	140	8.70%
No	1460	91.20%
How many people you live with		
0 (Alone)	289	18.10%
1	773	48.30%
2	z	19.50%
3	147	9.20%
4	53	3.30%
5+	26	1.60%
Marital status		
Single	203	12.70%
Married	1134	70.80%
Widowed/Divorced	263	16.40%
Living situation		
Rental	283	17.70%
Own House (Single standing)	986	61.60%
Own Apartment	331	20.70%

Table 11: Protective action taken by sampled population

	N	%
stockpiling food and water		
No	515	32.20%
Yes	1085	67.80%
knowledge of the evacuation shelter		
No	397	24.80%
Yes	1203	75.10%
Have an emergency pack.		
No	840	52.50%
Yes	760	47.50%
Discussion with family about emergencies.		
No	830	51.80%

Yes	770	48.10%
Can help and rely on neighbors		
No	1160	72.50%
Yes	440	27.50%
sum of 5 prep activities		
0	188	11.70%
1	251	15.70%
2	287	17.90%
3	309	19.30%
4	319	19.90%
5	246	15.40%

The sample demographic had about 8% of those who experienced difficulty walking (see Table 10). Through a chi-squared test, disability, or the ability to walk, does not significantly affect Risk perception, $p>0.05$. The ability to walk has no significant effect on the number of preparedness activities. is listed

In a multivariable regression, controlling for the number of people living with and the area of residence, difficulty walking was not associated with risk perception or the average number of earthquake preparation activities (see Table 11).

Table 12: Multivariable model predicting risk perception. Risk perception is the dependent variable.

Model						95.0% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
Constant	3.067	0.066		46.351	<.001	2.937	3.197
How many people do you live with?	0.087	0.022	0.098	3.867	<.001	0.043	0.131
Single	0.251	0.073	0.087	3.433	<.001	0.108	0.395
Rent	-0.349	0.053	-0.174	-6.579	<.001	-0.453	-0.245
Own single-standing house	-0.338	0.063	-0.141	-5.344	<.001	-0.463	-0.214

The number of people who lived with the participant was significantly related to risk perception; the more people they lived with, the higher the risk perception. Owning a house and being single were also significantly associated with risk perception (see Table 12).

Table 13: Likelihood of participating in each preparedness activity depending on different predictors

	Stockpiling food and water		Have an emergency pack		Evacuation plan with family		Can rely on neighbors for aid		knowledge of the evacuation shelter	
Predictor variables	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)
The number of people lived with	0.687	1.024	0.381	1.048	0.007	1.16	0.91	0.993	0.604	1.033
single	<.001	0.501	<.001	0.499	<.001	0.323	0.262	0.755	0.035	0.65
Married.	0.886	1.024	0.109	1.28	<.001	2.023	0.01	1.604	0.263	1.214
rent	0.037	0.683	0.831	0.964	0.255	1.23	0.042	0.649	0.027	0.657
Owning a single-house	0.527	1.105	0.022	1.382	0.079	1.291	0.183	1.233	0.272	1.201
Urban	<.001	2.102	<.001	1.718	0.104	1.235	0.411	0.891	0.005	1.5
Suburban	<.001	2.122	0.006	1.477	0.706	1.056	0.408	0.878	0.014	1.504
I have difficulty walking	0.754	1.062	0.326	0.835	0.557	0.895	0.779	1.061	0.839	1.043
Lindell risk perception	0.025	1.142	0.53	1.036	0.608	0.971	<.001	0.812	0.224	1.08
Constant	0.763	0.87	0.189	0.565	0.059	0.429	0.118	0.461	0.486	1.407

Risk perception and the total number of preparedness behaviors taken are highly correlated, but risk perception and individual preparedness activities were not correlated (Table 13).

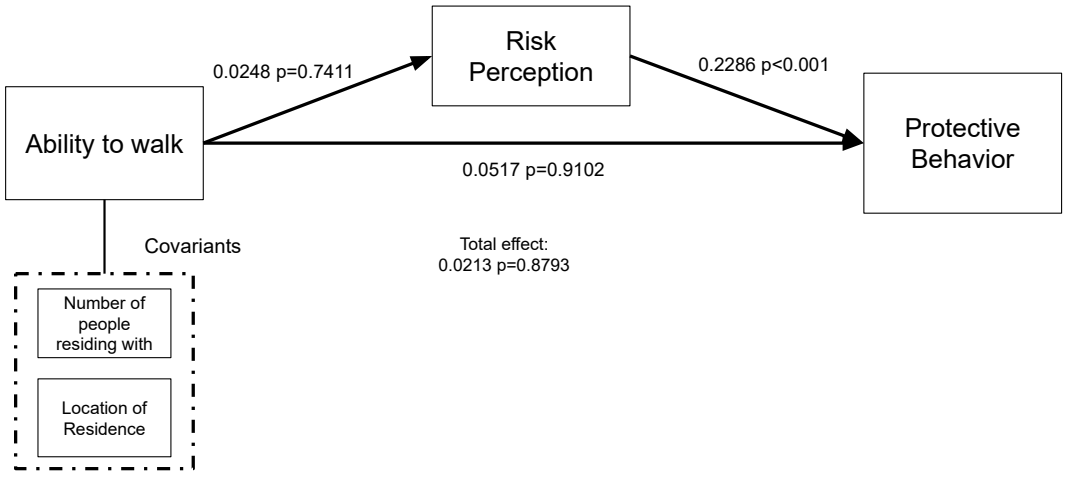

Figure 7 Mediation model visual.

In terms of predictors of risk perception, the coefficient for disability is 0.024658, p = .7144 (not significant), indicating that disability does not significantly predict average risk perception (see fig 3). For the type of residence environment: rural, suburban, and urban, the coefficient is 0.0458, p = .0336 (minimal sig not in figure), suggesting that more rural environment is positively related with higher risk perception.

In the mediation model describing the relation from disability to risk perception to preparedness measures, the R-squared was 0.0366, indicating that the predictors, including the mediator, explain about 3.66% of the variance in preparedness activities. The model is significant (p < .001), indicating that the combined effect of the predictor, disability, and risk perception significantly predicts preparedness activities. However, the coefficient of the ability to walk to preparedness was not significant. Risk perception's coefficient to preparedness was 0.2247, p = .0000 (significant), suggesting a significant mediating effect. The location of residence was also significantly related to readiness, 0.1456, p = .0010.

The total effect of the model connecting disability to the number of preparedness activities was significant with R squared: 0.0251, indicating that about 2.51% of the variance in prep activities

is explained by the predictors **without** the mediator. The total Effect of disability on preparedness activities: -0.0219, not significant (p = .8757). The indirect effect of disability on preparedness activities through average risk perception: -0.0056 (estimated via bootstrapping) suggesting that the indirect effect is not statistically significant. The mediation analysis suggests that the direct and indirect effects of disability on preparation activities are not significant when controlling for covariates and considering the mediating effect of average risk perception.

4. Discussion

It is a notable finding that those who reported difficulty walking did not have significantly different levels of risk perception and preparedness action taken from the able population sampled. This challenges the common assumptions about disability status and disaster preparedness, suggesting that other factors may play more crucial roles in determining preparedness behaviors among older adults in Japan.

4.1 Individual Characteristics, Risk Perception, and Earthquake Preparedness

In this study population, age did not significantly affect risk perception, although there was a slight positive relationship. In a previous study examining the age differences and risk perception in a population pre- and post-Tohoku Earthquake and Tsunami, diverging from existing literature, it was revealed that age differences and risk perception were not seen in participants between the ages of 20 and 60 [120].

4.2 Physical Disability Impact in Japan vs US.

The Japanese and American disaster preparedness systems for older adults reflect different approaches. Our study shows that 67.8% of Japanese seniors maintain emergency supplies, 75.1% know evacuation shelter locations, 47.5% have emergency packs ready, and 48.1% have discussed plans with family. Only 11.7% reported being completely unprepared. No significant

difference in risk perception was found between individuals with and without walking difficulties ($p > 0.05$). Preparedness activities did not vary between those who are able and those with walking challenges ($p > 0.05$) (see Table 13). A study of 1,304 older adults in the US showed that only 34.3% had an emergency supply kit, 24.8% had a 3-day water supply, 15.1% had discussed emergency plans with family, and fewer than 20% participated in disaster preparedness education [145]. In contrast, nearly half or more of our surveyed population engages in preparedness measures.

In the US, older adults with disabilities faced significant barriers in hazard preparation [146]. For example, they experienced limited access to emergency information, had physical barriers to stockpiling supplies, transportation challenges that affected evacuation planning, and higher rates of social isolation affecting community support, resulting in an environment that made individual disaster preparedness more difficult. In our sample of older adults, we only examined adults who lived in a community and focused on the population with difficulty walking, as we aimed to sample community-dwelling and independently living adults. Community-dwelling adults also tend to have higher ADLs (Activities of Daily Living), so the current study did not make that the research focus. Those with lower ADLs could have helpers or support systems in place, which may affect resource and information attainment in these populations. Also, due to the limitation of administering the survey online, we could not reliably sample adults with cognitive disability or ailments. A systematic review by Aldrich & Benson (2008) identified lower preparedness rates among older adults with functional limitations. Resource attainment was a significant contributor to urban-rural disparities in access to preparedness. An important difference between Japan's and the US's hazard preparedness measures could be due to the lack of older adults in planning and participating in community preparedness programs.

4.3 Community Integration

Between Japan and the US, there are differences in community engagement. Japan regularly holds community-wide disaster drills that include all residents, while in the US, preparedness is a more individual endeavor; everyone is responsible for their protection against hazards [147]. The government also supports Japanese residents with support systems by creating vulnerability maps and funding protective measures [148]. The US is less generous with its government support, leaving preparedness to individual and family resources [145]. Japan's centralized, systematic approach to disaster preparedness may lead to more equitable outcomes across ability statuses. Unlike US studies showing significant preparedness gaps between disabled and able older adults, our findings in Japan indicate no such disparities [145,146]. Japan's success suggests that community-based approaches are more effective than the individualized strategies implemented in the US (Aldrich & Benson, 2008). This success may stem from implementing the Sendai Framework for Disaster Risk Reduction.

4.4 Implementation of the Sendai Framework for Disaster Risk Reduction

Japan has been actively improving disaster response through the Sendai Framework for Disaster Risk Reduction. The framework establishes a significant shift in disaster preparedness by recognizing disabled individuals as crucial stakeholders in disaster planning and preparedness, involving them in policymaking. In an aging country like Japan, acknowledging older adults' valuable experience and knowledge in disaster situations can lead to inclusive public training and education programs to improve pre-disaster preparedness, response, and recovery. The US is limited in the outreach and involvement of elderly and disabled people as stakeholders in disaster preparedness. Cultural differences between countries could affect older adults' preparedness activities.

4.5 Infrastructure and Engineering Analysis between Japan and the US

Japan's building codes have significantly evolved since the 1995 Great Hanshin Earthquake, with improved accessibility requirements [149]. Doors must be wide enough to accommodate wheelchairs and beds (Tokyo Metropolitan Government, 2022). US codes are primarily shaped by the Americans with Disabilities Act (ADA). The ADA mandates ramps and specific implementation regulations [150], although state-specific differences in emergency plan implementation create varying readiness for elderly and disabled populations.

4.5 Emergency Infrastructure Recommendation

Research by the National Research Institute for Earth Science and Disaster Resilience (2023) recommends evacuation and communication infrastructure improvements. For evacuation routes, proposed measures include backup power for automatic doors, handrails on all emergency paths, and photoluminescent guidance systems for better visibility. Communication infrastructure strongly emphasizes the need for multi-modal warning systems, redundant networks, and visual/tactile alerts to ensure accessibility [151]. This infrastructure approach significantly improves disaster preparedness and response for mobility-impaired older adults. The initial costly investment is justified by lower response costs and better disaster outcomes (Asian Development Bank, 2023). The Japanese policies integrated accessibility and disaster preparedness and offer recommendations for other nations developing similar infrastructure.

5. Limitations:

The recent M7.5 earthquake and tsunami on the Noto Peninsula in January 2024, resulting in over 200 fatalities and 13,000 displaced people, serves as a reminder of the 2011 Tōhoku Earthquake [87]. Television programs and annual events commemorating March 11 keep the memory of the Tōhoku Earthquake vivid in the Japanese population's consciousness.

Experiencing two tsunamis and earthquakes within 15 years may maintain the perception of earthquake and tsunami threats, making the Japanese population more inclined to participate in seismic hazard preparedness. Cultural differences may also affect the generalizability of countries with different social and public infrastructures. Results emphasize Japan's unique disaster preparedness culture and collectivist society, which has few ethnic variations.

6. Conclusion

This study examined the relationship between walking disability and disaster preparedness among older adults in Japan, using a representative survey sample of 1,600 individuals across four earthquake-prone prefectures. Contrary to existing research, our findings revealed no statistically significant relationship between walking difficulty and earthquake risk perception or preparedness activities. Participants with and without mobility challenges reported similar levels of preparedness, challenging widely held assumptions about the inherent vulnerability of disabled older adults in disaster environments. Instead, contextual factors, such as residential environment (urban/suburban vs. rural), household size, marital status, and housing ownership, were stronger predictors of both risk perception and preparedness. Notably, individuals living with others were significantly more likely to perceive risk and engage in protective behaviors. Moreover, while risk perception strongly predicted the total number of preparedness actions taken ($p < .001$), it did **not mediate** the relationship between disability status and preparedness, suggesting that other structural and social factors are more influential in disaster readiness. These findings suggest that in Japan, multi-level supports in infrastructure, community engagements, and inclusive policy writing in the Sendai Framework of Disaster Risk Reduction may have contributed to reducing disparities in disaster preparedness often seen in the older adult population in other countries, such as the US. To be applicable internationally, an infrastructure

change and narratives and attitudes surrounding disaster preparedness must change, as a population and in political discourse. As aging populations grow worldwide, these insights are essential for shaping equitable, accessible disaster risk reduction strategies in both policy and practice.

Future research should consider comparing preparedness approaches between Japan and other countries. The impact of cultural values on disaster preparation effectiveness should be explored with special emphasis on disaster communication and public engagement, and eventually, the transfer of successful disaster preparedness practices across cultural contexts. With the rapidly aging population worldwide, we are observing an increase in vulnerable people and a more diverse population. In the 2011 Tohoku earthquake and tsunami, we observed that many old and disabled individuals were greatly unaccounted for. Japan has improved its preparedness efforts to be inclusive and accessible, including vulnerable groups in the preparedness discourse, learning from the 2011 Tohoku Earthquake and Tsunami.

CHAPTER V: Discussion and Conclusions

This dissertation contributes to the literature of disaster preparedness among older adults by revealing that preparedness behaviors are shaped not by a single factor but by the interaction of psychological, social, and structural conditions. While prior research has emphasized the role of risk perception, a cognitive understanding of risk, in motivating protective action, the findings presented here illustrate that risk perception alone is not enough to explain preparedness behaviors, particularly among aging populations.

Across the three studies, this work highlights the importance of situating preparedness within broader lived experiences. Chapter II illustrates that disaster experience can significantly alter risk perception, yet changes in perception do not always translate into sustained preparedness behaviors. Chapter III further provides insight that psychosocial factors, specifically loneliness, play a critical role in shaping preparedness, exerting both direct and indirect effects through risk perception. Chapter IV expands this perspective by showing that structural and infrastructural constraints, including mobility limitations and access to resources, may ultimately determine whether individuals are *able to* act on perceived risk.

Taken together, the findings challenge the assumption that increasing awareness or risk perception alone will lead to improved preparedness. Instead, they suggest that preparedness must be understood as a limited process, in which individuals operate within the constraints of their social connections, knowledge, physical capabilities, and environmental contexts. This perspective is particularly important for older adults, whose vulnerabilities are often multifaceted, highly diverse, and not fully captured by traditional behavioral theoretical models.

To address and organize these complex factors, this dissertation introduces the Japanese Older Adult Preparedness Model (JOAPM), an extension of the Protective Action Decision Model (PADM) developed by Lindell and Perry in 2012, as mentioned in Chapter II, that incorporates psychosocial and structural dimensions into the decision-making process. By integrating loneliness, social context, and structural constraints alongside established cognitive factors, the JOAPM provides a more comprehensive framework for understanding preparedness behaviors among older adults. This model contributes to the academic literature by bridging gaps between individual-level decision-making theories and broader social, population-wide determinants of health and vulnerability. Because when is individual decision-making not informed or affected by the social landscape in which people exist?

The implications of this work extend beyond theoretical contributions. From a policy and practice perspective, these findings emphasize the need for disaster preparedness strategies that reach beyond one-size-fits-all approaches. Interventions that focus solely on information dissemination or risk communication could be ineffective if they do not account for the social environments, such as loneliness, and structural barriers faced by older adults. To be more effective in disaster preparedness interventions, strategies such as strengthening social networks, designing community-based preparedness programs, and addressing accessibility and mobility challenges in the built environment may be essential.

This research also highlights the importance of cultural context in shaping preparedness behaviors. By focusing on Japan, this dissertation provides insights into how preparedness behaviors are influenced within a society that combines advanced technological systems with an evolving social structure, including urban migration, a large elderly population, and decreasing

rural populations. These findings may have broader relevance for other aging societies facing increasing disaster risk, including regions such as the Pacific Northwest in the United States, as well as other nations with larger older adult populations.

Cross-national comparisons also raise important questions regarding how responsibility for disaster preparedness is distributed between individuals, communities, and formal institutions, such as governments. In the United States, preparedness messaging often emphasizes personal responsibility and self-sufficiency, encouraging individuals to maintain emergency supplies, develop household plans, and take protective actions independently. Yet following large-scale disasters, substantial expectations are often placed on governmental institutions to support recovery, including providing financial assistance and other forms of aid. This tension illustrates that disaster preparedness is not solely a matter of individual decision-making but is shaped by broader societal understandings of responsibility, risk, and collective support. It also highlights the complex, ever-changing, and costly process of recovery.

In Japan, disaster preparedness has historically been embedded within a framework that combines individual preparedness, community participation, and governmental responsibility. Neighborhood disaster associations, evacuation drills, hazard education, and widespread disaster awareness campaigns reflect an integrated approach to risk reduction through preparedness. However, demographic aging, declining social cohesion, and increasing numbers of older adults living alone may challenge assumptions about the availability of community support during disasters

Although this research may have broader international implications, the findings are highly specific to Japan. Japan is a unique country both geographically and societally. Its

geography has made immigration to Japan scarce until recent decades. This population homogeneity makes it easier to develop a sense of camaraderie, giving the impression of a collectivist culture. Japan is frequently portrayed as a highly prepared society due to its long history of disasters and extensive investment in disaster education, early warning systems, and community preparedness. However, based on the findings of this dissertation, I would like to suggest that even within a society characterized by a strong culture of preparedness and wide knowledge and experience with natural hazards, psychosocial and structural barriers continue to shape individual preparedness behaviors. This observation highlights the limitations of viewing preparedness solely as a product of knowledge, culture, or hazard experience.

I feel the responsibility, through this dissertation, to communicate that Japan is an extraordinary country to study; however, the difficulty in extrapolating preparedness research and conclusions should be acknowledged. I would like to highlight, from my personal observations, that the often-perceived collectivist culture can lead older adults to resign themselves to death rather than burden or inconvenience younger populations with their presence during a natural disaster. In casual conversations with many individuals who survived the 2011 Tōhoku earthquake, tsunami, and nuclear power plant meltdown, there has been survivor's guilt present in most conversations. Regret over not checking in with an elderly neighbor. Not inviting older adult acquaintances to seek higher ground when they themselves were in a panicked haze to evacuate. Japan is also a country with both a modern, technologically advanced society, with urban city centers that value individualism and self-expression, and rural cultures and communities that place high importance on community cohesion, sharing resources and collaborating among community members. These ways of life coexist in Japan, and although the

population may seem homogenous, it is important to emphasize that, like in any population, a blanket policy, intervention, and communication strategy comes with its own challenges.

While pursuing my dissertation, I encountered important yet unexpected questions about disaster recovery and relocation among older adults from policy and land-use perspectives, and, more importantly, these questions were deeply intertwined with the concept of "ikigai." Ikigai can be translated to a "reason to live on" or "a sense of purpose in life." Following major disasters, policy discussions often focus on the physical and financial dimensions of recovery, including housing reconstruction, infrastructure restoration, relocation planning, and economic recovery. While all these recovery categories are essential, they overlook the social, occupational, and identity-related dimensions of post-disaster displacement and recovery in the population. They do not consider their reason for living. Especially in the aging population, these factors are important, for I believe they determine health and longevity after disasters. For many older adults, particularly those engaged in agriculture, fishing, forestry, and other place-based occupations, work represents more than a source of income. Occupations are often closely tied to family history, community identity, daily routines, and a sense of purpose. In regions affected by the 2011 Great East Japan Earthquake and Tsunami, including parts of Miyagi and Fukushima Prefectures, relocation efforts successfully addressed immediate safety concerns but often required individuals to leave behind communities, livelihoods, and landscapes that had shaped their identities over centuries and generations.

As populations age, disaster planning and policy must move beyond the question of where older adults can be relocated and consider how relocation may affect their ability to maintain meaningful social roles and activities. The loss of occupational identity and community

connection may contribute to loneliness and psychological distress, declining well-being, and increasing risk of ailments. Among older adults, psychological distress is frequently associated with adverse physical health outcomes, suggesting that relocation decisions may have consequences extending far beyond housing stability alone.

Future disaster recovery policies must consider not only physical safety and housing availability but also opportunities to maintain social networks, community participation, and meaningful roles in daily life. Recovery planning that preserves these dimensions may be particularly important in aging societies, where health and well-being are closely linked to social connection, purpose, and place attachment. Furthermore, consider not only physical safety and housing availability but also opportunities to maintain social networks, participate in the community, allow for meaningful aging-in-place standards, and hold meaningful roles in daily life.

Several limitations should be acknowledged. The analyses rely on self-reported data, which may be subject to recall bias and social desirability effects. Additionally, while this work focuses on Japan, the generalizability of findings to other cultural contexts may be limited. Future research should explore how psychosocial and structural factors interact across different hazard types and geographic settings, as well as examine interventions that effectively address loneliness and social isolation in disaster preparedness. Despite these limitations, this dissertation aims to provide a more nuanced understanding of disaster preparedness among older adults and offers a framework for future research and intervention design. As the countries in the Global North's populations continue to age and disaster risks intensify, it is increasingly important to

develop approaches that recognize the complexity of vulnerability and the diversity of lived experiences among older adults.

Currently, the dominant conversations about natural hazards focus on preparedness and reducing individual risk. However, as weather events intensify and hazards, including earthquakes, grow in size and prevalence, this work ultimately reframes disaster preparedness not as a simple individual responsibility but as a socially and structurally embedded process. By shifting the focus from whether individuals choose to prepare to whether they are able to prepare, this dissertation contributes to a more equitable and realistic understanding of disaster risk reduction in aging societies. Beyond reducing risk, we must look ahead to equitable recovery research, ensuring the whole population has the means to prepare adequately, feel secure, and have comfortable plans and policies.

The question is not simply whether older adults are willing to prepare for disasters, no matter what devastations they experience, but whether they are positioned—socially, structurally, and psychologically—to do so. In an aging and hazard-prone world, improving disaster outcomes requires shifting the focus from changing individual behavior to transforming the conditions that shape it.

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APPENDIX:

I Survey Questions (Translated to English):

Demographic information (other than the ones they already collect automatically)

1. Home ownership
2. Earthquake insurance enrollment status
3. Location of residence (urban, suburban, rural)
4.

Hazard experience (binary/yes-no)

5. Own property Damage due to earthquakes
6. Family death/injury due to earthquakes
7. Acquainted people's property damage due to earthquakes
8. Acquainted people's death or injury due to earthquakes

Hazard Risk Perception. (5 likert scale—1- not at all, 5 very great extent)

9. Will be damage to city.
10. Damage to own home
11. Injury to myself/family
12. Disruption to job
13. Disruption to daily activities

Abbreviated place attachment scale

14. I am very attached to my neighborhood.
15. My neighborhood is very special to me.
16. I identify strongly with my neighborhood.
17. My neighborhood is the best place for my lifestyle.
18. No other neighborhood in can compare to mine.
19. I wouldn't substitute any other neighborhood because of the quality of life my neighborhood provides.

UCLA Loneliness scale

20. I lack companionship.
21. I am no longer close to anyone.
22. My interests and ideas are not shared by those around me.
23. My social relations are superficial.

24. No one really knows me well.
25. I am unhappy being so withdrawn.
26. People are around me but not with me.

Preparedness scale used in this paper:

27. Measures to secure furniture
28. Food and water stockpiling
29. Identifying the designated evacuation center
30. Preparing emergency pack
31. Discussing disaster response with family
32. Can rely on potential mutual aid in the neighborhood.

Similar questions of government survey distributed in November 2011

Risk perception (5 item scale from strongly agree to strongly disagree)

33. A super large earthquake will degenerate Japan
34. lifelines such as gas, water, and rail's deterioration (due to time) are worrying
35. my children or grandchildren's generation will experience more destructive disasters
36. my child or grandchild being a victim of a disaster will be just as hard as the current generation's.

Government intervention in… (5 item scale from government should take all responsibility to government should not be responsible at all)

37. the maintenance of the infrastructures against disasters (lifeline, emergency response, information dissemination)
38. having at the very least, emergency food and water in stock in case of a disaster
39. making civilian buildings earthquake proof (houses and privately owned buildings)
40. provide aid in evacuating the elderly, disabled, and otherwise known as the vulnerable population in a disaster situation.