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Earthquake probability in the National Seismic Hazard Maps for Japan and people's risk perceptions: the search for more effective expression

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Abstract

This study summarizes the findings of an attitude survey focused on people's perceptions of seismic hazard maps, which illustrate the risk of an earthquake in each location throughout Japan. These seismic hazard maps depict the likelihood of an earthquake with a seismic intensity of "6 Lower" or more within 30 years, with 3.0% being considered a high possibility. The 3.0% occurrence probability within 30 years can be reworded to 2.0% occurrence probability within 20 years, 0.1% occurrence probability within a year, 4.9% occurrence probability within 50 years, or 39.4% occurrence probability within 500 years when being converted according to a Poisson distribution. In this study, we convert the occurrence probability within 30 years in the seismic hazard maps to obtain that within a year up to that within 1000 years, present the involved risk and demonstrate the yearly probability of the people who see the maps becoming most convinced of the need for countermeasures. Although those are shorter than the occurrence probability within 30 years anyway, it is a characteristic that the peaks existed at the occurrence probability within 10–20 years, not at the occurrence probability within one year or five years. However, the results changed according to the age of the people viewing the maps, and it was when the risk was presented as the occurrence probabilities within 20 and 30 years for the people in their 20–40 s, while it was when the risk was presented the occurrence probabilities within 10 years for the people in their 50–60 s, the perception toward the need of countermeasures increased the most. In addition, regardless of gender and place of residence (coast of the Sea of Japan or the Pacific coast), the perception toward the need of countermeasures peaked at the occurrence probabilities within 10 and 20 years.

Keywords: Earthquake, The National Seismic Hazard Maps for Japan, Risk communication, Probability, Perception of risk, Sea of Japan

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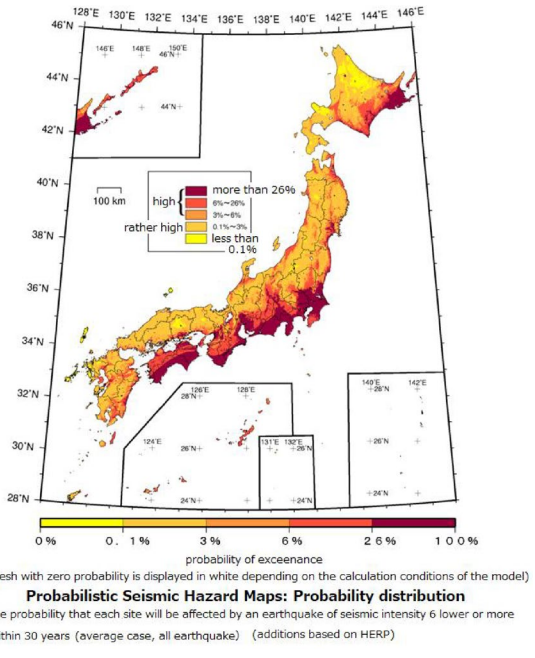
Graphical Abstract

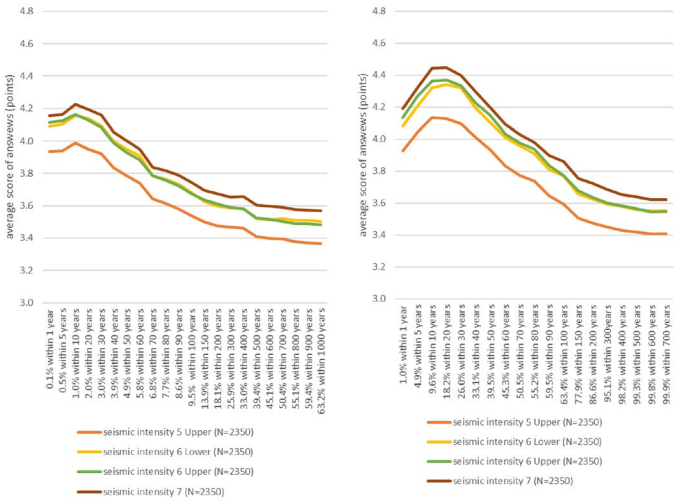


(Mesh with zero probability is displayed in white depending on the calculation conditions of the model)

Probabilistic Seismic Hazard Maps: Probability distribution

the probability that each site will be affected by an earthquake of seismic intensity 6 lower or more within 30 years (average case, all earthquake) (additions based on HERP)

"3.0% within 30 years"		"26.0% within 30 years"	
"0.1% within 1 year"	"9.5% within 100 years"	"1.0% within 1 year"	"63.4% within 100 years"
"0.5% within 5 years"	"13.9% within 150 years"	"4.9% within 5 years"	"77.9% within 150 years"
"1.0% within 10 years"	"18.1% within 200 years"	"9.6% within 10 years"	"86.6% within 200 years"
"2.0% within 20 years"	"25.9% within 300 years"	"18.2% within 20 years"	"95.1% within 300years"
"3.0% within 30 years"	"33.0% within 400 years"	"26.0% within 30 years"	"98.2% within 400 years"
"3.9% within 40 years"	"39.4% within 500 years"	"33.1% within 40 years"	"99.3% within 500 years"
"4.9% within 50 years"	"45.1% within 600 years"	"39.5% within 50 years"	"99.8% within 600 years"
"5.8% within 60 years"	"50.4% within 700 years"	"45.3% within 60 years"	"99.9% within 700 years"
"6.8% within 70 years"	"55.1% within 800 years"	"50.5% within 70 years"	-
"7.7% within 80 years"	"59.4% within 900 years"	"55.2% within 80 years"	-
"8.6% within 90 years"	"63.2% within 1000 years"	"59.5% within 90 years"	-



Introduction

In Japan, due to the extensive damage caused by the 1995 Hyogo-ken Nanbu earthquake, the Special Measure Law on Earthquake Disaster Prevention was enacted and the Headquarters for Earthquake Research Promotion (HERP) was established to promote comprehensive earthquake disaster prevention measures (HERP 2021a). Since 2005, the HERP has published the National Seismic Hazard Maps for Japan (hereafter referred to as seismic hazard maps) depicting earthquake risk throughout the country (Fig. 1). Seismic hazard maps predict and display the results of the strong motions caused by earthquakes that could occur in Japan in the future (National Research Institute for Earth Science and Disaster Resilience (NIED) 2021). These maps are expected to be used as basic documents to improve citizens' awareness of disaster prevention and to examine effective countermeasures against earthquakes (HERP 2021b).

Therefore, in this study, we observe how people perceive probability information from seismic hazard maps. To this end, we: (1) investigate how people recognize "the need to take measures" while looking at a map, (2) analyze how perceptions regarding these seismic hazard maps vary according to different attributes [gender, age, and residence (living on the coast of the Sea of Japan or the Pacific Ocean)], and (3) examine how to effectively express seismic risk (probability) in the seismic hazard maps.

A representative seismic hazard map shows the probability of each site being affected by an earthquake of 6 Lower or more seismic intensity within 30 years (NIED, 2021), as shown in Fig. 1. The provision "the seismic intensity of 6 Lower or more" is set because, at this intensity, the possibility of occurrence of human and material damage significantly increases and the provision "within 30 years" was set because it was thought that it could act as a standard when considering the future plans of each individual person(HERP 2021b). At present, there are empirical and objective grounds for seismic intensity, whereas no objective grounds seem to exist for the "within 30 years" provision. Thus, we investigate the latter. For example, as shown in Fig. 1, the probability of occurrence of 3.0% or more within 30 years (regarded as

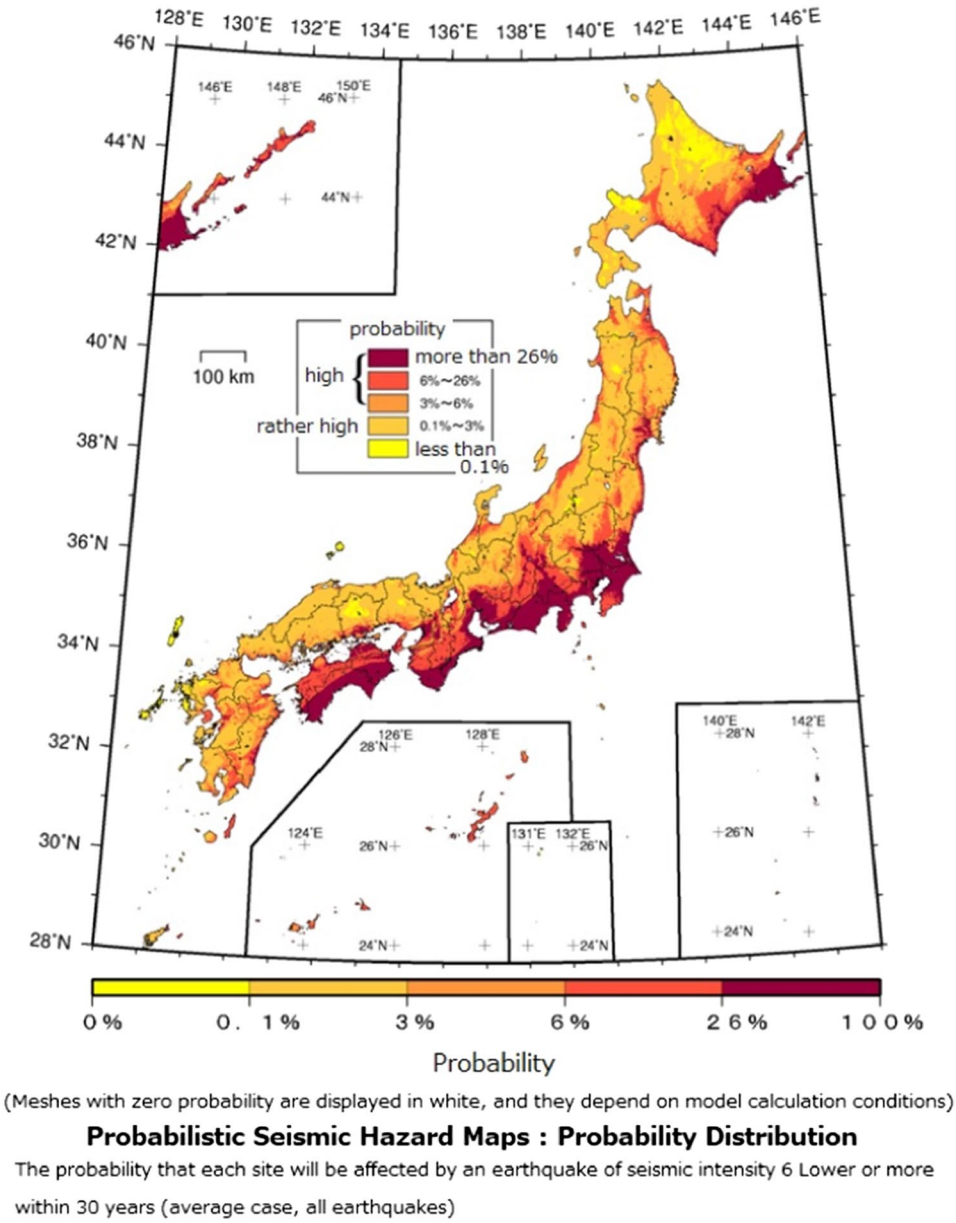


Fig. 1 The National Seismic Hazard Maps for Japan (Edition 2018) (additions based on HERP)

a high probability according to seismic hazard maps) can be converted to a shorter period and reworded as 2.0% within 20 years or 0.1% within one year and, for a longer period, as 4.9% within 50 years or 39.4% within 500 years (as shown in Table 2).

Thus, we convert the occurrence probability within 30 years used in the current map to that within one year up to that within 1000 years when presenting the risk (probability) of an earthquake to investigate how people's perceptions of seismic hazard maps change with changing yearly probabilities as well as which yearly probability raise their perception.

Previous research

In Japan, where natural disasters occur frequently, risk communication studies related to earthquakes have been carried out (for example, Architectural Institute of Japan 2011; Nara 2018). Here because risk is expressed in terms of probability, probabilistic expression is unavoidable (Kikkawa 1999); therefore, recognition and judgment of

the probabilistic and statistical elements are important factors (Nakayachi 2012). However, previous reports have shown that it is generally difficult for people to understand probabilities (Hirota 2005). In addition, it has also been reported that conveying probability theory to people on-site is also difficult (Kinoshita 2016). Although a considerable number of psychological empirical studies on the effects of probability on the receiving end have been conducted overseas (for example, Slovic et al. 2000; Visschers et al. 2009), it has been pointed out that there are no consistent results concerning these effects (Hirota 2011).

According to the above factors, it has been observed that although probability and its perception are important in risk communication, they are generally difficult to understand, and no coherent knowledge has accumulated regarding the effects of messages, including probability. Conversely, it is thought that the data rooted in an actual condition could be obtained by investigating individual cases, making it possible to develop discussions that would lead to on-site remedies.

Studies on seismic risk and people's perception have been conducted in various countries. According to Solberg et al. (2010), the factors that shape risk perception include earthquake experience, demographic factors such as gender and age, and so on, the various findings of which are summarized in the present study. However, among the foreign studies that have been conducted thus far on the topic, it is difficult to find an accumulation of survey research on earthquake probability expressions and perceptions for Japan. Therefore, this section focuses on the type of investigations performed on the probability expression for the Seismic Hazard Maps for Japan and people's perception to express the long-term probability of earthquakes.

Before these seismic hazard maps were published, Tanaka and Yoshii (1999) investigated people's perceptions of the long-term probability of earthquakes; they studied at what percentage the probability is recognized as dangerous, and at what percentage of the probability makes people take countermeasures. Regarding the probability that each site will be affected by large earthquake within the next 30 years, the above authors found that the number of people who began to feel the danger from approximately 10.0%, and "high" at 30.0%, and "very high" at 50.0%.

Since the publication of seismic hazard maps, HERP has continuously conducted surveys on perception. Among them, one survey was specified given to people who had responded that the maps were incomprehensible (i.e., those who responded that the maps were "somewhat incomprehensible" and "very difficult to understand") to respond. It is observed that 47.9% of the people find the maps to be incomprehensible, stating that they are difficult to see; 41.0% were unable to understand the meaning of the occurrence probability, and 31.8% think that the period used to calculate the probability, i.e., 30 years, is too long (HERP 2017).

These results show that the occurrence probability and period in which to calculate the probability are the issues.

Furthermore, when people were asked about the percentage of probabilistic occurrence of an earthquake having 6 Lower or more seismic intensity within 30 years, 17.1% and 15.0% of more people responded that the need for disaster prevention measures should be 50.0% or more and 30.0% or more, respectively (MEXT 2015).

In Tanaka and Yoshii (1999), 30.0% and 50.0% are the occurrence probabilities of an earthquake identified as high and significantly high, respectively.

Hirota and Oki (2015) investigated the recurrence interval and the probability at which people were terrified. The extreme method ("kyokugenhou"), that is, the period and probability being shown by increasing and decreasing little by little, and in which people feel "scared" and "not scared", is used for investigation. Consequently, it was discovered that the reccurence interval has a certain trend (the threshold at which people felt terrified or not scared was "10 years or longer but less than 20 years"). However, no apparent continuous trend was observed in the case of probability.

Furthermore, Hirota and Sloman (2019) examined people's judgment when the probability, recurrence interval, and seismic intensity were presented at random. Consequently, it was found that when the seismic intensity strength or probability increased, as well as when the recurrence interval decreased, the feeling of fear also increased. In addition, the effect was observed to decrease in the following order: probability > period > seismic intensity. Seismic intensity was found to have a threshold between 5 Upper and 6 Lower.

Nagamatsu et al. (2016) changed the way the seismic hazard map is displayed (for example, by making people check the probability or colors of the seismic hazard of their own homes after checking the probability of an earthquake in other cities on a world map). The above authors investigated whether people who saw the maps believed that they would actually encounter an earthquake. As a result, it was shown that people living in areas where seismic risk was high (i.e., the occurrence probability was 26% or higher within 30 years) tended to think that they would actually encounter an earthquake, regardless of how the maps were presented. Furthermore, feelings of fear were observed as intensifying particularly among people who checked the color of their homes on seismic hazard maps.

Table 1 Survey method

1	Target:	Males and females aged 20–69 living in 47 prefectures in Japan (gender age equal allocation). Each region with 200 people × 47 prefectures = 9400 peple in total.
2	Period:	From November 20th (Fri.) to November 25th (Wed.) of 2020.
3	Method:	Online survey research (Research Institution: Rakuten Insight, Inc.).

Fujimoto and Tozuka (2010) changed the seismic intensity, period (10, 30, 50, and 100 years), and probability (10%, 30%, 50%, 70%, and 90%) when showing the risk information and investigated the degree of risk felt by people (about an earthquake with a seismic intensity of 6 Lower). It was found that the recognition of this risk greatly increased when the probability increased from 30 to 50%, particularly when the information was shown for 10 years.

As discussed above, studies on the expression of the probability of an earthquake published thus far arbitrarily set the probability and number of years. In contrast, Saito and Sekiya (2017) considered the actual probabilities used in the seismic hazard maps to investigate the probability and number of years. The above authors used the 3.0% occurrence probability within 30 years, which is regarded as a high probability, and reworded its expression to an occurrence probability within 5 years (X% within 5 years), within one year (Y% within one year), and an average time interval (once every Z years); they also investigated how the perceived need for countermeasures among those people who saw the maps changed, finding that among these perceived need increased the most when the occurrence probability within 30 years was presented.

Moreover, what if additional extensive research on the probability of occurrence within 10, 20, 40, 50, 100, or 200 years were conducted? Furthermore, how does respondents' recognition of probabilistic expressions differ based on their gender, age, and area of residence? The most effective technique for expressing the risk of an earthquake may be understood by investigating the above questions, and the obtained knowledge may facilitate the communication of earthquake risk.

Therefore, we conduct detailed investigations based on the probabilistic expressions shown in the seismic hazard maps by changing the occurrence probability within 30 years to that from within one year to within 1000 years. Furthermore, we consider how people receive such information depending on gender, age, and residence (living on the coast of the Sea of Japan or the Pacific Ocean). According to previous investigations, the number of people that there is a likelihood of a major disaster occurring is high among those living on the Pacific coast and low among those living on the Sea of Japan coast (Cabinet Office 2016). Is such a difference also present in how people perceive the probabilistic expression in the seismic hazard maps depending on their residence? Thus, we conduct an investigative analysis based on the above question.

Method

The survey was administered to 9,400 males and females in their 20–60 s living in 47 prefectures in Japan (equal allocation of gender and age, with 200 people from each prefecture), as listed in Table 1. The survey period was from November 20 to November 25, 2020, and a questionnaire survey was administered to monitors on the internet through the investigative body Rakuten Insight, Inc. In the survey, some of the question items topics were as follows: anxiety about the earthquake, recognition rate of the seismic hazard maps, usual earthquake countermeasures, and what level of necessity of countermeasures were felt to be needed given each occurrence probability.

The survey was conducted based on two probabilities: "3% within 30 years", and "26% within 30 years". As shown in Fig. 1, in the seismic hazard map, the probability of an earthquake occurring "3% within 30 years" is considered "high". In addition, "26% within 30 years" is shown in the darkest red color, which visually emphasizes the high risk. Note that the 2018 version of the seismic hazard maps is shown.

In the questionnaire, we asked the following, "When the occurrence probability of an earthquake is presented in the following expressions, to what degree do you feel the need for countermeasures? Please select only one that applies to each." The probability(axis being 3% within 30 years) was calculated according to the Poisson distribution for the question items, and questions were asked for all probabilistic expressions shown on the left side of Table 2, from 0.1% within one year to 63.2% within 1000 years. Similarly, in the case with the axis being 26.0% within 30 years, questions were asked for all probabilistic expressions, from 1.0% within one year to 99.9% within 700 years as shown on the right side of Table 2.

It should be noted that two different methods were used to identify the exceedance probability on the seismic hazard maps for Japan; one for earthquakes whose epicenters

Table 2 Probability conversion table

"3.0% within 30 years"		**"26.0% within 30 years"**	
"0.1% within 1 year"	"9.5% within 100 years"	"1.0% within 1 year"	"63.4% within 100 years"
"0.5% within 5 years"	"13.9% within 150 years"	"4.9% within 5 years"	"77.9% within 150 years"
"1.0% within 10 years"	"18.1% within 200 years"	"9.6% within 10 years"	"86.6% within 200 years"
"2.0% within 20 years"	"25.9% within 300 years"	"18.2% within 20 years"	"95.1% within 300 years"
"3.0% within 30 years"	"33.0% within 400 years"	"26.0% within 30 years"	"98.2% within 400 years"
"3.9% within 40 years"	"39.4% within 500 years"	"33.1% within 40 years"	"99.3% within 500 years"
"4.9% within 50 years"	"45.1% within 600 years"	"39.5% within 50 years"	"99.8% within 600 years"
"5.8% within 60 years"	"50.4% within 700 years"	"45.3% within 60 years"	"99.9% within 700 years"
"6.8% within 70 years"	"55.1% within 800 years"	"50.5% within 70 years"	–
"7.7% within 80 years"	"59.4% within 900 years"	"55.2% within 80 years"	–
"8.6% within 90 years"	"63.2% within 1000 years"	"59.5% within 90 years"	–

and recurrence times can be well identified with characteristic earthquake processes, and the other for earthquakes without specified source faults with the Poisson process. Moreover, since the purpose of this study is to analyze how these "representations" of probabilities and probability evaluation periods affect people, we used the calculated "representations" assuming that probabilities and probability evaluation periods follow a Poisson distribution. In this respect, the original expression of the probability and probability assessment period used in the research item is different from the method of calculating the exceedance probability of seismic hazard maps for Japan.

Respondents were asked to choose one answer out of six choices—"I strongly feel the need for countermeasures", "I feel the need for countermeasures", "I sort of feel the need for countermeasures", "I sort of do not feel the need for countermeasures", "I do not feel the need for countermeasures", and "I absolutely do not feel the need for countermeasures".

The survey results were analyzed separately for gender, age, and area of residence. For area of residence, the differences between the residents living on the coast of the Sea of Japan and those living on the Pacific coast) were analyzed. The Sea of Japan coastal area includes nine prefectures (Akita, Yamagata, Niigata, Toyama, Ishikawa, Fukui, Kyoto, Tottori, and Shimane), many of which have an earthquake occurrence probability of less than 6.0%, meaning that in these areas, earthquake occurrence probability is relatively low. The Pacific coastal area includes 10 prefectures (Ibaraki, Chiba, Tokyo, Kanagawa, Shizuoka, Aichi, Mie, Wakayama, Tokushima, and Kochi), many of which have an earthquake occurrence probability of 26.0% or more, meaning that in these areas, are earthquake occurrence probability is relatively high.

Results

Perceptions of earthquake occurrence probability and seismic hazard maps

First, we investigated whether people have seen seismic hazard maps—the so-called recognition rate. As shown in Fig. 2, the results showed that 43.7% replied that they had seen the maps, while 56.3% replied that they had seen them for the first time in this survey. Those respondents who were female (41.4%), in their 20 s (41.0%), and lived along the coast of the Sea of Japan (37.8%) had recognition rates of the map that were relatively low.

In addition, regarding anxiety concerning earthquakes, 83.8% showed anxiety ("very anxious" and "somewhat anxious" combined) as shown in Fig. 3. While felt anxiety concerning earthquakes, those respondents who were female (87.9%), in their 20 s (85.6%) and 30 s (86.6%), and lived on the Pacific coast (90.0%) felt more anxiety than did other respondents.

Everyday behaviors regarding earthquake countermeasures

With reference to earthquake countermeasures, we then asked the following question; "What kind of countermeasures against earthquakes do you usually take? Please select as many choices as possible that apply." The results were, in order of percentage, the storage of water (43.7%), storage of food (40.6%), and checking of evacuation shelters and temporary evacuation sites (33.8%) as shown in Fig. 4. Moreover, approximately one in four or five people (23.0%) did not take any countermeasures.

Those who took more than one countermeasure totaled approximately 80%. However, when the number of people who took three or more countermeasures was examined, the results revealed that those who were and were not taking three or more countermeasures

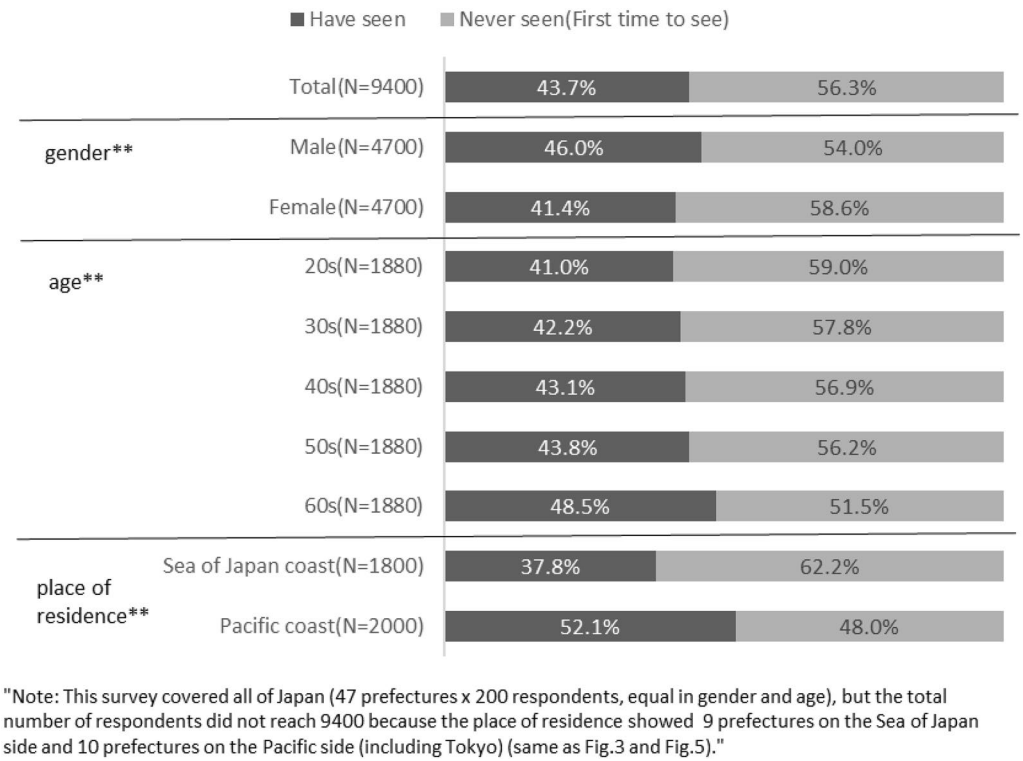


Fig. 2 Have you seen the Seismic Hazard Map for Japan? (**: p<.01; by chi-square test)

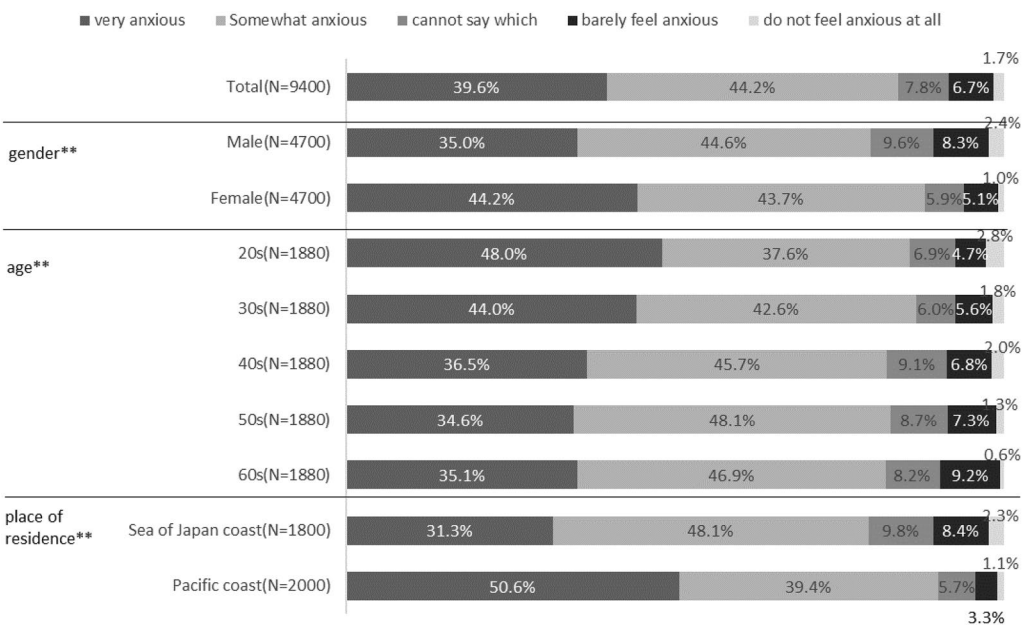


Fig. 3 Feeling of anxiety concerning earthquakes (**:p<.01; by chi-square test)

accounted for approximately half of the total, as shown in Fig. 5. Those respondents who were male (51.8%), in their 20 s (58.4%) and lived along the coast of the Sea of Japan (58.5%) accounted for the highest proportion among those respondents who did not take three or more countermeasures.

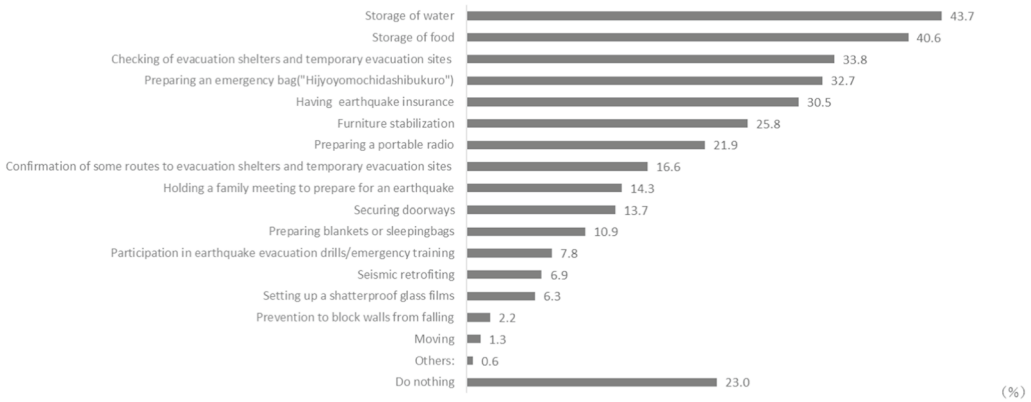


Fig. 4 Earthquake countermeasures ($N = 9400$)

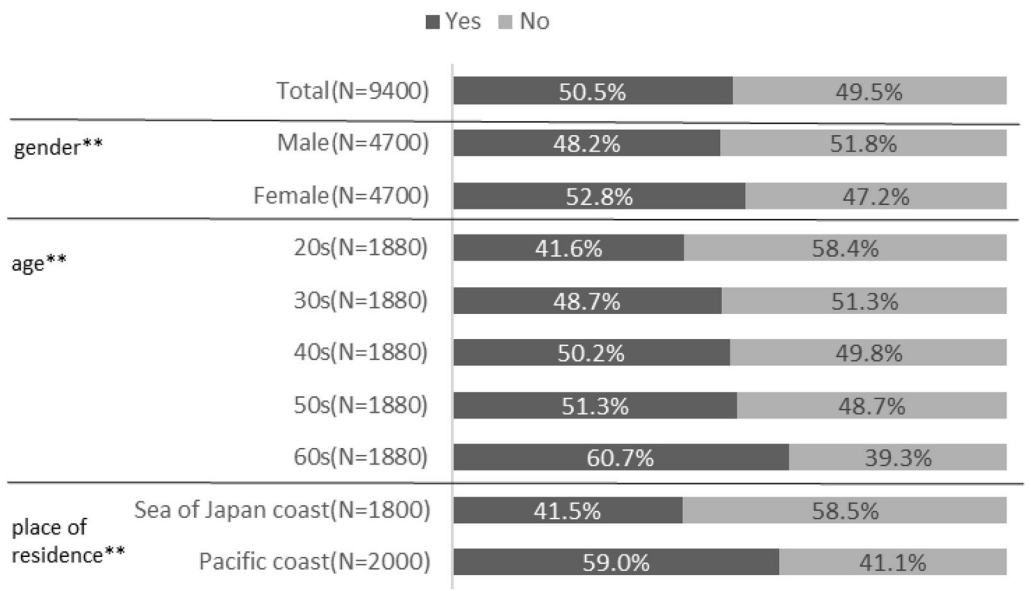


Fig. 5 Ratio of those who were taking earthquake countermeasures (three or more) to those who were not (**:p<.01; by chi-scuare test)

Perceptions of probabilistic expression—need for countermeasures

Next, we converted the probability of the seismic hazard maps, and presented the results of the survey to see how the consciousness of respondents changed.

From Fig. 6 onward, the graphs show the average scores of all respondents after assigning the following points to the response option: "I strongly feel the need for countermeasures", 6 points; "I feel the need for countermeasures", 5 points; "I sort of feel the need for countermeasures", 4 points; "I sort of do not feel the need for countermeasures", 3 points; "I do not feel the need for countermeasures", 2 points; and "I absolutely do not feel the need for countermeasures", 1 point. All 9400 respondents were divided into four groups so that gender, age, and area of residence (prefectures) were evenly distributed, and four seismic intensities (5 Upper, 6 Lower, 6 Upper, and 7) were assigned to them.

According to Fig. 6, in terms of the results for seismic intensity, there was a difference between 5 Upper and 6 Lower, while there was almost no difference between 6 Lower and 6 Upper. In addition, the peaks, where the perceived need for countermeasures increased the most, did not change at any seismic intensity and corresponded to the occurrence probabilities within 10 and 20 years (Table 3). Although those were shorter than the occurrence probability within 30 years, the peaks existed at the occurrence probability within 10–20 years, not at the

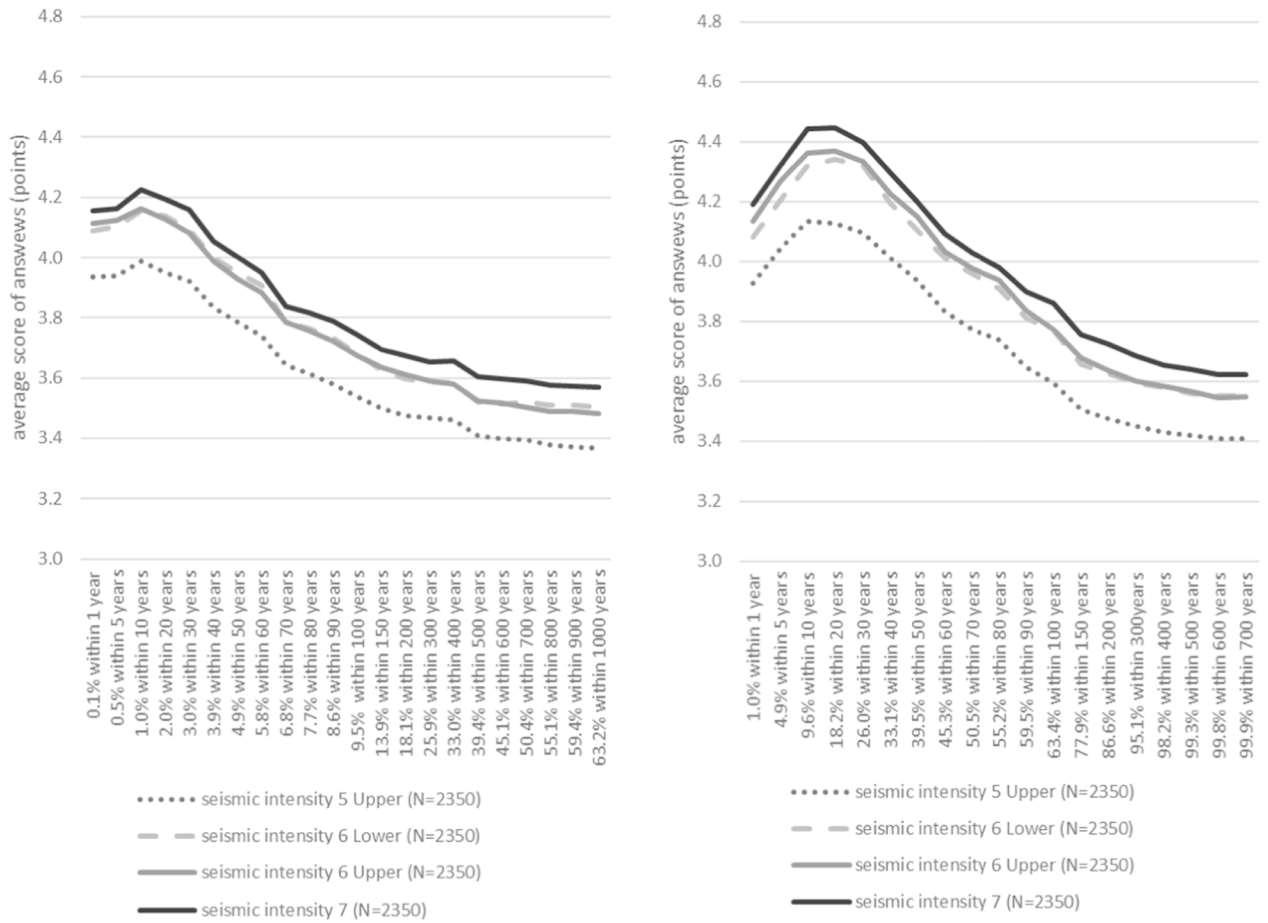


Fig. 6 Perceived need for countermeasures (average): (left): "3.0% within 30 years", (right): "26.0% within 30 years"

Table 3 Peak for maximized awareness of the need for countermeasures (average)

	A seismic intensity of 5 Upper (*N* = 2350)	**A seismic intensity 6 Lower (*N* = 2350)**	**A seismic intensity 6 Upper (*N* = 2350)**	**A seismic intensity 7 (*N* = 2350)**
In the case of 3.0% within 30 years	The occurrence probability within 10 years	The occurrence probability within 10 years	The occurrence probability within 10 years	The occurrence probability within 10 years
In the case of 26.0% within 30 years	The occurrence probability within 10 years	The occurrence probability within 20 years	The occurrence probability within 20 years	The occurrence probability within 20 years

occurrence probability within one year or 5 years. Next, we examined the differences in the attributes in focusing on the seismic intensity of 6 Lower, which is represented in the seismic hazard maps.

Regarding the gender, male respondents tended to have a lower perception of the need for countermeasures than did their female counterparts (Fig. 7). Inherently, male respondents had inherently lower anxiety toward earthquakes (Fig. 3), tended to have a lower percentage in terms of taking three or more countermeasures against earthquakes (Fig. 5), and had relatively low perceived need for countermeasures when viewing the maps. Moreover, the peak at which the perceived need or countermeasures increased was the occurrence probabilities within 10 and 20 years, and there was no gender-related difference (Table 4).

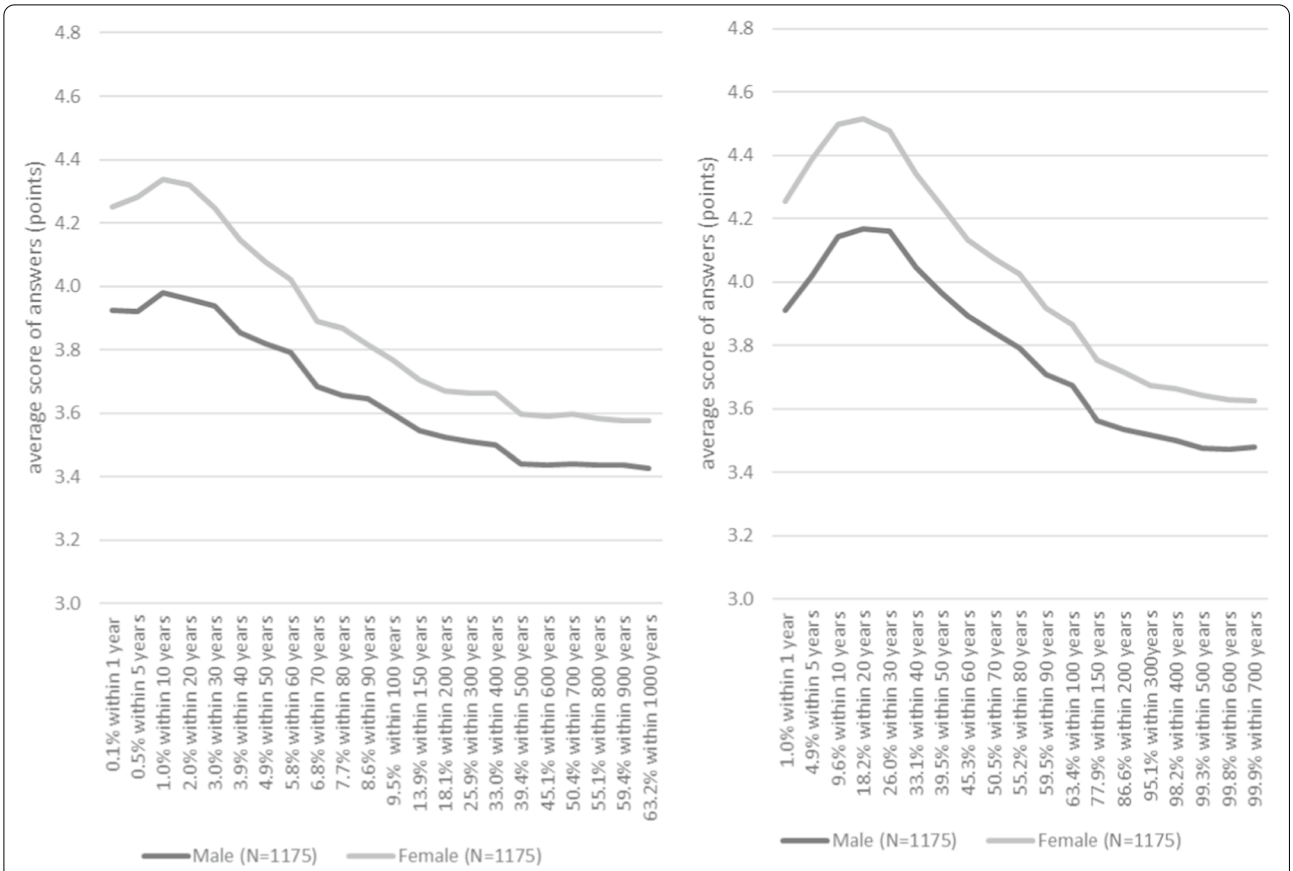


Fig. 7 Perceived need for countermeasures (by gender): (left):"3.0% within 30 years"; (right) "26.0% within 30 years"

Next, when considering the results by age, the perceived needs or toward the need of countermeasures became higher overall among people in their 20–30 s overall among those in their 50–60 s, as shown in Fig. 8. Inherently, the age group that included those in their 20 s had fewer people who were taking three or more countermeasures against earthquakes, and the age group that included those in their 60 s had more people who were taking three or more countermeasures (Fig. 5). When considering these results, the following challenge was identified: although younger generations were more likely to recognize the need for countermeasures, they took fewer everyday countermeasures against earthquakes compared to older generations. In addition, the peaks where the perceived need for countermeasures increased the most varied by age and were the occurrence probabilities within 20 and 30 years and those within 10 years for those in their 20–40 s and 50–60 s, respectively (Table 5).

When considering the results in terms of area of residence, according to Fig. 9, residents living on the coast of the Sea of Japan had a relatively lower perceived need for countermeasures than did those living on the Pacific coast. It was characteristic that anxiety (Fig. 3), the number of people taking three or more measures (Fig. 5), and the perceived need for countermeasures were all relatively low among the residents living along the coast of the Sea of Japan.

In other words, residents living on the Pacific coast tended to be more aware.

Table 4 Peak for maximized awareness of the need for countermeasures (average)

	Male (*N* = 1175)	**Female (*N* = 1175)**
In the case of 3.0% within 30 years	The occurrence probability within 10 years	The occurrence probability within 10 years
In the case of 26.0% within 30 years	The occurrence probability within 20 years	The occurrence probability within 20 years

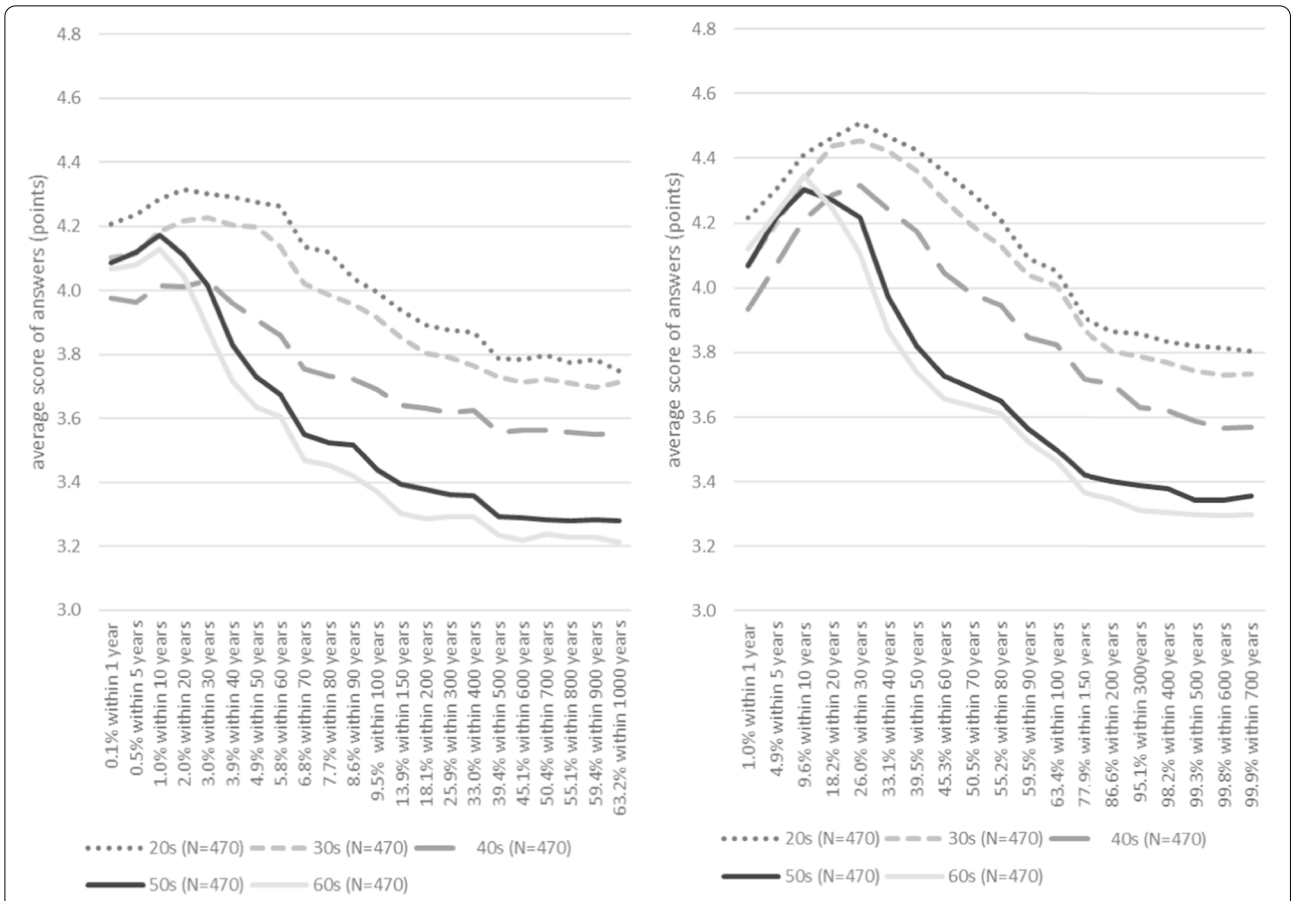


Fig. 8 Perceived need for countermeasures (by age group): (left): "3.0% within 30 years"; (right) "26.0% within 30 years"

Table 5 Peak for maximized awareness of the need for countermeasures (average)

	20 s (*N* = 470)	**30 s (*N* = 470)**	**40 s (*N* = 470)**	**50 s (*N* = 470)**	**60 s (*N* = 470)**
In the case of 3.0% within 30 years	The occurrence probability within 20 years	The occurrence probability within 30 years	the occurrence probability within 30 years	The occurrence probability within 10 years	The occurrence probability within 10 years
In the case of 26.0% within 30 years	The occurrence probability within 30 years	The occurrence probability within 30 years	The occurrence probability within 30 years	The occurrence probability within 10 years	The occurrence probability within 10 years

This may be due to the fact that the Pacific coastal region includes Ibaraki, Chiba, and Tokyo, which suffered a great amount of damage due to the Great East Japan Earthquake, though not as much as the Tohoku region, and moreover, it also includes areas where major earthquakes are likely to occur in the future, such as Tokyo Metropolitan Inland Earthquake and the Nankai Trough Earthquake.

In addition, the peaks where the perceived need for countermeasures increased the most were the same in both areas at the occurrence probabilities within 10 and 20 years (Table 6).

As mentioned above, the differences in the perceived need for countermeasures according to the probabilistic expression in the seismic hazard maps became clear. It was through simple survey analyses that we were able to understand the most effective risk expression regarding earthquakes and confirm the differences across attributes.

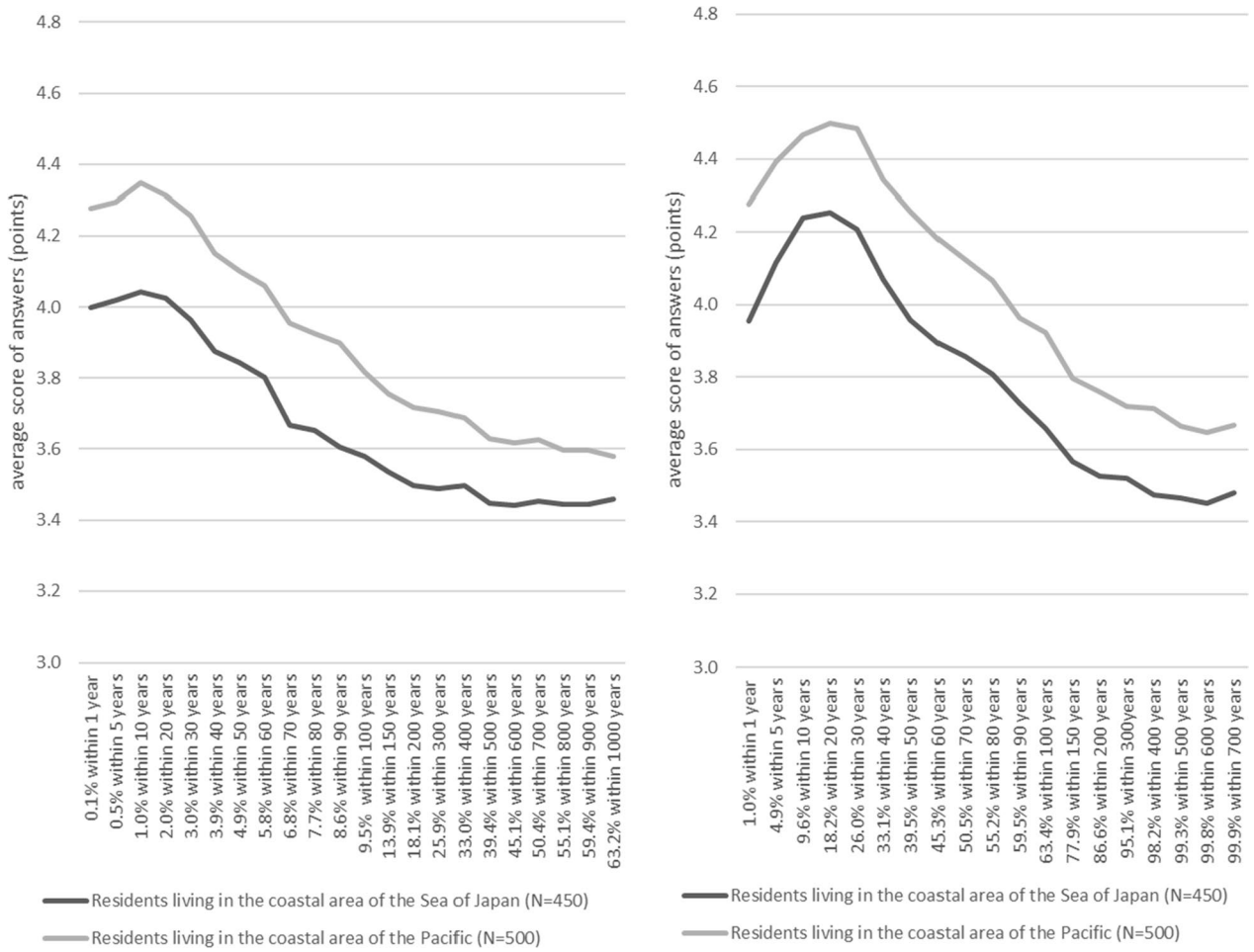


Fig. 9 Perceived need for countermeasures (by area of residence): (left): "3.0% within 30 years"; (right): "26.0% within 30 years"

Table 6 Peak for maximized awareness of the need for countermeasures (average)

	Residents living in the coastal area of the Sea of Japan (*N* = 450)	**Residents living in the coastal area of the Pacific (*N* = 500)**
In the case of 3.0% within 30 years	The occurrence probability within 10 years	The occurrence probability within 10 years
In the case of 26.0% within 30 years	The occurrence probability within 20 years	The occurrence probability within 20 years

Conclusion

The results of the survey analyses in this study can be summarized as follows.

First, in terms of the probability of an earthquake as shown in seismic hazard maps, the overall perceived need for countermeasures increased as seismic intensity increased. In more detail, there was a difference between 5 Upper and 6 Lower, whereas there was almost no difference between 6 Lower and 6 Upper. Furthermore, it was discovered that when earthquake danger was presented as occurrence probabilities within 10 and 20 years, regardless of earthquake intensity, perceived need for countermeasures increased the most. Based on these findings, it may be beneficial to investigate the yearly likelihood of earthquake that should be conveyed when seismic hazard maps are used to promote the awareness of the need for countermeasures, such as presenting the possibility of

earthquake occurrence within 10 or 20 years. Furthermore, although the probability period for seismic hazard maps varies from country to country, to increase people's awareness of the need for earthquake countermeasures, based on these survey results, it may be effective to reconsider the "representations" of seismic hazard maps worldwide. Since this survey analysis was conducted only for Japan, we think it is valid to expand it to countries around the world to verify the results.

However, the probability representations presented in this study have limitations in that they are converted according to a Poisson distribution, and are not strictly calculated from actual annual probabilities, as previously mentioned.

Second, when considering the results according to age, it was when the risk was presented as the occurrence probabilities within 20 and 30 years for those in their 20–40 s, while it was when the risk was presented the occurrence probabilities within 10 years for those in their 50–60 s, the perception toward the need of countermeasures increased the most. When it was possible to convey information separately according to age, it was thought that such information based on it could be effectively expressed. It was also found that although people in their 20–30 s tended to have a higher perceived need for countermeasures and their anxiety concerning earthquakes was high, the number of people taking three or more measures was smaller among younger generations. It is thought that social education and active reporting that can dissolve such gaps are necessary. The perceived need for countermeasures peaked at the occurrence probabilities within 10 and 20 years in all cases when the results were broken down by gender and area of residence (residents living on the coast of the Sea of Japan or the Pacific coast), which was similar to the overall result. In terms of gender, information provision had to take into account the fact that females had a lower rate of map recognition and that a lower number of males were taking three or more countermeasures. Residents living along the Sea of Japan coast had less concern, a smaller number of persons taking three or more steps against earthquakes, a lower rate of map recognition, and a lower perceived need for countermeasures when viewing the maps than did those living along the Pacific coast. As such, one concern is that the impact may be large when a strong earthquake occurs in the Sea of Japan coastal area. Disseminating the risks further in the future with the understanding of such current conditions in explaining the probability occurrence of earthquakes and approaches to promoting the countermeasures in terms of their perceived need and actions are needed.

The survey in this study aimed to clarify the perception of the transmission of basic risk information. In the future, we would like to develop a more detailed analysis.

Abbreviations

HERP: Headquarters for Earthquake Research Promotion; MEXT: Ministry of Education, Culture, Sports, Science and Technology; NIED: National Research Institute for Earth Science and Disaster Resilience.

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Author contributions

SS designed the survey for the study, performed the data analysis, interpreted the data, and wrote the manuscript. SY participated in the design of the survey. NS conceived of the study, participated in the design of the study, interpreted data, and helped draft the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during this study are not publicly available because there are many parts currently under analysis but are available from the corresponding author on reasonable request after analysis.

Declarations

Ethics approval and consent to participate

In this study, we outsourced the survey to a research company (Rakuten Insight, Inc.), which had acquired P(Privacy) mark, which means that the company has systems in place to appropriately protect personal information.

Consent for publication

Not applicable.

Competing interests

This study got the support of "Integrated Research Project on Seismic and Tsunami Hazards Around the Sea of Japan" of Ministry of Education, Culture, Sports, Science and Technology.

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