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Levels of trust in risk-only negative health messages issued by public agencies: a quantitative research-based mindsponge framework

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Trust in messengers is essential for a public agency to ensure effective benefit-risk communication. However, there is insufficient research on the difference in trust between risk-only or benefit-and-risk messages that deal with negative topics. To clarify these differences, this study used three radiation topics to determine the best benefit-risk communication design. We conducted a randomized comparative study in November 2020 on 1100 Japanese individuals (550 men and 550 women), who were allocated either to the risk message group (risk-only) or the benefit-and-risk message group (benefit-and-risk). The questionnaire focused on the trust level in a public agency for each message. We conducted an independent sample *t*-test using the trust mean at the time of registration. There were significant differences in the trust level in the public agency for all three topics ($p < 0.001$). The trust level was ranked as risk-only, followed by benefit-and-risk; however, the trust level was still high enough when the trust level at baseline was high from the outset. In risk-only communication on negative topics, perceptions were consistent with the types of risk message due to confirmation bias. Hence, trust in risk-only negative health messages promoted a preferential higher information absorptivity under the mindsponge mechanism. However, effective benefit-risk communication is assured by high trust levels between a public agency and the public, so it is important to consistently build trust with all stakeholders on a regular basis.

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Introduction

In Japan, risk analysis in the food safety administration was introduced in 2003 through the passage of the Basic Food Safety Act (Ministry of Health Labor and Welfare, 2020a). This Act was developed by considering the Working Principles for Risk Analysis for Food Safety for Application by Governments [CAC/GL 62–2007; (Codex Alimentarius Commission, 1997)], proposed by the Codex Alimentarius and developed by the Food and Agriculture Organization of the United Nations and the World Health Organization. Subsequently, Japan's Food Safety Commission conducted risk assessments based on the guidelines for assessing the effects of food on health (Ministry of Health, Labor and Welfare, 2020b). Accordingly, public agencies such as the Ministry of Health, Labor and Welfare have implemented risk management to reduce the risks identified by the Commission. Risk communication with the public was conducted as part of this process to exchange opinions and information to ensure food safety. This approach is different from that adopted in other countries that have guidelines for food risk assessments highlighting not only risks but also benefits (EFSA Scientific Committee, 2010; Assunção et al., 2019) through the use of a global and standard evaluation system. However, because Japanese food risk assessments since 2003 have been based on the regulations of the Basic Food Safety Act, they have focused on risk-only evaluations. Inevitably, therefore, public communication in Japan is focused on risk.

The omission of benefits in risk assessment communication reduces message completeness (Tsuchida and Itoh, 2003). To better address social problems, the assessment of both risks and benefits needs to be included. Additionally, the quality of risk information is crucial for the decision-making process of the receiver. For example, it has been shown that the food irradiation of agricultural products poses no health problems if the irradiation is less than 10 kGy. As a result, it has been used to inhibit potato germination in Japan since 1973, but it is critical that the public understands both the risks and the benefits of irradiation. Despite the benefits of food irradiation, there have been cases where supermarkets in Japan have stopped sales as a response to protests against food irradiation (Furuta, 2011). Thus, the public's risk perception of radiation is high. A report by the National Institute of Radiological Sciences in Japan, the results of surveys conducted in 1983, 1992, and 2007 on the risk perceptions of radiation topics (Tsuji et al., 2009) found that nuclear power was perceived as the most dangerous, followed by radioactive waste and food irradiation (Tsuji and Kanada, 2008). Furthermore, a risk perception survey on the health effects of radiation by the Ministry of the Environment (Ministry of the Environment, 2021) has shown a higher level of concern about radiation among about half of the public in Japan after the Fukushima nuclear accident in 2011.

In general, trust is key to enhancing effective communication to stakeholders. There are two types of risk management, namely self-management and organized risk management by another person (Tsuchida and Itoh, 2003; Hirakawa and Tsuchida, 2011). They differ according to the interests or perspectives of the recipients of the risk messages. Everyone is inherently responsible for risk management, although the methods are different. In self-management, people can protect themselves by avoiding unexpected accidents, such as car accidents by using preventive measures. In organized risk management, they cannot use preventive measures by themselves. Therefore, trust among stakeholders must be ensured in risk communication, such that the message from the public agencies is accepted by the public (Kinoshita, 2016). Therefore, it is essential to consider the best approach to enhance trust.

In Japan, the differences in trust between public agencies on radiation topics including "high-level waste disposal," "nuclear power generation," and "food irradiation" between benefit-only and benefit-and-risk messages were evaluated in 1989 through a survey (Kikkawa and Kinoshita, 1989). This survey revealed that benefit-and-risk communication could enhance trust.

However, there is little scientific evidence of effective communication between risk-only and benefit-and-risk messages after the Fukushima nuclear accident in Japan of 2011. The aim of this study was to clarify the differences in trust levels in a public agency between risk-only and benefit-and-risk messages on negative radiation topics with a randomized comparative study. It is meaningful to describe the impact of trust in public communication on the public's acceptance of regulatory health messages.

Methods

Identification of radiation-related controversial topics. We identified two topics ("high-level waste disposal" and "nuclear power generation") with a high level of perceived risk and one topic ("food irradiation") with a low level of perceived risk by the public (Kikkawa and Kinoshita, 1989; Kurikawa et al., 1995); see Supplementary Information). According to a report by the National Institute of Radiological Sciences in Japan, the results of surveys conducted in 1983, 1992, and 2007 on the risk perceptions of radiation topics (Tsuji et al., 2009) found that nuclear power was perceived as the most dangerous, followed by radioactive waste and food irradiation; these findings concurred with those from earlier reports (Tsuji and Kanada, 2008).

Study design. A randomized comparative online study was conducted among Japanese participants in November 2020 (Fig. 1). The following definitions of "risk" and "benefit" were used in this study (EFSA Scientific Committee, 2010):

- Risk refers to "the probability of an adverse effect in an organism, system, or (sub) population in reaction to exposure to an agent."
- Benefit refers to "the probability of a positive effect or the probability of a reduction of an adverse effect in an

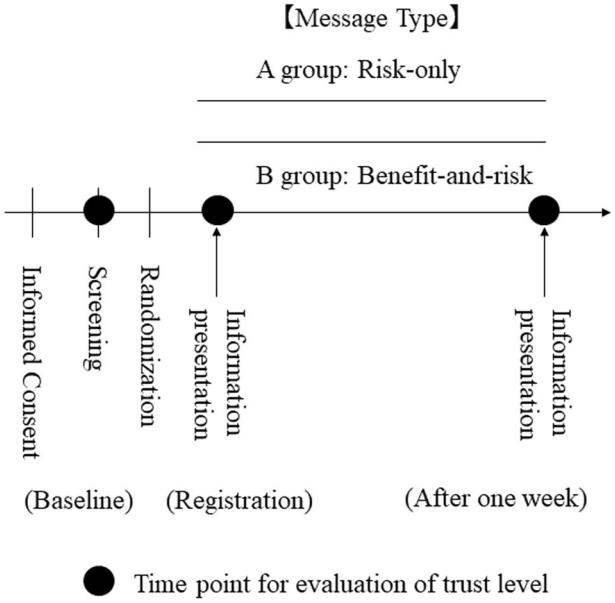

Fig. 1 Study design.

organism, system, or (sub) population, in reaction to exposure to an agent."

Study population and selection process. Japanese participants aged 20 years old and above who had completed at least junior college (Ikawa and Kusumi, 2018) and understood risk or benefit messages were recruited for this study by Rakuten Insight, Inc., an online market research company. The eligible participants were identified after they had completed a series of screening questions.

The participants were randomized into two groups—risk-only message (A) and benefit-and-risk message (B)—according to the national demographics (including age and gender) of Japan (Ministry of Internal Affairs and Communications, 2020). This was done to eliminate the confounding effect of regional differences in Japan and allow result generalizability.

Questionnaire. The investigated items consisted of three major domains, namely (1) the screening page, (2) background (age, gender, numeracy score (Ikawa and Kusumi, 2018), and trust level at baseline), and (3) trust level in a public agency, at the time of registration and after one week, with three controversial topics (see Supplementary Information).

Some data were provided by a survey company using basic panel information, such as age and gender. The numeracy score was measured with the question "How easy is the numerical information to understand?" using a six-point Likert scale ranging from "very difficult to understand" to "very easy to understand" (Ikawa and Kusumi, 2018). The trust level was measured with the item "Information sent from the public agency on the risks and benefits of certain products is trustworthy; please express your trust in the public agency," measured on a seven-point Likert scale ranging from "strongly agree" to "strongly disagree" (Kikkawa and Kinoshita, 1989). The numeracy score or trust level at baseline was classified into three categories—low, medium, or high—based on the distribution of scores in the sample. The thresholds for each are as follows: the cut off values of numeracy score are low = <4, middle = 4≤ or ≤4.5, high = <4.5 and those of the trust level are low = ≤4, middle = 5, high = ≥6.

Study process. The study was conducted online via a web page operated by Rakuten Insight, Inc. and closed after 1100 responses were received. An outline of the study and its objectives was shown on "(1) the screening page" (the first page) to inform the participants. Upon completing and submitting the online questionnaire, they were deemed to have provided their consent to participate in the study. Two major domains of this study—"(2) background" and "(3) trust level in a public agency"—were posed to the participants. Trust in a public agency was measured at three intervals: at screening, registration, and one week after the information was presented (Fig. 1). At the end of one week, the changes in the trust level in the public agency were measured. The same information was presented to the participants at two intervals: at registration and one week after the information was presented. Throughout the study, the information was available only online.

Statistical analysis. The background data were summarized, the frequencies and proportions were calculated for the categorical variables on each questionnaire item, and summary statistics were calculated for the continuous variables. The Likert scales were converted to scores on an ordinal scale with a range of 1–6 (higher values indicate greater numeracy) or 1–7 (higher values indicate greater trust). The primary outcomes were the differences in trust levels between the two groups—risk-only message (A) and benefit-and-risk message (B) at registration. The independent samples' *t*-test and effect size (Cohen's d) were compared between the two groups at the time of registration and after one week. The statistical significance was set at 5%, with the Bonferroni correction for multiple comparisons. The effect size confirmed the differences in trust levels between groups A and B from the time of registration to 1 week after.

Additionally, a sub-analysis was conducted to compare the trust levels between the two groups, with the effect size stratified by the three trust levels at baseline. This analysis was performed using SAS (version 9.4; SAS Institute Inc., Cary, NC, USA).

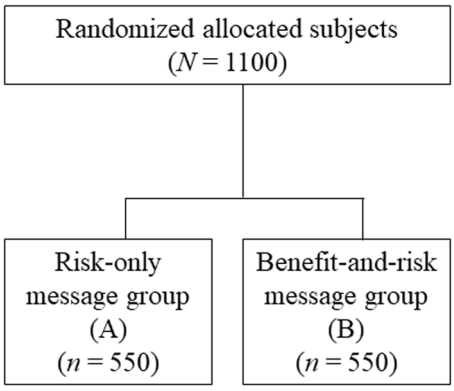

Fig. 2 Target population flow.

Results

A total of 1100 respondents completed the study, with 50% ($n = 550$) in the risk-only message group (A) and 50% ($n = 550$) in the benefit-and-risk message group (B). No respondents were excluded from the analysis (Fig. 2). There were no differences in background characteristics between the two groups (Table 1).

The mean age was 45.6 (SD = 14.7) years for all participants, 45.7 (SD = 14.5) years for the risk-only message group (A), and 45.4 (SD = 14.9) years for the benefit-and-risk message group (B). The mean numeracy score was 4.31 (SD = 0.93) for all participants, 4.31 (SD = 0.96) for the risk-only message group (A), and 4.31 (SD = 0.90) for the benefit-and-risk message group (B). The mean numeracy score in the high category was 5.26 (SD = 0.45) for all participants, 5.29 (SD = 0.45) for the risk-only message group (A), and 5.23 (SD = 0.44) for the benefit-and-risk message group (B). The mean trust in the public agency at baseline was 4.95 (SD = 1.11) for all participants, 4.91 (SD = 1.13) for the risk-only message group (A), and 4.99 (SD = 1.09) for the benefit-and-risk message group (B).

Differences in trust level in public agency between risk and benefit-risk message. The trust level was higher in the risk-only message group (A) than in the benefit-and-risk message group (B) for all topics (Table 2). There were significant differences in trust between the two groups at the time of registration ($p < 0.001$). The range of the effect size in the trust level difference was 0.3–0.5 (small-middle) between the two groups. The highest effect size in this study was 0.5 (middle) for "high-level waste disposal": the mean trust was 4.69 (SD = 1.29) for all participants, 5.03 (SD = 1.19) for the risk-only message group (A), and 4.36 (SD = 1.30) for the benefit-and-risk message group (B) ($p < 0.001$). The effect size in the other topics was small, with values of 0.4 for "nuclear power generation," and 0.3 for "food irradiation."

Table 1 Characteristics of the study sample.

Characteristic	All		Message type			
			Risk-only message group (A)		Benefit-and-risk message group (B)	
	N	(%)	*n*	(%)	*n*	(%)
Gender						
Men	550	50.0	275	50.0	275	50.0
Women	550	50.0	275	50.0	275	50.0
Age, mean (SD)	1100	45.6 (14.7)	550	45.7 (14.5)	550	45.4 (14.9)
Numeracy score[a]						
Mean (SD)	1100	4.31 (0.93)	550	4.31 (0.96)	550	4.31 (0.90)
Low	335	3.25 (0.54)	167	3.21 (0.58)	168	3.29 (0.50)
Middle	350	4.19 (0.20)	178	4.20 (0.21)	172	4.18 (0.20)
High	415	5.26 (0.45)	205	5.29 (0.45)	210	5.23 (0.44)
Trust level in public agency[b]						
Mean (SD)	1100	4.95 (1.11)	550	4.91 (1.13)	550	4.99 (1.09)
Low	367	3.69 (0.72)	188	3.66 (0.77)	179	3.73 (0.68)
Middle	366	5.00 (0.00)	186	5.00 (0.00)	180	5.00 (0.00)
High	367	6.16 (0.37)	176	6.15 (0.36)	191	6.17 (0.37)

1–6 (higher indicates greater numeracy) or 1–7 (higher indicates greater trust).
[a]Low < 4, 4 ≤ Middle ≤ 4.5, 4.5 < High.
[b]Low ≤ 4, Middle = 5, High ≥ 6.

Table 2 Differences of trust level in public agency between rink and benefit-risk message groups.

Topics	All			Message type						*p*-value	Effect size Cohen's *d*[a]	Change of effect size
				Risk-only message group (A)			Benefit-and-risk message group (B)					
	N	Mean	SD	*n*	Mean	SD	*n*	Mean	SD			
At the time of registration												
High-level waste disposal	1100	4.69	1.29	550	5.03	1.19	550	4.36	1.30	<0.001	0.5	-
Nuclear power generation	1100	4.82	1.22	550	5.05	1.15	550	4.60	1.24	<0.001	0.4	-
Food irradiation	1100	4.70	1.19	550	4.87	1.15	550	4.53	1.19	<0.001	0.3	-
After 1 week												
High-level waste disposal	1034	4.77	1.29	517	5.14	1.17	517	4.40	1.30	<0.001	0.6	0.1
Nuclear power generation	1034	4.85	1.27	517	5.16	1.15	517	4.55	1.31	<0.001	0.5	0.1
Food irradiation	1034	4.68	1.22	517	4.97	1.13	517	4.39	1.23	<0.001	0.5	0.2

[a]Effect size 0.2: small, 0.5: middle, 0.8: high.

The change of the effect size from the time of registration to that after one week between the risk-only message group (A) and benefit-and-risk message group (B) increased slightly (0.1–0.2) because the trust level increased in the risk-only message group (A) and decreased in the benefit-and-risk message group (B).

Trust level in public agency stratified by the level at baseline. The trust level in the risk-only message group (A) was higher than in the benefit-and-risk message group (B), stratified by the trust levels at baseline (Table 3). The highest effect size was found for "high-level waste disposal," stratified by the three trust levels at baseline, 0.5 (middle) in the low group: the mean trust was 4.00 (SD = 1.15) for all participants, 4.30 (SD = 1.20) for the risk-only message group (A), and 3.68 (SD = 1.02) for the benefit-and-risk message group (B), 0.7 (middle) in the middle group: the mean trust was 4.70 (SD = 1.08) for all participants, 5.07 (SD = 0.91) for the risk-only message group (A), and 4.31 (SD = 1.12) for the benefit-and-risk message group (B), and 0.6 (middle) in the high group: the mean trust was 5.39 (SD = 1.23) for all participants, 5.75 (SD = 0.97) for the risk-only message group (A), and 5.05 (SD = 1.34) for the benefit-and-risk message group (B). In both groups, the trust levels at registration—stratified by the three trust levels at baseline—were above five.

The change in the effect size from the time of registration to that after one week between the risk-only message group (A) and benefit-and-risk message group (B) was 0–0.2, being stable or slightly increasing in all topics.

Discussion

We examined the differences in the trust level in a public agency, wherein the messages were either a one-sided risk-only or a benefit-and-risk information handled three topics with high public risk perception. The study revealed that one-sided risk-only message created a higher trust in the agency. The effect sizes were small, except for the topic of "high-level waste disposal." This trend was maintained for one week.

Information filtering system in benefit-risk communication based on the "mindsponge mechanism". It is generally believed that the trust level is higher with two-sided messages (Winter and

Table 3 Trust level in public agency stratified by the level at the baseline.

Topics	All			Message type						Effect size Cohen's d^b	Change of effect size
				Risk-only message group (A)			Benefit-and-risk message group (B)				
	N	Mean	SD	*n*	Mean	SD	*n*	Mean	SD		
[a]Low											
At the time of registration											
High-level waste disposal	367	4.00	1.15	188	4.30	1.20	179	3.68	1.02	0.5	-
Nuclear power generation	367	4.10	1.11	188	4.30	1.19	179	3.90	0.98	0.4	-
Food irradiation	367	3.96	1.06	188	4.10	1.09	179	3.81	1.02	0.3	-
After 1 week											
High-level waste disposal	348	4.18	1.28	177	4.50	1.22	171	3.86	1.26	0.5	0.0
Nuclear power generation	348	4.28	1.27	177	4.57	1.16	171	3.97	1.32	0.5	0.1
Food irradiation	348	4.15	1.16	177	4.40	1.15	171	3.89	1.13	0.4	0.2
[a]Middle											
At the time of registration											
High-level waste disposal	366	4.70	1.08	186	5.07	0.91	180	4.31	1.12	0.7	-
Nuclear power generation	366	4.84	0.95	186	5.11	0.77	180	4.56	1.04	0.6	-
Food irradiation	366	4.76	0.90	186	4.98	0.86	180	4.53	0.87	0.5	-
After 1 week											
High-level waste disposal	343	4.81	1.12	174	5.25	0.93	169	4.36	1.13	0.8	0.1
Nuclear power generation	343	4.88	1.11	174	5.22	0.97	169	4.53	1.14	0.6	0.0
Food irradiation	343	4.73	1.04	174	5.05	0.90	169	4.41	1.08	0.6	0.1
[a]High											
At the time of registration											
High-level waste disposal	367	5.39	1.23	176	5.75	0.97	191	5.05	1.34	0.6	-
Nuclear power generation	367	5.53	1.13	176	5.78	0.95	191	5.30	1.24	0.4	-
Food irradiation	367	5.38	1.12	176	5.59	0.97	191	5.19	1.22	0.4	-
After 1 week											
High-level waste disposal	343	5.31	1.21	166	5.70	1.01	177	4.95	1.27	0.6	0.1
Nuclear power generation	343	5.41	1.17	166	5.72	1.03	177	5.12	1.23	0.5	0.1
Food irradiation	343	5.16	1.22	166	5.49	1.04	177	4.85	1.29	0.5	0.2

Notes: 1–7 (higher indicates greater trust).
[a]Trust in public institutions at the baseline, *L* low, *M* middle, *H* high.
[b]Effect size 0.2: small, 0.5: middle, 0.8: high.

Krämer, 2012; Mayweg-Paus and Jucks, 2017). However, one-sided messages are preferred in some cases due to the influence of confirmation bias, which is the tendency to focus only on information that is consistent with one's own beliefs in the processing process (Metzger et al., 2015). The impact of this psychological bias on information filtering in benefit-risk communication can be explained by "mindsponge mechanism" suggested by Vuong and Napier (Vuong and Napier, 2015).

There are three steps in the information absorption process under this mechanism (Fig. 3). At first, information from the external environment is moved from step 1 to step 2. In step 2, the "value" is subjectively decided based on both perceived cost and benefits there, referring to past personal experiences. If the "value" of information is judged positive when the perceived benefit is greater than the cost, the information with a new "value" is absorbed easily after moving to step 3. Furthermore, "trust (adding general value to information)" in the information or sources in this mechanism works as a "priority path" that speeds up these information absorption processes. Therefore, it is important to routinely enhance people's trust in the public agency for benefit-risk communication.

Trust level by comparison of the benefit-and-risk message. As the topics in this study refer to radiation, the level of risk perception was high (Kikkawa and Kinoshita, 1989; Kurikawa et al., 1995; Ministry of the Environment, 2021). This was attributed to a perception that, unlike natural risks, involuntary risks were associated with the development of radiation technology (Bennett, 1999). Communication that evokes negative emotions will induce a perception of higher risk and smaller benefit, a phenomenon known as "affect heuristic" (Kusumi et al., 2013). This leads to a preference for one-sided messages, which are easier to process cognitively because they are consistent with one's beliefs affected by "confirmation bias." For example, single-sided risk communication on radiation topics has induced higher

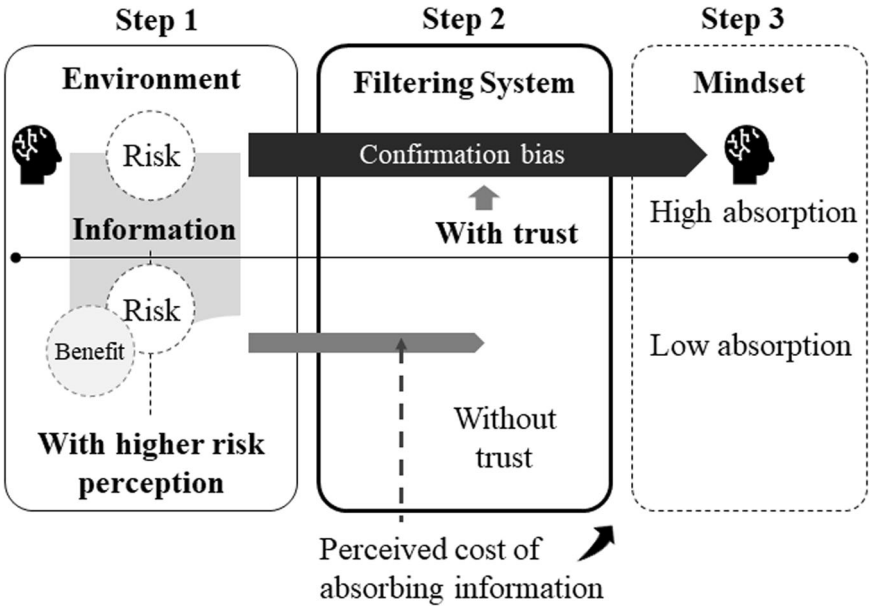

Fig. 3 Information filtering system based on the "mindsponge mechanism"-treated negative topics in benefit-risk communication.

trust levels in public than risk-and-safety communication in Japan (Kusumi et al., 2013; 2014). In other words, trust performs preferential information filtering, so single-sided risk-only message with value enhances information absorptivity. The perceived cost exceeds benefits when benefit message is added to negative topics with higher risk perception. As a result, no value is created in the message, so the ability to absorb information is weakened.

However, a higher level of trust in two-sided messages occurs when the message receiver is more flexible in their thinking (Flanagin et al., 2020). Early educational intervention may be important to change perceptions by increasing the flexibility of our thinking.

Importance of enhancing trust between a public agency and the public on a routine basis. As mentioned above, the remeasurement of trust level under the same topics or message after one week produced the same findings. However, the effect size was slightly larger than when the message was accessed for the first time. As the volume of risk messages increased, the trust levels in both types of messages decreased. The more negative the messages were, the more negative impressions the receiver had (Ohtomo et al., 2014). Consequently, it is more usual to have a lower level of trust in benefit-and-risk messages.

However, when stratified by trust levels at baseline, there was no difference in trust across topics. In particular, the double-sided messages had a significantly lower level of trust than the one-sided messages, but the trust level was still high enough when the level of trust at baseline was high from the outset. Even if the value of information was rejected because the perceived costs outweighed the benefits, the higher trust level could enhance the information absorption in risk communication. Therefore, it is important to consistently build trust with all stakeholders to ensure effective benefit-risk communication by receiving the benefits inextricably linked to risk (Vuong et al., 2022).

This is the first study to integrate the "mindsponge mechanism" into quantitative research to explain the information process of risk perception. This approach could prove an innovative method for social and psychological research in addition to the Bayesian mindsponge framework (Nguyen et al., 2022). In the future, further risk communication research in other food safety topics should be also conducted using this new quantitative research-based mindsponge framework globally.

Strength and limitations. This was a randomized comparative study, so the study design can be adjusted for confounding factors, including uncollected background data on the target population. However, this study has the following limitation: there were no data on the benefit-and-risk perceptions for the topics at the baseline level. Hence, we referred to previous reports for this information (Kikkawa and Kinoshita, 1989; Kurikawa et al., 1995).

Conclusions

This study showed significant differences in trust levels in a public agency between rink-only and benefit-and-risk messages on radiation topics. However, the key point for ensuring the success of a benefit-risk communication design is to routinely build a higher level of trust between a public agency and the public by considering the information absorption process in the mindsponge mechanism.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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Competing interests
The authors declare no competing interests.

Ethical approval
This survey was conducted in accordance with the local ethical guidelines for medical and health research involving human participants. The research was approved on September 9, 2020 (No. 223) by the Ethics Committee for Research Involving Humans.

Informed consent
The study's outline and objectives were provided on the web page to facilitate participants' understanding. Completing the survey was regarded as providing informed consent, based on the local ethical standard guidelines published in Japan.

Additional information
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