Common indicators across sectors for measuring effectiveness of risk communication practices in 2011–2017

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Background. Risk communication is implemented in diverse academic fields. However, there is a lack of comprehensive knowledge about how risk communication is conducted and how its “success” or “effectiveness” is measured across fields. To understand overall trends in current risk communication activities and evaluations, this study systematically searched materials from four search engines and one journal well known in the area of risk communication. **Methodology.** Following eligibility screenings, this study assessed 316 articles published in English or Japanese in 2011–2017 that evaluated risk communication activities in various fields involving medicine, food safety, chemical substances, nuclear and radiological disasters/emergencies, other disasters/emergencies, and climate change. We extracted information from the selected materials, such as study field, intervention timing, target audience, communication type, and evaluation indicators utilized. This information was examined by study fields and by evaluation indicators. In addition, this study compared the main indicators identified in the selected materials with the definitions and purposes of risk communication stated by selected international and national organizations. **Results.** The analysis showed that target audience and communication type differed between fields. Differences in the uses of indicators were also observed across fields, although “knowledge increase,” “change in risk perception and concern alleviation,” and “decision making and behavior change” were common. Furthermore, the analysis showed that “trust building” differed by field, and “change in risk perception and concern alleviation” differed by intervention timing and communication type. “Decision making and behavior change” differed by communication type. **Conclusion.** The

comparison assessment suggested that current activities rarely aim at trust building, mutual understanding among stakeholders, or citizen involvement in the decision-making process despite their frequent appearance in the selected organizations' perspectives of risk communication. The findings of this study offer valuable insights to help those engaged in risk communication strengthen their practices and assist in effective intersectoral and multisectoral collaboration.

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Abstract

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identified in the selected materials with the definitions and purposes of risk communication stated by selected international and national organizations.
Results. The analysis showed that target audience and communication type differed between fields. Differences in the uses of indicators were also observed across fields, although "knowledge increase," "change in risk perception and concern alleviation," and "decision making and behavior change" were common. Furthermore, the analysis showed that "trust building" differed by field, and "change in risk perception and concern alleviation" differed by intervention timing and communication type. "Decision making and behavior change" differed by communication type.
Conclusion. The comparison assessment suggested that current activities rarely aim at trust building, mutual understanding among stakeholders, or citizen involvement in the decision-making process despite their frequent appearance in the selected organizations' perspectives of risk communication. The findings of this study offer valuable insights to help those engaged in risk communication strengthen their practices and assist in effective intersectoral and multisectoral collaboration.

Introduction

Risk communication has been receiving tremendous attention from scholars and practitioners in the past few decades, and it has been ardently applied to avert risks occurring and reduce their impacts on human health and property and the environment, or to facilitate informed decisions by concerned parties about existing risks and possible options [1,2]. It has become a key element in risk reduction efforts across multiple sectors [3-5]. Risk communication can involve various interest groups and take different forms (e.g., individual, group, and mass communication) depending on its purposes and the surrounding circumstances [4]. Risk communication is a multi-faceted discipline reflecting the diversity of hazards and associated risks in life.
In 1989, the United States National Research Council published *Improving Risk Communication* [5], which spotlighted the importance of risk communication and introduced an influential new perspective. It stated that "risk communication is an interactive process of exchange of information and opinion among individuals, groups, and institutions. It involves multiple messages about the nature of risk and other messages, not strictly about risk, that express concerns, opinions, or reactions to risk messages or to legal and institutional arrangements for risk management." [5 p. 21] The report explained problems and difficulties surrounding risk communication and developed core concepts, principles, and recommendations for implementation. In response to a growing global awareness of the importance of risk communication, numerous international and national organizations have expressed their views on risk communication and have issued guidelines and manuals to facilitate its application in their area of focus. Notable examples of risk communication materials include the *Guidance on the Communication of Information on the Risks and Safe Use of Chemicals* of the European Chemicals Agency [6] and the *Crisis and Emergency Risk Communication* of the United States Centers for Disease Control and Prevention [7]. Some organizations produce risk communication

materials targeting a specific hazard, such as the *Guidelines for Risk Communication Messaging: Addressing Avian Influenza A (H7N9)* of the Food and Agriculture Organization of the United Nations [8]. Risk communication is now recognized as a fundamental and vital responsibility of governments, industry, and other concerned parties.

Along with the above efforts and commitment of entities and individual professionals, practices of risk communication are increasingly reported. However, not all the practices have been successful, and not all have been evaluated thoroughly or their effectiveness has been evaluated poorly owing to diverse challenges, such as the difficulty in taking all stakeholders' perspectives into consideration, the influences of different communication channels, and the sensitivity of asking evaluation questions in the case of emergencies [9,10]. Lack of evidence-based evaluation and reliable data may raise questions about the quality of the activities and may impede further promotion of risk communication. Even when the impacts of risk communication activities are documented, the methods used to assess their effectiveness—for instance, the indicators that are applied—vary greatly between cases because risk communication is implemented for a wide variety of goals and objectives, which is a factor linked to its dynamic concept [11]. It is not straightforward to comprehend how risk communication activities have been commonly evaluated in a given field, and it is even more cumbersome to grasp overall trends of risk communication evaluations across different fields.

There are studies that have reviewed evaluation methods to measure the effectiveness of risk communication within a specific field [12,13]. To our knowledge, however, there is still a lack of synthetic research that assesses risk communication experiences across fields and provides a comprehensive overview on how the effectiveness of risk communication activities has actually been measured. Such information is important to understand the trends of risk communication activities in different fields and facilitate intersectoral and multisectoral collaboration for reducing risk vulnerability and building relevant capacity of individuals and institutions.

For that reason, this study attempted to identify, appraise, and summarize indicators used to evaluate risk communication activities across sectors. Furthermore, this study assessed identified indicators referring to the definitions and key objectives of risk communication proposed by major international and national organizations to investigate if any discrepancies exist between their perspectives and expectations on risk communication and current practices. This paper was prepared after we added analyses, results, and discussion to a report for the Research on the Health Effects of Radiation organized by the Ministry of the Environment, Japan [14].

Survey methodology

Inclusion and exclusion criteria

Inclusion criteria for this study were (1) empirical studies that evaluated risk communication activities in any field, (2) written in English or Japanese, and (3) published in journals between 2011 and 2017. This study also included studies that did not directly evaluate risk communication but asked implementers, such as medical professionals, about the purposes and impacts of their activities relevant to risk communication. Review studies, commentaries,

conference proceedings, and books were excluded. Because abstracts were assessed for the eligibility screening and for finalizing the plan for data extraction and synthesis, materials that did not provide an abstract were excluded. Articles that discuss the procedures of future risk communication activities—meaning that the activities had not been implemented at the time of publication—were also excluded. The detailed search strategy is discussed below.

Search strategy

In the search process, first, potential materials to be used for this study were manually identified on April 18, 2018, through relevant academic search engines, namely, PubMed, ScienceDirect, and PsycINFO for English publications and CiNii for Japanese publications. For the English search engines, the only search term used was "risk communication." The search terms for the Japanese search engine were "*risukukomyunikēshon*" ("risk communication" in the Japanese language) and "*risukomi*," which is a contracted word frequently used in Japan for risk communication. The *Journal of Risk Research* was also included as a source for the material collection because the journal contains many study articles on the topic of risk communication but is not covered by these search engines. Other well-known journals in relation to risk communication studies include *Risk Analysis* and the *Japanese Journal of Risk Analysis*, and they are in PubMed and CiNii, respectively. At this point, the material search was not limited by the year of publication. Second, duplicated articles were eliminated from identified articles. Third, articles that did not provide an abstract in English or Japanese languages were removed. Finally, this study focused on materials published between 2011 and 2017, which were eventually about half of the identified materials (the details are explained in the Results section), and they were extracted for subsequent full-text assessment.

Once titles and abstracts of pre-extracted articles were obtained from the databases, they were divided into six groups (five groups for English materials and one group for Japanese materials). Each group of titles and abstracts was allocated to and independently screened by two or more researchers of the research team (i.e., all of the authors of this paper) based on whether or not the assigned articles were studies that (1) evaluated the effectiveness of risk communication activities quantitatively using a numeric-based instrument(s), such as providing participants pre- and post-training knowledge tests at an educational program relevant to risk communication; (2) assessed the purpose, intended success, and/or impact of risk communication activities qualitatively, such as by asking participants what they gained from a public forum relevant to risk communication; or (3) discussed the purpose, intended success, and/or impact of risk communication activities based on prior experiences, and/or existing scientific knowledge involving theories and models, such as by asking implementers (i.e., medical professionals) about their experiences and perspectives in relation to risk communication. The principal investigator of the research project (MM) coordinated this evaluation and selection process. MM checked all articles and facilitated discussions between the researchers to achieve consensus when there was a disagreement.

Data collection process

On the basis of the assessment of titles and abstracts during the screening process, the research team jointly determined what data should be extracted and how they should be tabulated. Once full texts of selected articles were obtained, they were re-grouped into nine groups, and a pair of researchers independently read assigned articles that they had not checked during the initial screening process and confirmed the eligibility of the articles. Then, researchers individually extracted the following data from each article and coded it as follows:

- Evaluation approach: (coded as 1) quantitative, (2) qualitative, and (3) based on prior experience and/or existing scientific knowledge
- Study field: (1) medicine, such as health and pharmaceutical realms; (2) food safety; (3) chemical substances (other than food safety matters); (4) nuclear and radiological disasters/emergencies; (5) other disasters/emergencies; (6) climate change; and (7) other
- Timing when a risk communication intervention was implemented, in line with the phases in the disaster management cycle: (1) non-crisis or pre-crisis, including non-specified; (2) crisis; and (3) post-crisis, including recovery phase. Regarding the term "crisis," this study referred to the definition proposed by Coombs [15 para. 2] as "a significant threat to operations that can have negative consequences if not handled properly." It can be an event (or series of events) and situation(s) that may cause health, financial, and/or social problems to individuals, organizations, communities, or even the whole of society
- Target audience: (1) citizens (e.g., individual citizens, residents, unspecified persons, non-profit organizations, and citizen groups) and (2) other (e.g., government, professionals, and companies)
- Communication type: (1) individual/small group communication (e.g., doctor–patient–family communication and family communication) and (2) other (e.g., mass communication)
- Indicator used for evaluation, including desired or intended impacts on target audience: (1) knowledge increase; (2) communication satisfaction; (3) change in risk perception and concern alleviation; (4) reduction in psychological distress; (5) trust building; (6) decision making and behavior change (e.g., risk acceptance, risk avoidance, and risk management, such as avoidance of unhealthy foods, healthcare seeking, disaster mitigation and preparedness, and community partnerships; attitude toward behavior and behavioral intention were also included in this category); (7) self-efficacy improvement; and (8) other.

Where applicable, multiple response categories were selected. When the two researchers coded differently, discrepancies were evaluated by a third researcher. When needed, the third researcher discussed the issues with MM until they reached agreement on code selection. In addition, the number of citations of each article was assessed on May 10, 2019, through Google Scholar to draw examples of indicators for this paper from the most frequently cited articles. Data were entered into a Microsoft Office Excel spreadsheet for administration and analytical purposes. Excel was used to compute descriptive information of the collected data. R [16] was used to conduct sets of Pearson's chi-squared tests with Yates's continuity correction and Fisher's exact test to assess the correlations between study field and timing when a risk

communication intervention was implemented, target audience, and communication type, as well to assess as the correlations between evaluation indicators and study field, intervention timing, target audience, and communication type. With analyses involving more than two independent comparison groups (i.e., analyses involving study field), post hoc tests were conducted to determine where differences lay if initial analyses identified a significant difference between groups [17]. *P*-value adjustment by Holm's method was applied for multiple comparisons. Because variables allowed multiple responses, statistical analyses were performed only with studies that were not multi-coded for the variables of study field, intervention timing, target audience, and communication type. The variable of indicators was dichotomized for each indicator and recoded as either "yes" (i.e., the particular indicator was applied or related information was assessed in a given study) or "no." Study fields and other variable categories with a small number of relevant articles and those that were not related to any of the six academic fields (i.e., those coded as "other" for the study field variable) were also excluded from the statistical analyses. Test results were considered significant at $P < 0.05$.

With regard to definitions and purposes of risk communications presented by key international and national organizations, this study searched them from documents and websites of relevant United Nations organizations, the European Union, and other intergovernmental organizations, as well as government departments and agencies in the United States and Japan. Materials that provided clear definitions and/or purposes of risk communication were selected for analysis.

Results

Search results

Figure 1 summarizes the flow of the material search and selection for this study. The database search in English and Japanese languages found 5,841 articles. Of those, 3,710 articles were identified through the database search in English: 2,127 from PubMed, 918 from PsycINFO, 513 from ScienceDirect, and 152 from the *Journal of Risk Research*. The remaining 2,131 articles were identified by the CiNii search with Japanese keywords. Among the 5,841 articles, a total of 1,026 were duplicates. The subsequent screening identified 1,668 articles without an abstract or with an abstract not written in English or Japanese.

Fig 1. Flow diagram of material selection. JRR = Journal of Risk Research

Figure 2 shows the publication years of the remaining 3,147 articles; it reveals a sharp increase in the number of journal articles concerning risk communication published over the years, especially after 1998. As stated earlier, this study focused on recent risk communication activities, specifically those published in 2011–2017. This particular criterion reduced the list of materials for full-text eligibility assessment to 1,696 articles (1,443 from the database search in English and 253 from the database search in Japanese), which was approximately half of the 3,147 articles. The two rounds of eligibility assessment excluded an additional 1,380 articles. The majority of the excluded articles did not evaluate a risk communication activity or did not

clearly address the purpose, intended success, or impact of a risk communication activity. Some articles discussed protocols of future risk communication activities. In the end, 316 articles were analyzed.

Fig 2. Trend in the number of risk communication publications over time.

Characteristics of risk communication studies

The data generated for this study are provided in Table S1. The table contains basic information of all the 316 articles. Below is a descriptive summary of the data (Table 1).

More than 80% of the 316 studies quantitatively evaluated their risk communication activities. Nearly 60% of identified studies were related to medicine, followed by 12% related to disasters/emergencies other than nuclear and radiological events. Only 2% were related to nuclear and radiological disasters/emergencies and 2% to climate change. Studies classified as "other" included those addressing human–wildlife conflicts [18] and traffic safety [19,20], as well as studies that used a risk scenario or involved multiple risk topic domains to identify effective methodology or to assess intrapersonal and other factors in relation to risk communication [21,22]. Among the 316 studies, five studies (2%) fell in multiple fields.
The vast majority of risk communication activities were implemented during a non-/pre-crisis phase (94%). Only a few percent were implemented in a crisis phase or post-crisis phase. One study involved multiple phases. Over 90% targeted citizens (of those, 18 studies or 6% approached both citizens and others). Other target groups included medical professionals and farmers. As for communication type, 68% were communications to a large group audience (of those, seven studies or 2% of the overall 316 studies were also conducted in the form of individual/small group communication). Intervention impacts commonly assessed or identified in the selected studies were "decision making and behavior change," "change in risk perception and concern alleviation," and "knowledge increase" (61%, 44%, and 40%, respectively), whereas "self-efficacy improvement" and "reduction in psychological distress" were rarely addressed (4% and 2%, respectively).
Examples of evaluation instruments per indicator were selected from frequently cited articles and are shown in Table 2. One example for each indicator was chosen from the field of medicine, and another was chosen from other fields because of the generally large number of citations of medicine-related articles. Examples were chosen based not only on the frequency of citation but also on the clarity of applied instruments. In addition, although some frequently cited studies targeted multiple indicators, in Table 2, they were referred to for only one indicator among all the applicable indicators. Consequently, the studies listed in the table are not necessarily the most frequently cited studies in a given field.

Many studies applied single or multiple Likert-scale items to measure intended outcomes of their risk communication activities. Some studies that introduced multiple Likert-scale items

combined scores and created a single index, whereas others used a total, average, or individual item score to assess the outcome. Regarding qualitative studies, this study looked at participants' responses to topics relating to the purpose, intended success, and/or impact of a given risk communication activity. For instance, the study of Besser et al. [31] found that quality of doctor–patient communication affected their relationship and in turn affected patients' adherence to medication. As for other outcomes besides these seven indicators, one example was quality of life, including physical and social functions and mental health, in the study of Cheng et al. [36] which assessed oral cancer patients' involvement in medical decision making and their health-related quality of life. Another example was the medication satisfaction of rheumatoid arthritis patients in the study of Blalock et al. [37] which assessed the association between central elements that study participants extracted from the information provided during their office visits and their perceptions of the treatment.

Differences in intervention timing, target audience, and communication style by study field

In most study fields, risk communication activities were conducted in a non-/pre-crisis phase, whereas nearly half of the risk communications in the field of nuclear and radiological disasters/emergencies were conducted in a non-/pre-crisis phase and the remaining were in a post-crisis phase (Table 3). The table shows that the majority of risk communications targeted citizens. At the same time, 32% in the field of chemical substances targeted other groups (including those that targeted both citizens and non-citizens). In the medical field, half of the risk communications were conducted at an individual level or in a small group, whereas risk communications in other fields were conducted mainly in a larger group or to an entire population of interest.

Fisher's exact tests were performed with studies that belonged to a single category of all the variables of study field, intervention timing, target audience, and communication type to prevent violating the test assumption of observation independence. Regarding the study field, those classified as "nuclear and radiological disasters/emergencies," "climate change," and "other" were excluded from the analysis owing to their small sizes. For intervention timing, the "crisis" and "post-crisis" groups were combined because of their small sizes to make the variable dichotomous. The series of analyses found significant associations between study field and target audience and between study field and communication type ($P < 0.01$) (Table S2). Multiple comparisons with Fisher's tests suggested a significant difference pertaining to communication type between risk communications in the field of medicine and those in food safety and non-nuclear/-radiological disasters and emergencies ($P < 0.05$).

Differences in study field, intervention timing, target audience, and communication style by evaluation indicator

Table 4 shows the diversity in indicators for risk communication activities. On the whole, "knowledge increase," "change in risk perception and concern alleviation," and "decision

making and behavior change" were frequently focused on across study fields (40%, 44%, and 61%, respectively). At the same time, when looking at indicators by study field, for example, the table shows that a higher percentage of risk communications in the field of nuclear and radiological disasters/emergencies looked at communication satisfaction (29%), compared with risk communications in other fields. Similarly, higher percentages of risk communications in the fields of food safety and climate change looked at "change in risk perception and concern alleviation" (62% and 60%, respectively). The fields of food safety and other (non-nuclear/-radiological) disasters and emergencies had a higher percentage in terms of risk communications aiming or addressing "trust building" (23% and 19%, respectively) than other fields, especially the field of medicine (5%). The chemical substance field had a higher percentage (74%), and the field of nuclear and radiological disasters/emergencies had a lower percentage (29%) compared with other fields with regard to risk communications focusing on "decision making and behavior change."

Table 4 also suggests some percentage differences in intervention timing, target audience, and communication type by evaluation indicator. The main indicators of risk communications conducted in a non-/pre-crisis period were "knowledge increase," "change in risk perception and concern alleviation," and "decision making and behavior change" (40%, 46%, and 62%, respectively). "Decision making and behavior change" was a main indicator for risk communications conducted in a crisis period (57%). "Knowledge increase," "communication satisfaction," and "change in risk perception and concern alleviation" were the main indicators for risk communications conducted in a post-crisis period (71%, 43%, and 43%, respectively). There was over 10% difference in "change in risk perception and concern alleviation" between risk communications targeting citizens and risk communications targeting others (45% vs. 27%). The same was observed for "change in risk perception and concern alleviation" and "decision making and behavior change" between risk communications conducted at an individual/small group level and risk communications conducted in larger groups (32% vs. 49% and 72% vs. 57%, respectively).

Pearson's chi-squared tests and Fisher's exact tests were performed with studies that (1) fell within a single category of all the variables of "study field," "intervention timing," "target audience," and "communication type" and (2) were in the field of "medicine," "food safety," "chemical substances," or "other disasters/emergencies." The analyses (summarized in Table S3) revealed a significant association between study field and "trust building" ($P < 0.01$), between intervention timing and "change in risk perception and concern alleviation" ($P < 0.05$), between communication type and "change in risk perception and concern alleviation" ($P < 0.05$), and between communication type and "decision making and behavior change" ($P < 0.05$). Multiple comparisons found a significant difference in "trust building," specifically between the field of medicine and the field of other (non-nuclear/-radiological) disasters and emergencies ($P < 0.05$).

Comparison between risk communication definitions and purposes stated by international and national organizations and the main evaluation indicators identified in this study

Table 5 lists the definitions and purposes of risk communication for each field presented by some prominent international organizations, as well as those by national departments and agencies in the United States and Japan. Underlines were added by the authors of this study to highlight content corresponding to the indicators identified in this study.

Besides the organizations whose risk communication definitions and purposes are listed in Table 5, there are many other organizations that emphasize the importance of risk communication and put in strenuous efforts to promote it even though they do not present risk communications definitions directly. For example, the United Nations Office for Disaster Risk Reduction [52 p. 4] states as a part of its thematic guidelines that "Effective communication helps technical experts develop and share data, it enables professional users to understand the data, and it influences how ordinary people take actions to reduce risk in their everyday lives. Communication is a process and should be considered throughout every stage of risk assessments." It offers governments an overview of risk communication principles and recommendations to support development and effective implementation of member states' practices. The International Federation of Red Cross and Red Crescent Societies has developed a set of guidelines for nuclear and radiological emergencies informed by the hardships encountered in responding to the 2011 Fukushima Daiichi nuclear disaster [53]. These guidelines discuss the difficulties and suboptimal communication following previous nuclear disasters and describe the challenges and offer suggestions regarding communication for an unfamiliar and unexpected technological disaster. In addition to guidelines, the International Atomic Energy Agency introduced in their bulletin the risk communication definition developed by Ropeik [54 p. 59] as "actions, words, and other interactions that incorporate and respect the perceptions of the information recipients, intended to help people make more informed decisions about threats to their health and safety," and has significantly contributed to widening historical perspectives of risk communication.

All the above considered, in general, indicators identified from risk communication studies in each field correspond to the main elements of risk communication definitions and purposes of the international and national organizations. For example, this study identified "knowledge increase," "change in risk perception and concern alleviation," and "decision making and behavior change" as areas of focus in all fields, and these are also discussed in the definitions and purposes of most organizations and agencies. Especially, as shown in Table 5, "knowledge increase" through information sharing appears in nearly all the definitions and purposes of the selected international and national organizations. Here, "knowledge" is about the risks of concern and related risk management policies and actions. "Change in risk perception" is primarily about guiding individuals' subjective judgment of risk to align with available scientific evidence. Table 5 also shows that "reduction in psychological distress" and "self-efficacy improvement" do not appear in the selected organizations' definitions and purposes of risk

communication, which is commensurate with this study: they were rarely addressed in the studies assessed in this study (2% and 4%, respectively; Table 1).

Concurrently, Table 5 reveals components in the selected organizations' definitions and purposes of risk communication that are not underlined, meaning that they do not correspond with any of the major indicators identified in this study. Examples include "to facilitate dialog and understanding among all interested stakeholders" stated by the Food and Agriculture Organization of the United Nations and World Health Organization [44 p. 7] and "to ask stakeholders for input in a decision-making process" stated by the United States Nuclear Regulatory Commission [51 p. 6]. Such "facilitation of mutual understanding" and "citizen participation in policy making," in fact, hardly appeared at all in the materials assessed in this study (Table S1). Similarly, "trust building" is frequently included among the proposed purposes of risk communication, whereas it was rarely addressed in the studies assessed in this study (8%, Table 1). Furthermore, although the organizations extended the target of risk communication to non-citizen parties, such as industries and media, in their statements, those groups were rarely targeted in risk communication activities in the articles assessed in this study. Naturally, relevant indicators were not discussed in the articles.

It is also worth noting that there seem to be some variations between organizations in terms of their views on risk communication. For instance, the listed definitions and purposes of some organizations, such as the Organization for Economic Co-operation and Development [38], focus on the provision of information and scientific knowledge, whereas others, such as the Japanese Ministry of the Environment [41], state an exchange of information and opinions as a central part of risk communication. These variations result in a difference in their main purposes of risk communication.

Discussion

~~This study was implemented to obtain a comprehensive picture on the purposes of risk communication and the methods by which it is practiced across academic fields.~~ This study captured well the diverse landscape of risks that have been communicated, such as types (existing–emerging–potential and known–unknown threats), the likelihood of occurrence (common–rare events), and the magnitude and severity of consequences (high–low impact). It is shown in the number of risk communication studies in each field. For instance, there were far more risk communication studies from the medical field compared with those related to nuclear and radiological disasters/emergencies and climate change. One reason behind this result is presumed to be a generally larger number of medical industry publications [55]. This may also be partly because medical issues, such as chronic diseases, are generally common and well-known problems that severely affect a considerable number of individuals across national borders. In contrast, nuclear and radiological accidents and climate change issues are relatively new challenges, and uncertainties remain in their possible consequences and also with prevention and control measures [56]. For other disasters and emergencies, such as natural disasters, they are less frequent than certain illnesses, such as some types of cancers, although they can have a

high impact on society and the environment overall. In addition, vulnerability to natural disasters varies greatly depending on physical, environmental, demographic, and social characteristics [57]. Many medical issues are considered “classic” and high-likelihood risks, and therefore, it was not surprising that risk communications have been frequently performed in the medical field.

This study also indicated that the majority of risk communication practices were conducted in a non-/pre-crisis period. This was expected because of the difference in the size of the target audience: there are naturally many more individuals who are at risk but not yet affected by certain threats, compared with those who are already affected. Furthermore, communication that takes place during or shortly after the occurrence of an unexpected event is often called “crisis communication” and is differentiated from other types of risk communication. The United States Centers for Disease Control and Prevention [7 p. 4] defined crisis communication as “the process of providing facts to the public about an unexpected emergency, beyond an organization’s control, that involves the organization and requires an immediate response.” This shows that the main purposes of crisis communication are to alert the public about an emergency and to instruct them to take recommended actions to reduce the impacts of the event, whereas risk communications can be to empower individuals and support their decision making. It was predictable that this study would find few risk communication studies conducted in a crisis or post-crisis period.

The majority of the targets of risk communications assessed in this study were citizens. However, stakeholders concerning risk communications, as a whole, include not only affected/at-risk individuals and communities but also academics/professionals, governments, media, industry, individual producers, emergency-responding agencies, and others [7,44]. Many studies did not approach non-citizen groups. Those that addressed non-citizen groups targeted mainly professionals and individual producers for enhancement of their communication skills or risk knowledge. Others were implemented by non-citizen groups or were performed with their collaboration [58-61]. Nonetheless, it is presumably important that all stakeholders receive regular risk communication trainings or sessions to impart up-to-date knowledge about relevant risks and to foster and maintain their ability to effectively communicate about the risk to other stakeholder groups and respond appropriately in emergencies.

Communication type reflected the characteristics of the various fields. For instance, this study suggested that approximately half of the risk communications conducted in the field of medicine were implemented individually or in a small group. Medical risk communications at an individual level include those to assist the individuals concerned in choosing from among treatment options. In contrast, communications for disease prevention, such as promotions of health screening, vaccination, and risk awareness of lifestyle illnesses, can be at a community or national level [25,62,63]. Risks in other fields appeared to be rarely communicated at an individual level. This may be associated with different levels of possible influence of specific risks. For example, the impacts of disasters go beyond individuals and result in a significant disruption to communities or society, and thus, risk communication in relation to disaster risk

reduction tends to target a larger audience [61,64]. Similarly, food safety issues are not only a risk concerning particular individuals. Effective risk controls relating to food contaminants, such as infectious agents and chemicals, require community mobilization to promote safe food production, handling, and consumption along with other interventions [65]. This demonstrates that effective ways to reach out and communicate with the intended audience differ by risk characteristics, the intervention needs of relevant groups and/or individuals, and other circumstances.

This study revealed intriguing patterns regarding the use of evaluation indicators and intended intervention outcomes. For instance, multiple comparison analyses on the association between study field and the use of the "trust building" indicator suggested that risk communications in the medical field were less likely to be aimed at trust building than were risk communications in relation to non-nuclear/-radiation disasters or emergencies. Lack of trust, solidarity, and collaboration between stakeholders have been repeatedly raised as a critical bottleneck of effective disaster management [66-69]. Fostering trust relationships is a vital task in such fields. In contrast, one plausible reason for the limited number of studies for trust building in the medical field is that physicians are usually considered competent and trustworthy by the general public, and they are already more trusted than other professionals, such as journalists and politicians [70,71]. Therefore, patient trust already lies, to a certain extent, in patient–physician relationships, and building public trust may not be a major objective of risk communications. At the same time, however, public trust in medicine and the healthcare system is declining, and stronger emphasis is being given to the needs of improving doctors' communication skills for better doctor–patient relationships [72-75]. Risk communication studies for trust building has gained a growing importance in the medical field.

Other findings from this study also reflect the characteristics and circumstances of risk communications. Risk communications conducted in a non-/pre-crisis period were more likely to aim at changing risk perceptions of the target audience and/or alleviating their concerns, compared with risk communications conducted in a crisis period. This result is understandable because, for the sake of protecting public safety and security in an emergency situation, it is critical to promptly instruct people to take recommended actions rather than approaching individuals' personal perceptions and preferences [7]. This study also revealed that risk communications conducted individually or in a small group were less likely to aim at changing risk perceptions of the target audience and/or alleviating their concerns and were more likely to aim at supporting the decision making of the target audience or changing their behavior. Such small-scale forms of communication may be suitable for the purpose of decision making and behavior change because it can accommodate individual circumstances and objectives. Taking individual-level risk communications in the field of medicine as an example, they are frequently conducted in clinical settings. Similarly, with the study of Welschen et al. [76] and Thomas et al. [77], these communications help patients make informed decisions referring to treatment options available to them or encouraging them to perform recommended actions relating to their health problems. The application of small-scale communication for behavioral change is also

reported in non-medical fields [78]. In contrast, large-scale risk communications would be more for raising public awareness of possible hazards or addressing public perceptions based on scientific evidence.

This analysis of recent literature suggests that current risk communication practices are heavily directed to lay citizens to increase their knowledge, change risk perception, and/or facilitate behavior change and decision making. This was consistent with some of the main perspectives of the organizations selected for this study. These three purposes are closely linked. As the United States Food and Drug Administration concisely describes, the central goals of risk communication are to "share information, change beliefs, change behavior" (Table 5) [47 p. 4]. The Health Belief Model [79-81] explains that knowledge together with other modifying factors influence individual perceptions about risks and can guide people to perform recommended preventive behavior, which directly or indirectly leads to better health outcomes. The Health Belief Model was developed by social psychologists, and it is one of the most influential theoretical models. It has been broadly and successfully applied in various public health settings [82-84]. Addressing knowledge, perception, and behavior are basic components of health education and health promotion, and this study result indicates that current approaches are concordant with the cognitive behavior theory.

At the same time, however, the comparison assessment of the main evaluation indicators identified in this study and the selected international and national organizations' definitions and purposes of risk communication revealed that mutual understanding between stakeholders, citizen participation in a policy making process, and trust building were insufficiently focused on or evaluated in risk communication activities in any field despite them being frequently listed as important risk communication purposes proposed by the organizations selected for this study. This suggests that there are some discrepancies between policy-level perspectives and expectations on risk communication and current practices.

The marginalization of mutual understanding between stakeholders and citizens' participation in risk decisions in actual risk communication activities, to stretch a point, may imply that current risk communication activities—except for some exceptions—tend to center on transferring information in one direction from the sender to the receiver. A notable example of an exception is an intervention of Hicks et al. [64] in which an educational film to promote volcano preparedness and mitigation was developed with the participation of residents in their target communities and local scientists. Importantly, Gurabardhi et al. [85] claimed on the basis of their literature reviews that there is a steady increase in two-way communications (via advisory committees, consensus conferences, and negotiation), dialogs between stakeholders, and stakeholder involvement in risk-related decision-making processes. Nevertheless, many studies pointed out challenges involved with public engagement, highlighting the differences in terms of technical knowledge and perspectives about risk and risk management between scientists and lay citizens and even among citizens themselves, along with other social–psychological and political factors [1,39,41,86]. Probably, these challenges in dealing with public participation prevent its active and effective implementation. Together with the insufficient attention to trust building,

558 which is fundamental for risk communication, the marginalization of mutual understanding
559 between stakeholders and citizens' participation in risk decisions can aggregate conflicts
560 between different parties, even though risk communication may not necessarily resolve all the
561 differences in stakeholder perceptions and opinions, nor conflicts between parties.
562 This study had several limitations. One was the possible selection bias due to search limitations.
563 For instance, relevant conference presentations and books were not included for the analysis.
564 Furthermore, the quality and methodological appropriateness and the validity of individual
565 studies were not evaluated during the material selection process. There might be studies whose
566 quality of evidence was suboptimal. Also, this study included only a limited number of studies
567 from certain groups, such as risk communications in the fields of nuclear and radiological
568 disasters/emergencies and climate change. Moreover, the majority of risk communication fields
569 included in this study were related to public health and safety. With the designed methodology,
570 very few risk communications were identified in relation to other risks, such as occupational,
571 financial, and business risks. Because this study focused on looking at how the effectiveness of
572 risk communication activities has been measured in recent years, it did not evaluate how they
573 have changed over time, which limited the scope of the analysis. Lastly, the international and
574 national organizations' definitions to which this study referred were not exhaustive.
575 In spite of the above limitations, this study makes a significant contribution to risk
576 communication research. It provides a broad overview of frequently used indicators that
577 approximate the key purposes of current risk communication practices across fields. It will be
578 able to assist individuals and institutions engaged in risk communication in developing,
579 monitoring, and evaluating their interventions in their field of focus. It will possibly enable
580 relevant institutions and professionals to conduct multisectoral activities by fostering their
581 understanding of current risk communication activities in other fields. This study also identifies
582 some commonalities and differences between evaluation indicators used on the ground and the
583 definitions and purposes of risk communication stated by relevant international and national
584 organizations, which provides some insights for future improvement in risk communication
585 materials and implementation.
586

587 ## Conclusions

588 Risks surrounding individuals and communities are diverse in nature, and they are becoming
589 more complex and difficult because of global-level social, technological, and environmental
590 changes. Risk communication is an integral element of risk reduction efforts to protect human
591 safety, health, and wellbeing, as well as to prevent and reduce damage to the environment.
592 Accordingly, risk communication has been rapidly accepted in a wide range of fields. There are
593 diverse viewpoints and positions in relation to risk communication, and it has been implemented
594 in a variety of ways for different purposes in multiple contexts. Despite this complexity, this
595 study was able to successfully develop a comprehensive and analytic summary of current risk
596 communication practices across fields, with reference to policy-level risk communication
597 perspectives of international and national communities. In particular, the study demonstrated that

current risk communication practices reflect the characteristics of and circumstances surrounding the risks of focus. Although there seem to be differences with regard to the aims or intended outcomes of risk communications between fields, “knowledge increase,” “change in risk perception,” and “decision making/behavior change” are common across all of them. Furthermore, this study showed that some aims or intended outcomes of risk communications may differ by study field, intervention timing, and communication type. Risk communication needs to be designed, monitored, and evaluated cautiously in consideration of prior practices within a field of interest and needs to incorporate, where applicable, practices in other fields in view of strengthening current practices and promoting an intersectoral and multisectoral approach for public health and overall societal protection.

This study also suggested that there are limited risk communication practices in certain fields and poor engagement with certain stakeholders. It also showed discrepancies between current practices and desirable practices suggested by the selected international and national organizations, especially in the facilitation of mutual understanding, trust building, and citizen participation in risk-related decisions. Additional research will be useful to understand the background reasons for these discrepancies in current practices and to identify how the discrepancies should be addressed with careful consideration of risk characteristics and the needs and circumstances of at-risk populations. Ensuring active engagement and effective collaboration of citizens and all other relevant stakeholders in risk communication nurtured by mutual trust creates a sustainable path toward effective risk management and better resilience.

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Supplemental information captions

Table S1. Data extracted from selected articles

Table S2. Results of statistical analyses on the correlation of study field with intervention timing, target audience, and communication type ($N = 240$)

Table S3. Results of statistical analyses on the correlation of evaluation indicator with study field, intervention timing, target audience, and communication type

Table 1(on next page)

Descriptive statistics of the study variables (N=316).

Table 1. Descriptive statistics of the study variables (*N* = 316)

Variable	Value	*n*	%
Evaluation approach	Quantitative	264	84
	Qualitative	53	17
	Prior experiences, existing knowledge	8	3
Study field	Medicine	187	59
	Food safety	26	8
	Chemical substances	19	6
	Nuclear and radiological disasters/emergencies	7	2
	Other disasters/emergencies	37	12
	Climate change	5	2
	Other	40	13
Intervention timing	Non-/pre-crisis	296	94
	Crisis	14	4
	Post-crisis	7	2
Target audience	Citizens	289	91
	Other	45	14
Communication type	Individual/small group communication	109	34
	Other	214	68
Evaluation indicator	Knowledge increase	127	40
	Communication satisfaction	50	16
	Change in risk perception and concern alleviation	139	44
	Reduction in psychological distress	7	2
	Trust building	26	8
	Decision making and behavior change	192	61
	Self-efficacy improvement	13	4
	Other	13	4

The total number of each variable varies owing to the allowance of multiple responses. Percentages are based on the total number of studies included in the analysis (*N* = 316).

Table 2(on next page)

Examples of evaluation instruments used in risk communication studies

1 **Table 2. Examples of evaluation instruments used in risk communication studies**

Indicator	Author(s), year of publication	Study field	Study description	Instrument(s)
Knowledge increase	Brown et al., 2011 [23]	Medicine	This study assessed the relationships between health literacy, numeracy, and the ability to interpret graphs. Participants were asked to interpret different types of graphs in the context of breast cancer risk and make hypothetical treatment decisions.	Interpreting the risk of a new breast cancer occurring in the other breast following preventive surgical options based on the hypothetical information from the provided graphs, making a surgical option, and describing differences in remaining risk between surgical options.
	Moussaïd et al., 2015 [24]	Chemical substances	This study analyzed social transmission of risk information by examining how messages on the risk of a controversial antibacterial agent changed when being passed from one person to another in a chain of up to 10 persons.	Information diversions and defects occurred while being transferred from one person to the next.
Communication satisfaction	Garcia-Retamero et al., 2011 [25]	Medicine	This study evaluated the effectiveness of gain- and loss-framed messages and visual aids about sexually transmitted diseases (STDs) on participants' reactions to intervention material and their STD-related risk perception, attitude, behavioral intention, and behaviors.	Participants' evaluation on how interesting, involving, and informative the intervention material was.
	Tiozzo et al., 2011 [26]	Food safety	This study evaluated the effectiveness of a campaign on salmonellosis on public risk awareness and knowledge on risk and prevention behavior.	Participants' evaluation of the usefulness of the campaign material.
Change in risk perception and concern alleviation	Nan et al., 2015 [27]	Medicine	This study investigated the impact of evidence-oriented messages and narrative-type messages about human papillomavirus (HPV) on recipients' risk perception and vaccination intentions.	Participants' perceived susceptibility to HPV.
	Binder et al., 2011 [28]	Other disasters/ emergencies	This study analyzed the influence of interpersonal discussions on residents' perceptions about the risks and benefits of the planned US National Bio- and Agro-Defense Facility.	Residents' perceived risk of negative impacts associated with the facility on their safety, health, and the environment.

Reduction in psychological distress	Henneman et al., 2013 [29]	Medicine	This study assessed the effects of the provision of graphs in addition to frequency information about breast cancer on at-risk women's risk understanding, psychological wellbeing, and intention to have breast screening.	Psychological wellbeing measured by an adapted version of the Lerman Cancer Worry Scale (CWS) and the Dutch version of the six-item version of the state scale of the Spielberger State–Trait Anxiety Inventory.
	MacDonald Gibson et al., 2013 [30 p. 4008]	Chemical substances	This study explored how probabilistic information influences risk understanding, opinions regarding risk/site management, risk perception, and concerns of residents who live nearby a closed site contaminated with unexploded ordnance.	Negative emotional reactions to the provided information: "How (worried, afraid, anxious) would you be about (getting hurt if you worked at the site, letting children play near the site, living near the site)?"
Trust building	Besser et al., 2012 [31]	Medicine	This study conducted interviews with patients with osteoporosis and collected their drawings to assess their views on the illness and treatment, as well as their conditions.	Doctor–patient relationship was reported as one motivation to adhere to medication regimen.
	Cronin et al., 2014 [32]	Other (genetic engineering)	This study introduced "Issues Mapping" to facilitate dialogues between different stakeholders, clarify different perspectives, and promote mutual understanding. It applied the techniques to social conflicts relating to genetic engineering issues.	Perceptions of genetic engineering including participants' trust in other stakeholders and their views on current debate in society.
Decision making and behavior change	Lopez-Gonzalez et al., 2015 [33]	Medicine	This was an intervention study to see if communicating to people about cardiovascular diseases (CVDs) by using risk assessment tools (Framingham REGICOR and Heart Age) would lead to improvement in their CVD risk factors.	Changes in physical activity (number of sessions of physical activity per week), smoking behavior, and other modifiable risk factors, involving anthropometrical and blood pressure data.
	Rabinovich et al., 2012 [34]	Climate change	This study assessed the effect of people's beliefs about nature and science on their perspective about uncertainty in relation to climate change.	Participants' willingness to carry out positive environmental behaviors (e.g., reducing water use) and agree on a household carbon budget.

Self-efficacy improvement	Harris et al., 2013 [35 p. 144]	Medicine	This study analyzed the influence of parents' marital status, and parent–child sexual communication and relationship on male adolescents' knowledge regarding HIV and STDs, and their intentions and their implementation of preventive behaviors.	Six-item Condom Use Self-Efficacy scale (e.g., "I am confident that I know how to use a condom.")
	Feenstra et al., 2014 [19]	Other (traffic safety)	This study assessed the impacts of a school-based road safety program on risk perception, attitude, intention, and behaviors in relation to risky cycling among 9th–11th-grade students.	Perceived self-efficacy for safe cycling (e.g., controlling the bicycle and applying traffic rules) in comparison with peers.

2

Table 3(on next page)

Intervention timing, target audience, and communication type by study field (*N*=316)

Table 3. Intervention timing, target audience, and communication type by study field (*N* = 316)

		Study field						
		Medicine (*n* = 187)	Food safety (*n* = 26)	Chemical substances (*n* = 19)	Nuclear and radiological disasters/ emergencies (*n* = 7)	Other disasters/ emergencies (*n* = 37)	Climate change (*n* = 5)	Other (*n* = 40)
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Intervention timing	Non-/pre-crisis	177 (95)	24 (92)	18 (95)	3 (43)	32 (86)	5 (100)	40 (100)
	Crisis	9 (5)	1 (4)	1 (5)	0 (0)	4 (11)	0 (0)	0 (0)
	Post-crisis	1(1)	2 (8)	0 (0)	4 (57)	1 (3)	0 (0)	0 (0)
Target audience	Citizens	166 (89)	26 (100)	15 (79)	6 (86)	37 (100)	5 (100)	39 (98)
	Other	33 (18)	0 (0)	6 (32)	1 (14)	2 (5)	0 (0)	3 (8)
Communication type	Individual/ small group	93 (50)	1 (4)	5 (26)	1 (14)	7 (19)	0 (0)	2 (5)
	Other	97 (52)	25 (96)	16 (84)	6 (86)	32 (86)	5 (100)	38 (95)

Although the total number of studies included in the analysis was 316, the total number of each variable varies owing to the allowance of multiple responses. The percentages were based on the total number of each study field.

Table 4(on next page)

Study field, intervention timing, target audience, and communication type by evaluation indicator (*N*=316)

Table 4. Study field, intervention timing, target audience, and communication type by evaluation indicator ($N = 316$)

		Evaluation indicator							
		Knowledge increase	Communication satisfaction	Change in risk perception and concern alleviation	Reduction in psychological distress	Trust building	Decision making and behavior change	Self-efficacy improvement	Other
		n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Study field	Medicine ($n = 187$)	79 (42)	37 (20)	68 (36)	6 (3)	10 (5)	118 (63)	10 (5)	8 (4)
	Food safety ($n = 26$)	12 (46)	5 (19)	16 (62)	0 (0)	6 (23)	11 (42)	0 (0)	1 (4)
	Chemical substances ($n = 19$)	10 (53)	1 (5)	7 (37)	1 (5)	0 (0)	14 (74)	0 (0)	0 (0)
	Nuclear and radiological disasters/emergencies ($n = 7$)	3 (43)	2 (29)	3 (43)	0 (0)	1 (14)	2 (29)	0 (0)	0 (0)
	Other disasters/emergencies ($n = 37$)	12 (32)	3 (8)	20 (54)	0 (0)	7 (19)	24 (65)	1 (3)	2 (5)
	Climate change ($n = 5$)	1 (20)	0 (0)	3 (60)	0 (0)	0 (0)	2 (40)	0 (0)	0 (0)
	Other ($n = 40$)	13 (33)	2 (5)	25 (63)	0 (0)	3 (8)	22 (55)	2 (5)	2 (5)
Intervention timing	Non-/pre-crisis ($n = 296$)	119 (40)	46 (16)	135 (46)	7 (2)	23 (8)	183 (62)	13 (4)	12 (4)
	Crisis ($n = 14$)	3 (21)	1 (7)	2 (14)	0 (0)	3 (21)	8 (57)	0 (0)	1 (7)
	Post-crisis ($n = 7$)	5 (71)	3 (43)	3 (43)	0 (0)	1 (14)	2 (29)	0 (0)	0 (0)
Target audience	Citizens ($n = 289$)	118 (41)	49 (17)	130 (45)	6 (2)	24 (8)	176 (61)	13 (4)	12 (4)
	Other ($n = 45$)	17 (38)	5 (11)	12 (27)	2 (4)	3 (7)	29 (64)	1 (2)	2 (4)
Communication type	Individual/small group ($n = 109$)	44 (40)	19 (17)	35 (32)	5 (5)	5 (5)	78 (72)	5 (5)	6 (6)
	Other ($n = 214$)	85 (40)	31 (14)	105 (49)	2 (1)	21 (10)	121 (57)	9 (4)	7 (3)
OVERALL	($N = 316$)	127 (40)	50 (16)	139 (44)	7 (2)	26 (8)	192 (61)	13 (4)	13 (4)

The total number of each variable varies because of the allowance of multiple responses. Percentages were based on the total number of each value.

Table 5(on next page)

Definitions and purposes of risk communication stated by selected international and national organizations, and corresponding evaluation indicators identified in this study

1 **Table 5. Definitions and purposes of risk communication stated by selected international and national organizations, and**
2 **corresponding evaluation indicators identified in this study**

Field	Organization	Definition	Purpose	Corresponding indicators identified in this study[a]						
				1	2	3	4	5	6	7
Chemical substances	Organization for Economic Co-operation and Development [38 p. 7] (cited Covello et al. [39 p. 172])	The act of conveying or transmitting information between interested parties about (a) levels of health or environmental risks; (b) the significance or meaning of health or environmental risks; or (c) decisions, actions, or policies aimed at managing or controlling health or environmental risks.		✓						
	European Chemicals Agency [6 p. 6]		Helping to build trust among organizations that risks are being adequately assessed and managed; assisting with making better decisions on how to address risks; helping to ensure smoother implementation of risk management policies; helping to empower and reassure the general public; helping to bridge the gap between real risks and perceived risks; and helping to prevent crises from developing and managing them when they do occur.	✓		✓		✓	✓	

	United States Environmental Protection Agency [40 para. 1,2]	The process of informing people about potential hazards to their person, property, or community.	To help residents of affected communities understand the processes of risk assessment and management, to form scientifically valid perceptions of the likely hazards, and to participate in making decisions about how risk should be managed.	✓		✓				
	Ministry of the Environment, Japan[b] [41 p. 14] (cited the Chemical Society of Japan [42])	Sharing accurate information and exchanging opinions between citizens, industry, government, and other interested parties on health and environmental risks related to chemical substances.	To increase awareness and understanding of the relevant risk and its management and to build a trust relationship among all concerned stakeholders, and reduce the risk through demanding and providing information and exchanging opinions between stakeholders.	✓		✓		✓		

Food safety	Food and Agriculture Organization of the United Nations and World Health Organization [43 p. 3; 44 p. 7] Codex Alimentarius Commission [45 p. 129–131]	The exchange of information and opinions concerning risk and risk-related factors among risk assessors, risk managers, consumers and other interested parties. The interactive exchange of information and opinions throughout the risk analysis process concerning risk, risk-related factors and risk perceptions, among risk assessors, risk managers, consumers, industry, the academic community and other interested parties, including the explanation of risk assessment findings and the basis of risk management decisions.	To enable people to protect their health from food safety risks by providing information that enables them to make informed food safety decisions, to facilitate dialogue and understanding among all interested stakeholders, and to improve the overall effectiveness of the risk analysis process. Risk communication should: (i) promote awareness and understanding of the specific issues under consideration during the risk analysis; (ii) promote consistency and transparency in formulating risk management options/recommendations; (iii) provide a sound basis for understanding the risk management decisions proposed; (iv) improve the overall effectiveness and efficiency of the risk analysis; (v) strengthen the working relationships among participants; (vi) foster public understanding of the process, so as to enhance trust and confidence in the safety of the food supply; (vii) promote the appropriate involvement of all interested parties; and (viii) exchange information in relation to the concerns of interested parties about the risks associated with food.	✓		✓		✓	✓	

	European Food Safety Authority [46 p. 7]		To assist stakeholders, consumers and the general public to understand the rationale behind risk-based decisions and, to help them make balanced judgements about the risks that they face in their own lives. Effective risk communication can contribute to the success of a risk management program by: (1) ensuring that consumers are aware of the risks associated with a product and thereby use or consume it safely; (2) building public confidence in risk assessment and management decisions and the associated risk/benefit considerations; (3) contributing to the public's understanding of the nature of a risk or risks; and (4) providing fair, accurate, and appropriate information, so that consumers are able to choose among a variety of options that can meet their own "risk acceptance" criteria.	✓		✓		✓	✓	

Food safety & medicine	United States Food and Drug Administration [47 p. 4, 48 para. 27,43]	Risk communication activities fall into two broad categories: (1) interactively sharing risk and benefit information to enable people to make informed judgments about use of FDA-regulated products and (2) providing guidance to relevant industries about how they can most effectively communicate the risks and benefits of regulated products.	Share information, change beliefs, change behavior. (Examples listed as intermediate outcomes that can lead to the improvement of overall public health are as follows:) (1) improved understanding of the risks and benefits of regulated products by the multiple audiences with whom FDA communicates, including relevant international audiences; (2) increased public awareness of crisis events and the increased likelihood that affected individuals or groups will take recommended actions; (3) increased public satisfaction with FDA as an expert and credible source of information about regulated products; and (4) increased confidence that target audiences are getting useful, timely information as it becomes available, to help them make informed choices.	✓	✓	✓		✓	✓	

Medicine & disasters	World Health Organization [49 p. 1,2; 50 para. 1]	The two-way and multi-directional communications and engagement with affected populations. The exchange of real-time information, advice and opinions between experts and people facing threats to their health, economic or social well-being.	To share information vital for saving life, protecting health and minimizing harm to self and others; to change beliefs; and/or to change behavior. To enable people at risk to take informed decisions to protect themselves and their loved ones.	✓		✓			✓	
	United States Nuclear Regulatory Commission [51 p. 1,5,6]	An interactive process used in talking or writing about topics that cause concern about health, safety, security, or the environment.	(Examples listed:) (1) providing information to the public about numerous issues, including inspection findings and their significance, changes to regulatory requirements, security and safeguards issues, or how the decision-making process works; (2) to learn about stakeholder concerns, perceptions about risks, expectations about involvement in risk management decisions, or local information that will assist in risk analysis; (3) building/restoring trust and relationships; (4) to ask stakeholders for input in a decision-making process; and (5) influencing people's behavior and perceptions about risk.	✓		✓		✓	✓	

	United States Centers for Disease Control and Prevention [7, p. 4]	Risk communication provides the community with information about the specific type (good or bad) and magnitude (strong or weak) of an outcome from an exposure or behavior. Typically, risk communication is a discussion of a negative outcome and the probability that the outcomes will occur.	Risk communication can be employed to help an individual make a choice about a behavior such as smoking, getting vaccinated, or undergoing a medical treatment.	✓					✓	

Underlined parts correspond to indicators identified in this study.

[a] 1 = knowledge increase, 2 = communication satisfaction, 3 = change in risk perception and concern alleviation, 4 = reduction in psychological distress, 5 = trust building, 6 = decision making and behavior change, 7 = self-efficacy improvement.

[b] Translated by an author of this article (AS).

Figure 1

Flow diagram of material selection.

JRR = Journal of Risk Research

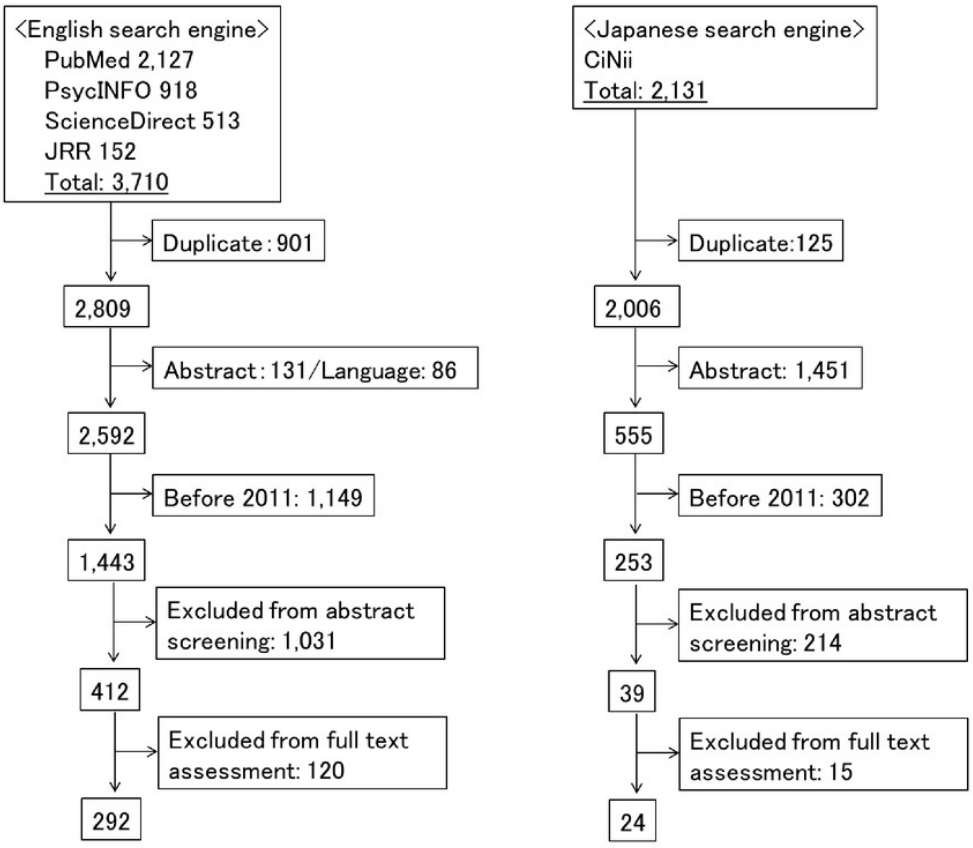

Fig 1. Flow diagram of material selection.

Figure 2

Trend in the number of risk communication publications over time.

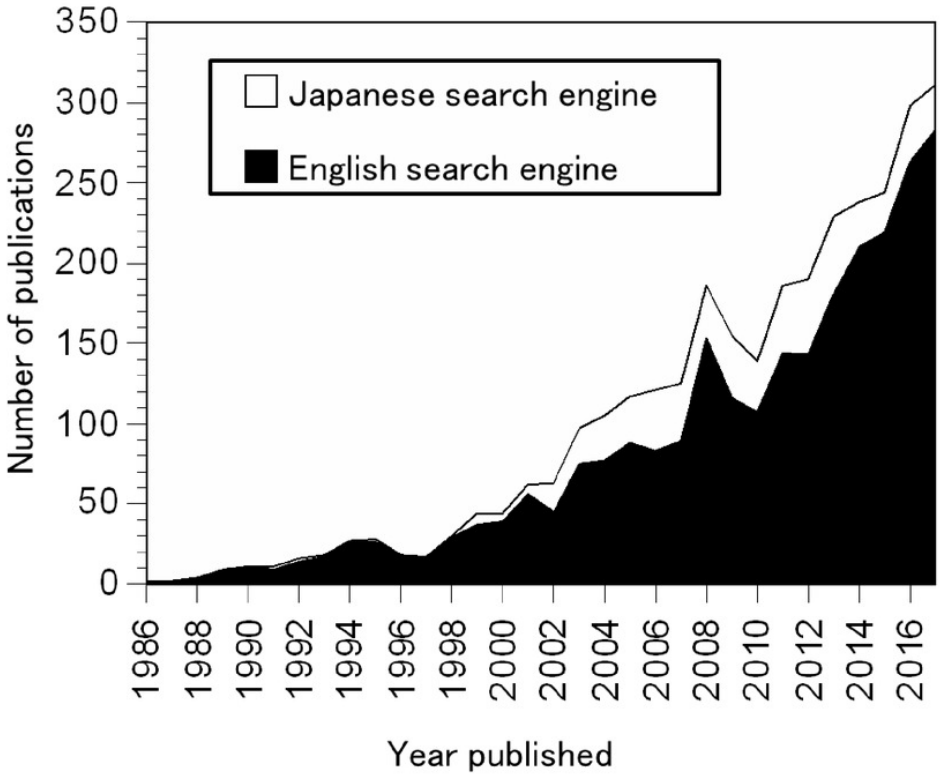

Fig 2. Trend in the number of risk communication publications over time