Radiation Research Trends by Young Scientists and the Future Tasks in Northern Japan: Report on "The 10th Educational Symposium on Radiation and Health (ESRAH) by Young Scientists in 2023"

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Running title:
Research Trends and the Future Tasks of ESRAH

Radiation Research Trends by Young Scientists and the Future Tasks in Northern Japan: Report on "The 10th Educational Symposium on Radiation and Health (ESRAH) by Young Scientists in 2023"

Purpose: Since 2014, an educational activity on radiation and health in northern Japan has been carried out by young scientists, the so-called "Educational Symposium on Radiation and Health (ESRAH)". Close cooperation has been continued in preparing for any possible emergency response to radiation accidents because several facilities, e.g., the Tomari Nuclear Power Plant in Hokkaido and the Low-Level Radioactive Waste Disposal Facility in Aomori prefecture. The ESRAH meeting has provided informational exchange and discussion forum on a broad range of subjects in various. In 2023, the 10th Memorial ESRAH meeting took place to boost scientific understanding and multidisciplinary collaborations for young scientists. Herein, we report on the ESRAH2023 symposium and analyze the research categories of young scientists from the past 10-year presentations.

Conclusions: To date, the ESRAH meeting has successfully provided a chance for multi-disciplinary research, which accounted for 27% of the total despite the COVID-19 pandemic. We found that the fraction of multi-disciplinary research in 2023 was the highest during 10-year ESRAH meetings. Meanwhile, amongst the research categories, physics, chemistry, and pharmacological studies were indicated to be less for young scientists. It is desired that further collaboration between physics, chemistry, and pharmacology in addition to the current fields would not only clarify radiation effects on the human body but also promote emergency medical care for radiation exposure in the future.

Keywords: Educational activity, northern Japan, ESRAH, multidisciplinary research, young scientists

Introduction

Radiological technologies in clinics, e.g., diagnosis and therapy, have been developed taking advantage of the positive aspect of ionizing radiation (Joiner 2009). Meanwhile, ionizing radiation can induce adverse effects, such as DNA damage (Wouters 2009a), chromosome aberration (Wouters 2009b), and carcinogenesis (Trott

2009). Recent radiation risk assessment is mainly based on epidemiological data from atomic bomb survivors (Ron 1998). Meanwhile, in 2011, the accident at the Fukushima Daiichi Nuclear Power Plant (F1-NPP) following the earthquake and tsunami released large amounts of artificial radioactive isotopes (Hosoda 2013; Satou 2016). Close attention to human health after low-dose (e.g., below 200 mGy (ICRP1990)) protraction exposure has been focused (Calabrese 2011; Tang 2018; Matsuya 2024); however, the accurate mechanisms of human health after low-dose protraction exposure remain uncertain. From such a scientific background, it is urgent to clarify the relationship between radiation exposure and human health.

In northern Japan, several nuclear facilities, e.g., the Tomari Nuclear Power Plant in Hokkaido (Inatsu 2019) and the Low-Level Radioactive Waste Disposal Facility in Aomori prefecture (Baba 2002; Kishimoto 2003), exist. Regarding this, close cooperation in northern Japan is required in preparation for any radiation emergency incidents. As such background, an annual meeting between Hokkaido and Hirosaki Universities has been held since 2008. After the accident at F1-NPP, this meeting was upgraded to an international meeting named Educational Symposium on Radiation and Health (ESRAH) by young scientists" in 2014 (Hosoda 2015; Nakamura 2015), aiming to be an informational exchange and discussion forum on a broad range of subjects in radiation health, such as radiation physics, chemistry, biology, measurement, protection (emergency medicine) and clinical study (diagnosis and therapy), and computational science. ESRAH is mainly organized by young researchers, including graduate students and postdoctoral researchers, successfully providing a network and radiation emergency system that can be applied worldwide. (Matsuya 2017).

ESRAH in 2023 (hereafter called ESRAH2023) was the 10th memorial meeting, which provided a chance to accelerate scientific understanding of radiation effects on the human body and multidisciplinary collaborations for radiation research by young scientists. During the 10-year ESRAH history (Hosoda 2015; Nakamura 2015; Tsujiguchi 2016; Matsuya 2017; Saga 2018; Yamashina 2021; Hasegawa 2021; Sato 2021; Nakayama 2022; Hashimoto 2024), despite the coronavirus (COVID-19) pandemic since 2020 (Zoumpourlis 2020), 85 educational and invited lectures and 258 studies by young researchers have been presented in the symposiums, utilizing the radiation emergency system based on the specialisms in northern Japan. Herein, we report on the ESRAH2023 symposium and analyze the research categories of young scientists from the past 10-year presentations. Throughout this report, we present the high fraction of multidisciplinary research in northern Japan and the issues of radiation research for the next-generation young scientists, which would contribute to guidance for young researchers around the world.

Latest research topics based on educational lectures

To deepen our understanding of radiation and human health, in 2023, five leading researchers presented the latest topics of radiation research in various fields, including radiation measurement, radiation protection, radiation emergency medicine, radiation therapy, radiation biology, and computational science. The titles and research fields of five educational lectures are summarized in Table 1. The educational lectures can be roughly classified into two research topics: (a) dose assessment and radiation protection and (b) biological effects on the human body. Figure 1 shows a schematic representation that summarizes the lessons for efficiently establishing radiation emergency system based on recent research topics. As shown in Table 1 and Fig. 1, the research topics are intertwined with each other and performed bottom-up studies coupled with biology and computational science.

Dose assessment and radiation protection

Dr. Kovács presented the types of biomonitors (i.e., plants and animals) widely used to assess radioactivity and the impact of contaminated sites (Kovács 2017, 2020) by visualization methods. Dr. Kovács's research focused on an example of exposure to toxic heavy metal content in soil and inherent naturally occurring radioactive materials (NORM), especially after industrial accidents and remediation efforts, so far (Kovács 2017). From such background, the selection of appropriate biomonitors is in general not a simple task. Against this issue, Dr. Kovács proposed that the radiological characteristics of the contamination (i.e., type and quantity of isotopes) and the flora and fauna of the area including the consumption habits of the people living in the area or the vicinity of the area play key factors for a more accurate estimation of the radiation exposure. Due to the closed characteristic of cave, radon and thoron can be found with high concentration in the cave. Hence, it is important to conduct survey to measure radon and thoron level in the cave to properly minimize radiation risk received by cavers and visitors. Second, based on such measurement techniques, Dr. Kelleher reported the continuous monitoring of radiation levels in Ireland since accidents abroad might result in the contamination of the environment (Kelleher 2020). Dr. Kelleher introduced an efficient handling method for emergencies as the main priority for emergency management (Kelleher 2020, 2021), highlighting public communication as a key element of any emergency response. In addition, Dr. Kelleher concludes public health messages should be documented in an understandable and straightforward format, drawing comparisons to common radiation exposures that the general public is subjected to. Third, using a simulation approach, Dr. Tamarat showed the detailed three-dimensional anatomical dose assessment method at Institut de Radioprotection et de Sûreté Nucléaire (IRSN) and Percy Military Hospital (Tamarat 2024). As a critical factor for testing the dose evaluation systems for nuclear and radiological emergencies, Dr. Tamarat strongly recommended long-term systemic development that spends years preparing, conducting, and evaluating exercises.

Biological effects on the human body

As intertwined with dose assessment and protection, the biological impacts of radiation exposure on human health were also presented. Following the introduction of dose assessment, Dr. Tamarat presented past radiation accident cases and knowledge about the latest treatment methods. Particularly, Dr. Tamarat showed a practical example that a simulation-based dose assessment and mesenchymal stem cell (MSC) transplantation should be performed after the prediction and resection of areas that are not expected to heal at the hospital when a radiation accident occurs. (Tamarat 2012, 2024). As for biological impacts after environmental exposure and biodosimetry, Dr. Autsavapromporn focused on carcinogenesis, i.e., lung cancer, in Chiang Mai (Autsavapromporn 2024), and pointed out the limitation that there is no reliable biomarker for lung cancer screening from indoor radon exposure yet. Against such issues, utilizing expertise in radiobiology (Autsavapromporn 2023), Dr. Autsavapromporn proposed telomere length (Autsavapromporn 2018), which is complex DNA-protein structures located at the end of chromosomes, in lung tissue can be a potential bio-marker of carcinogenesis in lung. Furthermore, focusing on oxidative stress and DNA repair from the viewpoints of cellular and molecular biologies, Prof. Haghdoost introduced the fundamental mechanisms of radiosensitivity (Drobin 2020) (i.e., healthy tissue radiosensitivity and tumor radioresistance) to various radiation types. Individual radiosensitivity potentially depends on gene expression in addition to ATM, identified DNA damage recognition, and repair (Godoy 2020; Hammad 2023). Meanwhile, Prof. Haghdoost showed that cancer stem cells (CSCs) can self-renew and differentiate from the cell populations present in the tumors (Godoy 2020; Hammad 2023). Therefore, Prof. Haghdoost concludes that gene- and CSC-dependent heterogeneous responses are crucial factors in the case of determining radiosensitivity.

Recent research trends by young researchers

Following the educational lectures, young scientists presented their 23 studies through the 1 min-oral and 2-day poster presentation. In the presentation, young scientists introduced their studies to each other and enhanced communication forums on a broad range of subjects, i.e., radiation measurement (ecology), radiation protection (emergency medicine), radiation physics, radiation biology (in vitro, in vivo), clinical study (radiotherapy), and computational science.

Research categories of young scientists

Based on the abstract of ESRAH2023, we classified their studies into 7 categories described above. The research categories of young scientists in ESRAH2023 were found to be 41.9% for measurement (ecology), 6.5% for protection (emergency medicine), 3.2% for physics, 12.9% for biology (in vitro), 3.2% for biology (in vivo), 9.7% for clinical study (human data in radiotherapy), and 22.6% for computational science (see Fig. S1A in the *Supplementary material*). As a result, again we realized that radiation measurement, biology (in vitro), and computational science are the top research topics in ESRAH2023. Here, we reviewed all studies of young scientists over the past 10 years ESRAH (Hosoda 2015; Nakamura 2015; Tsujiguchi 2016; Matsuya 2017; Saga 2018; Yamashina 2021; Hasegawa 2021; Sato 2021; Nakayama 2022; Hashimoto 2024), evaluating research trend change following the above categories. The presentations by young scientists so far are summarized in Tables S1–S10, in which the research categories are also given. Figure 2 shows the temporal change of research categories, in which radiation measurement, biology, and computational science were major topics in the same manner as the ESRAH2023.

Among the categories, biology (in vivo and in vitro) accounted for more than 14.6% in the first five years from 2014 to 2018 but has been almost nonexistent in recent years. In addition, physical, chemical, and pharmacological studies were indicated to be less for young scientists. This suggests a tendency to favor applied research over fundamental research. It has been well recognized that measured absorbed dose can be utilized as a piece of input information for evaluating biological effects, and the biological effects can be at last discussed based on the series of radiation actions via atomic interactions with matter (physical stage) (Nikjoo 1991; Wouters 2009a) and radiolysis in human tissue (chemical stage) (Kreipl 2009; Plante 2017). Therefore, to precisely understand radiation effects on the human body, comprehensive research, including not only applied research but also basic research, would be required in the future.

Trend of multi-disciplinary research by young scientists

Based on the fraction of research categories shown in Fig. 2, we next evaluated the contents of multi-disciplinary research by young scientists. Figure 3 depicts the fraction of multi-disciplinary research from 2014 to 2023, in which studies containing at least two categories were classified as multi-disciplinary research in this report. As a results of reviewing the studies by young scientists over the past 10 years, the fraction of multi-disciplinary research tends to increase over the years. Among them, the fraction in 2023 (i.e., 34.8%) is the highest during the past ESRAH (see Fig. S1B in the *Supplementary material*). Despite the COVID-19 pandemic since 2020, the high level of multi-disciplinary research has been kept during the ESRAH meeting so far. This feature in northern Japan might be by virtue of the bottom-up research with biology and computational science, which is a significant advantage. Meanwhile, the information on the expertise areas of young scientists (listed in Tables S1–S10) is not available, which is a limitation of this evaluation. However, as indicated above, the collaborations with physical, chemical, and pharmacological studies are insufficient. Needless to say, the development of radioprotective agents (Hosseinimehr 2007) is essential in preparation for any accidents. In addition, cancer-selective treatments such as boron neutron capture therapy (BNCT) and internal radiotherapy with alpha emitters (Sato 2018, 2021, Matsuya 2024) have attracted attention recently and required collaboration with pharmacological studies. Further collaborations of the existing fields with fundamental studies of physics, chemistry, and pharmacy would be therefore required for young scientists to develop radiation research and sophisticated emergency systems in the future.

Summary and future tasks

In 2023, the 10th Memorial ESRAH meeting took place. To date, the ESRAH meeting has successfully provided a chance for multi-disciplinary research, which accounted for 27% of the total despite the COVID-19 pandemic. Reviewing the studies by young scientists over the past 10 years, the high level of multi-disciplinary research has been kept during the ESRAH meeting so far, particularly the highest in 2023, which might be by virtue of the bottom-up research with biology and computational science. However, physics, chemistry, and pharmacological and clinical studies were indicated to be less for young scientists. Meanwhile, most studies by world-leading researchers were found to be multi-disciplinary research which intertwined with various fields. Therefore, to develop an emergency system and precisely understand the biological effects, further collaborations in the existing fields of physics, chemistry, and pharmacy would be needed for young scientists in future activities.

Declaration of interest

The authors declare no conflict of interest.

References

Autsavapromporn N, Klunklin P, Threeratana C, Tuntiwechapikul W, Hosoda M, et al. 2018. Short telomere length as a biomarker risk of lung cancer development induced by high radon levels: A pilot study. *Int. J. Environ. Res. Pub. Heal.* 15(10), 2152.

Autsavapromporn N, Kobayashi A, Liu C, Duangya A, Oikawa M, et al. 2023. Primary and Secondary Bystander Effects of Proton Microbeam Irradiation on Human Lung Cancer Cells under Hypoxic Conditions. *Biology* 12(12), 1485.

Autsavapromporn N, Kranrod C, Kritsananuwat R, Sola P, Klunklin P, et al. 2024. Health Impacts of Natural Background Radiation in High Air Pollution Area of Thailand. *Toxics* 12(6), 428.

Baba Y. 2002. The Problems Facing Nuclear Power in Japan-Emphasising Law and Regulations. Nuclear Law Bulletin 69, 16–28.

Calabrese E. 2011 Improving the scientific foundations for estimating health risks from the Fukushima incident. *Proc. Nat. Aca. Sci.* 108(49), 19447–19448.

Drobin K, Marczyk M, Halle M, Danielsson D, Papiez A, et al. 2020. Molecular profiling for predictors of radiosensitivity in patients with breast or head-and-neck cancer. *Cancers* 12(3), 753.

Godoy PR, Pour Khavari A, Rizzo M, Sakamoto-Hojo ET, Haghdoost S. 2020. Targeting Nrf2, regulator of antioxidant system, to sensitize glioblastoma neurosphere cells to radiation-induced oxidative stress. *Oxidat. Med. Cell. Longev.* 2020(1), 2534643.

Hammad M, Raftari M, Cesário R, Salma R, Godoy P, et al. 2023. Roles of oxidative stress and Nrf2 signaling in pathogenic and non-pathogenic cells: a possible general mechanism of resistance to therapy. *Antioxidants* 12(7), 1371.

Hasegawa K, Kitayama Y, Djatnika E, Yoshie Y, Naijo S, et al. 2021. Meeting Report on "The 6th Educational Symposium on Radiation and Health by Young Scientists (ESRAH2019)". *Radiat. Environ. Med.* 10(2), 108–114.

Hashimoto H, Nakayama R, Kuwata H, Poltabtim W, Seino R, et al. 2024. Meeting Report on "The 9th Educational Symposium on Radiation and Health by Young Scientists (ESRAH 2022)". *Radiat. Environ. Med.* 13(1), 35–43.

Hosoda M, Yoshino H, Yamaguchi M, Tsujiguchi T, Chiba M, Nakamura T. 2025. The Report of the 1st Educational Symposium on Radiation and Health by Young Scientists (ESRAH2014). J. *Jpn Heal. Phys. Soci.* 50(1), 20–24.

Hosoda M, Tokonami S, Tazoe H, Sorimachi A, Monzen S, et al. 2013. Activity concentrations of environmental samples collected in Fukushima Prefecture immediately after the Fukushima nuclear accident. *Sci. Rep*. 3, 2283.

Hosseinimehr SJ. 2007. Trends in the development of radioprotective agents. *Drug Discov. Today*. 12(19–20), 794–805.

ICRP1990. Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. *Ann. ICRP* 21(1–3).

Inatsu M, Suzuki H, Kajino M. 2019. Relative Risk Assessment for Hypothetical Radioactivity Emission at a Snow Climate Site. *J. Meteorol. Soci. Japan. Ser. II,* 97(1), 175–190.

Joiner MC, Van Der Kogel AJ, Steel GG. 2009. Introduction: the significance of radiobiology and radiotherapy for cancer treatment. In: Joiner M, Van Der Kogel AJ. (eds). Basic Clinical Radiobiology. London, Hodder Arnold, p. 1–10.

Kelleher K, O'Connor C, Currivan L, Cunningham N, Lewis M, et al. 2020. Estimating the Annual Average Dose to the Public from Ionizing Radiation in Ireland. *Radiat. Environ. Med.* 9(2), 62–69.

Kelleher K. 2021. Preparedness and Response to Nuclear and Radiological Emergencies in Animal Production Systems in the Context of IAEA Safety Standards. In: Naletoski I, Luckins AG, Viljoen G (eds). Nuclear and Radiological Emergencies in Animal Production Systems, Preparedness, Response and Recovery. Berlin, Springer, p. 35–52.

Kishimoto H. 2003. Japanese site for ITER; Rokkasho. *Fusion Eng. Design* 69(1), 553–561.

Kovacs T, Bator G, Schroeyers W, Labrincha J, Puertas F, et al. 2017. From raw materials to NORM by-products. In: Schroeyers W (ed), Naturally Occurring Radioactive Materials in Construction. UK, Woodhead Publishing, p. 135–182.

Kovács T, Horváth M, Csordás A, Bátor G, Tóth-Bodrogi E. 2020. Tobacco plant as possible biomonitoring tool of red mud dust fallout and increased natural radioactivity. *Heliyon*, 6(3), e03455.

Kreipl MS, Friedland W, Paretzke HG. 2009. Time-and space-resolved Monte Carlo study of water radiolysis for photon, electron and ion irradiation. *Radiat. Environ. Biophys.* 48(1), 11–20.

Matsuya Y, Tsujiguchi T, Yamaguchi M, Kimura T, Mori R, et al. 2017. Educational Activity for the Radiation Emergency System in the Northern Part of Japan: Meeting Report on "The 3rd Educational Symposium on Radiation and Health (ESRAH) by Young Scientists in 2016". *Radiat. Res.* 187(6), 641–646.

Matsuya Y, Hamada N, Yachi Y, Satou Y, Ishikawa M, et al. 2022. Inflammatory Signaling and DNA Damage Responses after Local Exposure to an Insoluble Radioactive Microparticle. *Cancers* 14, 1045.

Matsuya Y, Sato T, Kusumoto T, Yachi Y, Seino R, Miwa M, Ishikawa M, Matsuyama S, Fukunaga H. 2024. Cell-cycle dependence on the biological effects of boron neutron capture therapy and its modification by polyvinyl alcohol. *Sci. Rep.* 14, 1669.

Nakamura T, Yoshino H, Yamaguchi M, Tsujiguchi T, Chiba M, et al. 2015. Report on the 1st Educational Symposium on RADIATION AND HEALTH by Young Scientists (ESRAH2014). *Radiat. Emerg. Med.* 4(2), 58–62.

Nakayama R, Sato Y, Hasegawa K, Takebayashi K, Sato H, et al. 2022. Meeting report of the 8th Educational Symposium in Radiation and Health by Young Scientists (ESRAH2021) and the 4th Workshop on Radiation Research and Its Related Issue: summary of lectures presentations and troubleshooting when running international online symposium. *Radiat. Environ. Med.* 11(2), 66–74.

Nikjoo H, Goodhead DT, Charlton DE, Paretzke HG. 1991. Energy deposition in small cylindrical targets by monoenergetic electrons. *Int. J. Radiat. Biol.* 60, 739–756.

Plante I, Devroye L. 2017. Considerations for the independent reaction times and step-by-step methods for radiation chemistry simulations. *Radiat. Phys. Chem.* 139, 157–72.

Ron E. 1998. Ionizing radiation and cancer risk: evidence from epidemiology. *Radiat. Res.* 150(5s), S30–S41.

Saga R, Tsujiguchi T, Yamaguchi M, Fukushi Y, Fujishima Y, et al. 2018. Meeting Report on “The 4th Educational Symposium on Radiation and Health (ESRAH) by Young Scientists in 2017”. *Radiat. Environ. Med.* 7(2), 121–124.

Sato T, Hashimoto S, Inaniwa T, Takada T and KumadaH. 2021. Implementation of simplified stochastic microdosimetric kinetic models into PHITS for application to radiation treatment planning. *Int. J. Radiat. Biol.* 97 1450–1146

Sato T, Masunaga S-I, KumadaHand HamadaN. 2018. Microdosimetric modeling of biological effectiveness for boron neutron capture therapy considering intra- and intercellular heterogeneity in ^{10}B distribution. *Sci. Rep.* 8 988

Sato Y, Hasegawa K, Sakamoto M, Suzuki Y, Goh VST, et al. 2021. Virtual meeting report: the 3rd Workshop on Radiation Research and It’s Related Issues and the 7th Educational Symposium on Radiation and Health by Young Scientists (ESRAH2020). *Radiat. Environ. Med.* 10(2), 115–21.

Satou Y, Sueki K, Sasa K, Adachi K, Igarashi Y. 2016. First successful isolation of radioactive particles from soil near the Fukushima Daiichi Nuclear Power Plant. *Anthropocene* 14, 71–76.

Tamarat R, Lataillade JJ, Bey E, Gourmelon P, Benderitter M. 2012. Stem cell therapy: from bench to bedside. *Radiat. Prot. Dos.* 151(4), 633–639.

Tamarat R, Satyamitra MM, Benderitter M, DiCarlo AL. 2024. Radiation-induced gastrointestinal and cutaneous injuries: understanding models, pathologies, assessments, and clinically accepted practices. *Int. J. Radiat. Biol.* 1–13.

Tang FR, Loganovsky K. 2018. Low dose or low dose rate ionizing radiation-induced health effect in the human. *J. Environ. Radioact.* 192, 32–47.

Trott KR. 2009. Second cancers after radiotherapy. In: Joiner M, Van Der Kogel AJ. (eds). Basic Clinical Radiobiology. London, Hodder Arnold, p. 339–351.

Tsujiguchi T, Yamaguchi M, Nanashima N, Chiba M, Terashima S, et al. 2016. Report on the 2nd Educational Symposium on RADIATION AND HEALTH by Young Scientists (ESRAH2015). *Radiat. Environ. Med.* 5(1), 65–71.

Wouters BG, Begg AC. 2009a. Irradiation-induced damage and the DNA damage response. In: Joiner M, Van Der Kogel AJ. (eds). Basic Clinical Radiobiology. London, Hodder Arnold, p. 11–26.

Wouters BG. 2009b. Cell death after irradiation: how, when and why cells die. In: Joiner M, Van Der Kogel AJ. (eds). Basic Clinical Radiobiology. London, Hodder Arnold, p. 27–40.

Yamashina H, Terashima M, Oikawa J, Naijo S, Miyao T, et al. 2021. Radiation Safety and Public Health for Radiological Professionals: Meeting Report on The 5th Educational Symposium on Radiation and Health (ESRAH) by Young Scientists in 2018. *Radiat. Environ. Med.* 10(1), 48–54.

Zoumpourlis V, Goulielmaki M, Rizos E, Baliou S, Spandidos DA. 2020. The COVID-19 pandemic as a scientific and social challenge in the 21st century. *Mol. Med. Rep.* 22, 3035–3048.

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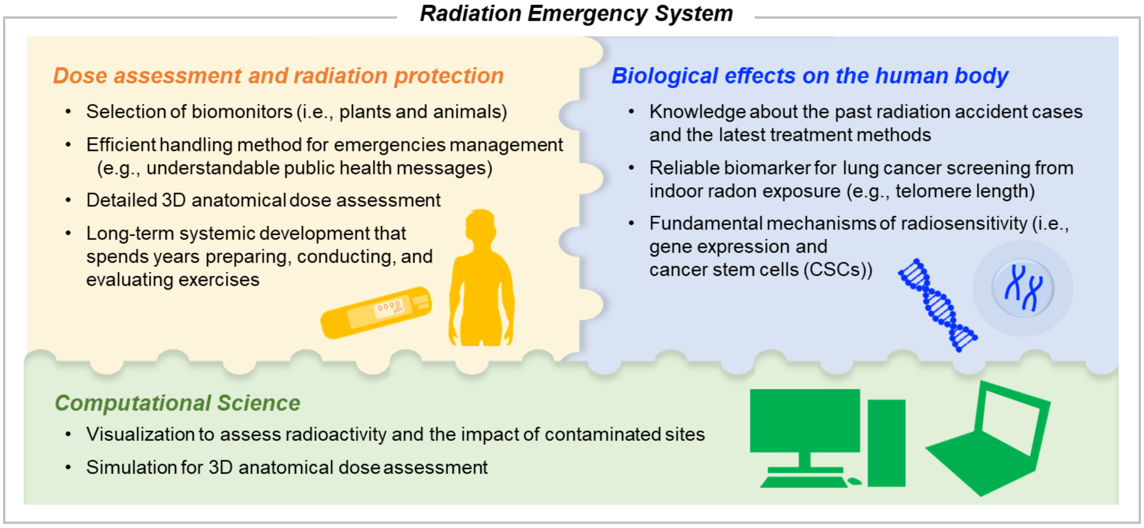

Figure 1. Schematic illustration of the research topics by educational lectures. Five leading researchers presented the latest effects of radiation in various research fields, which can be categorized as dose assessment and (b) biological effects. The research topics are intertwined with each other and performed bottom-up studies coupled with biology and computational science.

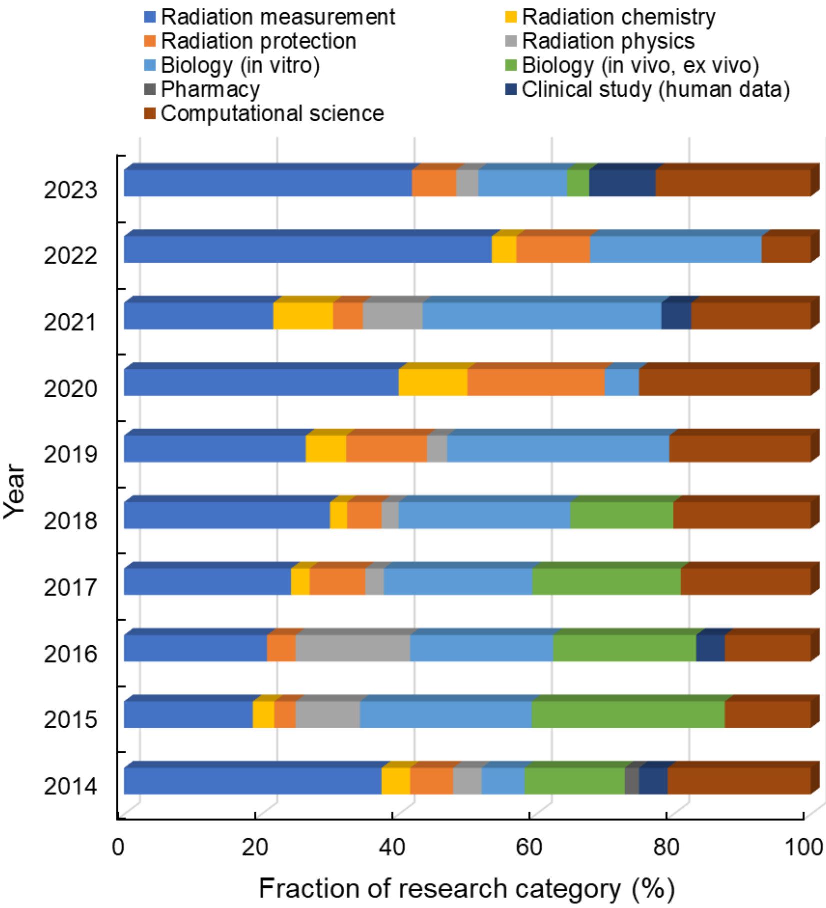

Figure 2. Fraction of research categories presented by young scientists during the ESRAH 2014–2023. The total number of poster presentations by young scientists was 288 since 2014. While the major categories were found to be radiation measurement, biology (*in vitro*, *in vivo*, and *ex vivo*), and computational science (*in silico*), the fraction of *in vivo* (including *ex vivo*) studies decreased after 2019. Amongst the categories, pharmacological and clinical studies were indicated to be less in research for radiation and health, so far.

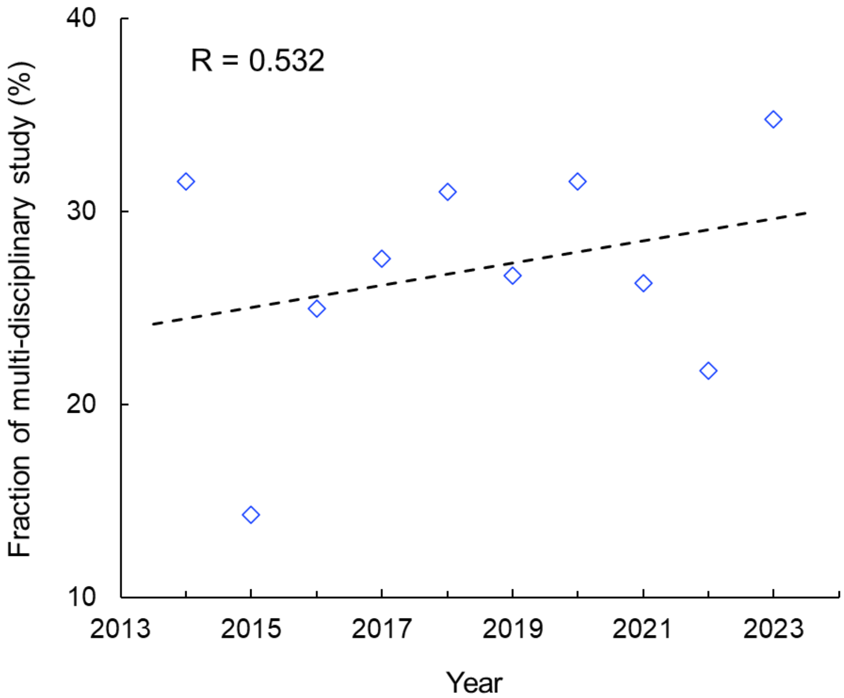

Figure 3. Fraction of multi-disciplinary research by young scientists during the ESRAH 2014–2023. In the same manner as Fig. 2, the total number of presentations by young scientists was 288 since 2014. The studies containing at least the two categories were classified as multi-disciplinary research in this report, and the fractions of multi-disciplinary researches were calculated. Among them, the fraction in 2023 (i.e., 34.8%) is the highest during the past ESRAH meetings.

Table 1. Educational lectures by five leading researchers and their research categories

Educational lecture title	Research category	Lecturer	Affiliation
Selection of the biomonitors for the contaminated sites	･Measurement (Environment) ･Biology (plants and animals) ･Computational science	T. Kovács, Ph.D.	Pannonia University, Hungary
Development of public health advice messaging in Ireland following a nuclear or radiological accident	･Protection (Emergency medicine) ･Measurement (Environment)	K. Kelleher, Ph.D.	Environmental Protection Agency, Ireland
Local radiation injuries: extracellular vesicles diagnosis and treatment	･Protection (Emergency medicine) ･Radiation therapy ･Computational science	R. Tamarat, Ph.D.	IRSN, Institut de radioprotection et de sûreté nucléaire, France
Residential radon exposure in Chiang Mai, Thailand: A promising biomarkers for lung cancer	･Measurement (Environment) ･Biology	N. Autsavapromporn, Ph.D.	Chiang Mai University, Thailand
Mechanisms of radiosensitivity and radioresistance	･Radiation therapy ･Biology	S. Haghdoost, Ph.D.	Caen Normandy University / Stockholm University, Sweden