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Perceived Risks from Radiation and Nuclear Testing Near Semipalatinsk, Kazakhstan: A Comparison Between Physicians, Scientists, and the Public

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Determining the difference in perception of risk between experts, or more educated professionals, and laypeople is important so that a potential hazard can be effectively communicated to the public. Many surveys have been conducted to better understand the difference between expert and public opinions, and often laypeople exhibit higher perceptions of risk to hazards in comparison to experts. This is especially true when health risk is due to radiation, nuclear power, and nuclear waste. This article focuses on one section of a risk perception survey given to two groups of individuals with a more specialized education (scientists and physicians) and laypeople (villagers) in the Semipalatinsk region of Kazakhstan. All of these groups live near the former Soviet nuclear test site. Originally, it was expected that the scientists and physicians would have similar perceptions of radiation risk, while the public perceptions would be higher, but this was not always the case. For example, when perceptions of risk pertain to the health impacts of nuclear testing or the dose-response nature of radiation exposure, the physicians tend to agree with the laypeople, not the scientists. The villagers are always the most risk-averse group, followed by the physicians and then the scientists. These differences are likely due to different frames of reference for each of the populations.

KEY WORDS: Kazakhstan; laypeople; nuclear testing; radiation; risk perception

1. INTRODUCTION

Risk perception is an important measure of how people view various technologies and potentially hazardous activities. Studies have shown that if a technology is perceived to be uncontrollable, especially with catastrophic and fatal potential, laypeople tend to dread the hazard and consider it to be very risky.(1) For example, nuclear power and nuclear weapons are often misrepresented to be a very high risk relative to the statistical odds that death or illness is likely to result from these sources. When such technologies are so dreaded, the rates of death can be greatly overestimated while other high-risk phenomena, such as lightning and asthma, can be greatly underestimated by the general public.(2)

Because technologies related to potential radiation exposure, such as nuclear power and/or weapons, are perceived as a high-risk endeavor, many studies have been undertaken in an attempt to understand how people develop their perceptions of risk.(3–7) This is especially important with the recent National Research Council report, *Health Risks from Exposure to Low Levels of Ionizing Radiation*, which states that although smaller doses exhibit lower risk, there is no safe level of radiation exposure.(8) Radiation is typically viewed as an "uncontrollable," risk in part

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because one is unable to detect the radiation without special scientific equipment. People exposed to invisible environmental contaminants, such as radiation, have demonstrated traumatic psychological effects from the unknown health impacts.[9] All of these factors may increase a person's negative perception of potential risk.

Risk perceptions can vary when comparing different groups of people. Many studies have been conducted that distinguish the differing perceptions of experts versus laypeople. For example, when comparing judgments of risk for high-level nuclear waste disposal between the general public and attendees of an American Nuclear Society meeting, the perceived seriousness of the risk was much higher for the laypeople.[6] The public has been found to have a multidimensional view of risk and benefits that differs from the frameworks used by technical experts.[10–13] Similarly, when discussing chemical exposure, laypeople model risk decisions differently than experts.[14] Even when comparing expert groups, such as scientists, opinions about nuclear waste can vary greatly between disciplines, such as biology, chemistry, and physics.[15] Others have learned that expert opinion tends to be flawed and have similar biases as laypeople, due to increasing specialization.[16–18] Also, depending on their backgrounds, different cohorts rationalize information differently, which can explain differences in risk perception.[19]

Many risk perception studies regarding chemical exposure and/or nuclear technologies have been fielded in Western countries, but fewer have focused on non-Western populations. The results from the work in Canada and Western Europe were often similar to those results found in the United States.[20–23] An example of a cross-cultural risk perception study includes a comparison between the Japanese and American views on nuclear technologies where the researchers discovered that laypeople have a shared dread toward the consequences of nuclear power and war more than they dread AIDS or crime.[24] Another study found that Americans and residents of Hong Kong rank order technological hazards very differently.[25] A hazards perception survey was conducted in Hungary and the United States during the Cold War and determined that the Hungarians' perception of risk was lower than the Americans.[26] This study explained differential risk perceptions by the level of media coverage on the various hazards.

This study builds on the previous work just referenced to compare the risk perception of nuclear testing in Kazakhstan, a former Soviet Republic, between three groups: scientists, physicians, and villagers. Understanding risk perception in non-Western countries and among various population groups, not just technical experts and laypeople, is of interest. In this case, the more educated cohorts, the scientists and physicians, are expected to have a lower perception of radiation risk than the villagers, due to their knowledge of nuclear science and medicine.

1.1. Background

In 1947, the Union of Soviet Socialist Republics (USSR) opened the Semipalatinsk Nuclear Test Site (SNTS) in northeastern Kazkahstan (Fig. 1). The site was chosen because of the relatively low density of people living in the area, easy access to river transport, an airport in the city of Semipalatinsk 160 km away, and favorable geologic and climatic conditions. Many state farms did exist in the area, including about a dozen villages and smaller settlements located less than 40 km from the test site boundaries (Fig. 2). Population statistics for this region for the years of atmospheric testing are difficult to obtain, although some information is available. Over 6,000 villagers lived in five of the villages in 1960, in addition to 163,000 residents in the City of Semipalatinsk.[27] Further, over 20,000 villagers were treated over the decades at a secret military clinic.[28]

Radioactive clouds would often pass over the villages, exposing people, who were told by authorities to stay outside during the blasts, as aftershocks sometimes caused houses to crumble. The first atomic test on August 29, 1949 was one of the most devastating for human exposure, as high wind velocities moved the radioactive cloud directly over the villages of Dolon and Mostik.[29] In addition to direct exposure in the first weeks after the test, radiation migrated into the environment and exposed the villagers through their food, water, and air. The residents in the surrounding area were not informed that they had been exposed to nuclear radiation until a few years before the test site was closed in 1991.

Between 1949 and 1962, 26 surface and 92 atmospheric tests were detonated in the area known as Ground Zero.[30] After the Partial Test Ban Treaty went into effect in 1963, limiting nuclear tests to underground shafts and tunnels, nuclear tests were conducted at several locations in the southern portion of the SNTS. Between 1965 and 1989, 370 underground nuclear tests were performed at the site.[30] Although these tests were designed to contain the radiation underground, over one-third of the radioactive gases

Fig. 1. Map of Kazakhstan with outline of the Semipalatinsk Nuclear Test Site (SNTS).

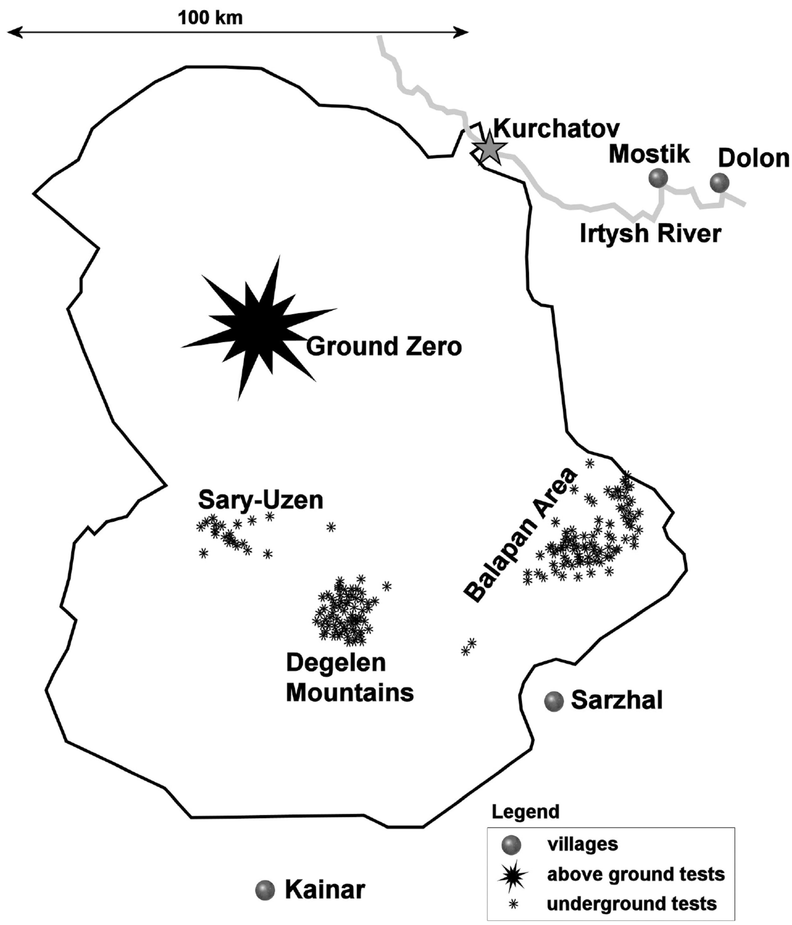

Fig. 2. Map of the Semipalatinsk Nuclear Test Site (SNTS).

from the tests escaped into the atmosphere.[(28)] People who live in the area surrounding the SNTS have shown an increase in the number of cancers and birth defects, due to the radiation exposure.[(31–33)] The health impacts have only recently been divulged, as during the Cold War, doctors were forced to give false diagnoses for cancer in order to conceal the negative impacts of nuclear testing.

1.2. Objectives of Research

The main purpose of this risk perception survey was to understand the different perceptions of risk from nuclear testing for three different groups, scientists, physicians, and villagers in a non-Western country (Kazakhstan). The more educationally specialized cohort was divided into scientists who work on issues related to the former nuclear test site in Kazakhstan and physicians who treat the people affected by nuclear testing. The laypeople surveyed included people from two villages who live near the SNTS and one village approximately 500 km away from the SNTS. While it was expected that the further one lived from the SNTS, the lower perception of risk, we found that the villagers have similar perceptions of risk, regardless of distance from the site. As in similar research from surveys in Western countries, a higher perception of risk toward radiation and nuclear testing was expected from the public.

2. METHOD

2.1. Survey Content

The survey was designed to test perceptions of health risk due to nuclear testing in the Semipalatinsk, Kazakhstan region. The survey included sections on basic demographics, knowledge of radiation and nuclear power, perceptions of health risks, perceptions of risk to various hazards and technologies, attitudes toward nuclear tests in Kazakhstan, trust in the government, nongovernmental organizations, and the international community, the impact of nuclear testing on the community, and general attitudes toward life and religion. The villagers from Dolon and Kainar were also asked about their personal experiences with nuclear testing. This article focuses on the questions pertaining to knowledge of radiation and nuclear power.

Questions for the survey were developed after conducting qualitative interviews with villagers (20), doctors (10), and scientists (6) in the summers of 2000 and 2001.[(34)] The survey was administered in June and July of 2003. Additional ethnographic and focus-group interviews were conducted in the summer of 2004 in order to better inform the results of the survey.

2.2. Survey Administration

The public sample consists of rural residents as they are the ones who have been most affected by radiation exposure. The sample was subdivided into "test" villagers and "control" villagers. The survey was administered in June and July of 2003 to a random sample of households in each of three villages: Dolon and Kainar villages and the control village of Zharbulak. While Dolon and Kainar are situated less than 40 km from the boundaries of the SNTS, Zharbulak is approximately 500 km away. Two villages near the test site were selected in order to compare a Kazakh village with a more diverse village. While Kainar is exclusively Kazakh, Dolon has a mixed population of Kazakh (51.6%), Russian (39.1%), and other (9.3%). Zharbulak is primarily Kazakh, though there are a small number of individuals (1.6%) representing different ethnic backgrounds.

In order to ensure a high response rate, eight local nurses familiar to local residents were hired in each village to conduct face-to-face interviews. The survey was given to the respondents in the language most comfortable to them, either Kazakh or Russian. Before administering the surveys, the questions were translated from English both into Kazakh and Russian and then translated back into English by another translator to assure correct meaning of the questions. For randomization purposes, the number of houses in each village was determined and then based on the target number of respondents, the interviewers were instructed to visit every 4th (or Xth) household in the village (depending on population size). Kainar has a total of 471 households and 2,453 residents, Dolon has 234 households and 732 residents, and Zharbulak has 877 households and 4,492 residents. The nurses interviewed the adult (18 or older) currently residing in the household with the most recent birthday.[3] These procedures allowed us to approximate a random sample. In all, 624 surveys were completed in the villages with

[3] The proportion of women interviewed is high for all of the villages. More men migrate to the cities to find work and leave the women at home to take care of the children, parents, house, and animals. Compounding this factor is that during the summer period, the men who have not moved to the city tend their livestock far away from the village.

Table I. Demographics of Survey Populations

Sample Group	Number of Interviews	Gender		Age			Education			
		% Male	% Female	18–41 Years (%)	41–54 Years (%)	54 Years and Older (%)	Less than 8th Grade (%)	High School (%)	Technical (%)	Higher Ed (%)
Dolon village	184	31.5	68.5	38.7	23.3	38.0	31.7	36.1	22.4	8.7
Kainar village	222	20.7	79.3	54.5	23.9	21.6	9.0	32.4	39.6	16.2
Zharbulak village	195	32.3	67.7	50.8	33.3	15.9	5.1	56.9	20.0	12.8
Physicians	138	41.7	58.3	63.1	24.3	12.6	0	0	0	97.8
Scientists	26	34.6	65.4	77.0	19.2	3.8	0	0	11.5	80.8

an overall response rate of 94.5%.[4] After discarding 23 surveys from Dolon due to interviewer error, the public sample contains 184 surveys for Dolon, 222 for Kainar, and 195 for Zharbulak.

The more educationally specialized population consists of two groups: research scientists and physicians. For both groups, the survey was presented to the entire population of eligible individuals (i.e., physicians, not nurses) employed at the target institutions. In order to ensure a high response rate, supervisors were asked for their support, and a local staff member was hired to hand deliver and collect each self-administered survey. The survey was completed by physicians (138 people) at two hospitals, the Semipalatinsk Oncological Hospital, which treats cancer patients, and the Semipalatinsk Regional Hospital, a general hospital. This sample includes all doctors in Semipalatinsk who treat people negatively impacted by nuclear testing. One might expect the doctors who treat cancer patients to have a different risk perception than other physicians, but one-way ANOVA analysis of questions answered by the physicians at two different hospitals show no significant difference between the two groups. The survey was also completed by scientists (26 people) who work at the Institute for Radiation, Safety, and Ecology, which is part of the National Nuclear Center in Kurchatov, and researchers at the Institute for Radiation, Medicine, and Ecology in Semipalatinsk. Some of the scientists surveyed were those who helped design and test nuclear weapons or determined the health impacts of nuclear testing. In the post-Cold War era, these scientists now work on either environmental clean-up of the test site or do medical research to assist people negatively affected by nuclear testing. The experts were given the same survey as administered to the public, without village nuclear testing experience questions. The response rate for the physicians was 91.4% and the response rate for the scientists was 96.2%.

[4] The response rate is calculated by the number of rejections received by people currently residing in the household. Currently residing does not including people who have moved to the cities or who are tending their livestock on the steppe for the entire summer period.

3. RESULTS

3.1. Population Demographics

The number of interviews, gender, age, and education for each target population are provided in Table I. The ages of the villagers tend to be skewed toward the lower end, except for Dolon, with over 50% of the residents of Kainar and Zharbulak villages in the 18–41 age range. In Dolon the youngest and oldest age cohorts are similar. The age categories were chosen to correspond to the different nuclear testing periods. If a person was greater than 54 years old at the time of the survey, he or she lived during the entire atmospheric testing period; those between 41–54 years old were born during atmospheric testing; and those younger than 41 years lived during the underground testing period. The villagers as a whole are fairly well educated. Except for Dolon Village, most of the people at least graduated from 8th grade. At least 30% of each of the villages attended technical school or higher education. Overall, the proportion of groups in the sample does reflect the target populations.

As expected, both the physician and scientist cohorts were very well educated, with 97.8% and 92.3%, respectively, having higher education or technical training. The figures are likely to be higher as some respondents did not answer the question. The majority of the experts were between 18–41 years old, with just 12.6% of the physicians and 3.8% of the scientists above 54 years of age. More women than men

Table II. ANOVA Analysis of Scientific Knowledge Summary Questions

Topic of Summary Questions	Target Population	Villagers	Scientists	Physicians
Scientific knowledge	Villagers (mean difference) (significance)[a]		16.4 (P = 0.002)	8.3 ($p < 0.001$)
	Scientists (mean difference) (significance)			−8.1 ($p = 0.206$)
	n	601	26	138
Health effects	Villagers (mean difference) (significance)		28.3 ($p < 0.001$)	11.1 ($p < 0.001$)
	Scientists (mean difference) (significance)			−17.1 ($p = 0.007$)
	n	601	26	138
Dose response	Villagers (mean difference) (significance)		12.8 ($p = 0.009$)	4.4 ($p = 0.011$)
	Scientists (mean difference) (significance)			−8.4 ($p = 0.144$)
	n	601	26	138
Radiation in Kazakhstan	Villagers (mean difference) (significance)		10.6 ($p < 0.001$)	6.0 ($p < 0.001$)
	Scientists (mean difference) (significance)			−4.5 ($p = 0.308$)
	n	600	26	137
Mechanics of nuclear testing	Villagers (mean difference) (significance)		16.6 ($p < 0.001$)	15.9 ($p < 0.001$)
	Scientists (mean difference) (significance)			−0.8 ($p = 1.000$)
	n	601	26	137

[a] Equal variances are not assumed, so are based on Tamhane's T2 *post hoc* statistical test.

tend to be in the professional fields of environmental science and medicine in Kazakhstan.

3.2. More Educated Versus Layperson Comparison

Table II represents data gathered from one section of the risk perception survey pertaining to knowledge of radiation and nuclear power. The respondents were asked to rate a variety of statements as definitely false, probably false, probably true, definitely true, or do not know. The questions were grouped into theoretical categories of similar subject matter in order to understand how the different cohorts perceive the risk of radiation and technologies related to nuclear energy.

1. Scientific Knowledge of Radiation
2. Health Effects of Radiation Exposure
3. Dose-Response Relationships
4. Nuclear Testing in Kazakhstan
5. Mechanics of Nuclear Testing

A summary score was then calculated for each respondent for each of these subjects, hence five scores were calculated per person. Each respective summary score was used to calculate the percentage of that score relative to the maximum value that could be selected, 20% being very accepting of risk whereas 100% is a high perception of radiation risk (Fig. 3). For example, if a person answered "Definitely True" for all three questions in the subject set, then their summary score was 15, with a relative risk score of 100%.[5] The villagers exhibited higher summary scores overall, which is evidence that they have a very high perception of risk, followed by the physicians and then the scientists. For each of the summary scores, the null hypothesis of equal variances across our categories could not be accepted as the Levine test was significant. A standard ANOVA analysis was conducted, but used Welsh and Brown-Forsythe statistics to test the null hypotheses. For the *post hoc* comparison of means, the Tamhane's T2 statistical test was used.

Throughout this article, the responses for the three villages, Dolon, Kainar, and Zharbulak, are combined for statistical analysis, as the results of the survey questions were similar and not statistically significant from one another, even though they are in different locations with respect to the SNTS. Many articles have been published in Kazakh newspapers about the health impacts of nuclear testing in general and with regard to the SNTS in particular, mostly in regional or national papers. These newspapers are the primary sources of information for the villagers about the impacts of radiation exposure, which explains why knowledge of radiation and nuclear testing are statistically similar between the three villages.

[5] In calculating these relative summary scores, the lowest point value would be either 3 or 4 if the respondent answered "definitely false" for all questions, depending on the number of questions in a subject set. The relative percentage score for such a person would be 20%. The highest point value for a respondent selecting all "definitely true" answers would be 15 or 20, again depending on the number of questions in the subject set. The highest relative percentage score would be 100%

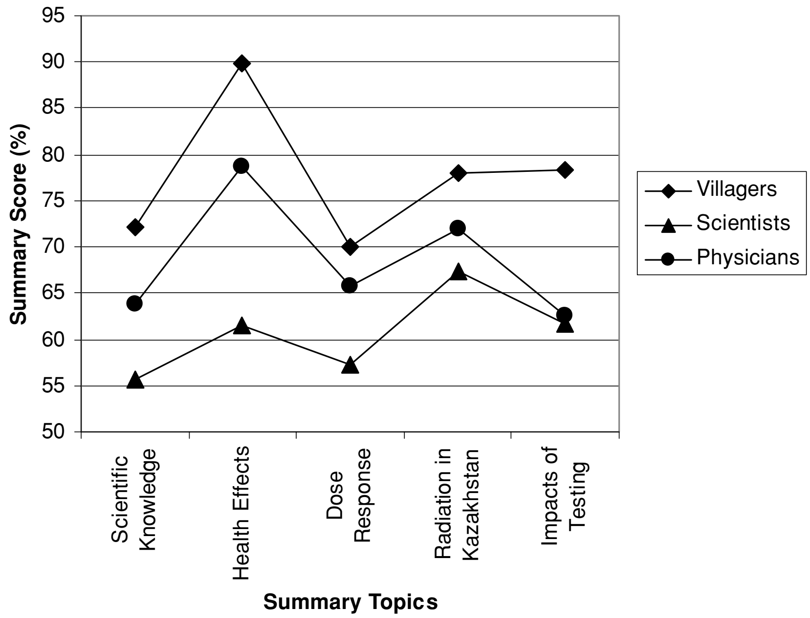

Fig. 3. Summary scores of risk question topics (20% = low perception of risk, 100% high perception of risk) across the different populations.

3.2.1. Self-Rated Knowledge of Nuclear Energy and Radiation

The first question each person was asked in the survey section about knowledge of radiation and nuclear power was to rate themselves on how much they know about the topic. The results are interesting and typical of general findings throughout our analysis (Fig. 4). All three villages exhibited about the same median, a little less than 5 on the knowledge scale between 0–10, but the spread of answers for Zharbulak is much less than that for the two villages situated directly adjacent to the SNTS. Perhaps the small deviation of answers from villagers in Zharbulak is because those people do not have as much experience with the SNTS as the other two villages that are closer to the site. According to the knowledge scale, the scientists view themselves to be the most knowledgeable population, whereas physicians place themselves between the laypeople and the scientists.

3.2.2. Scientific Knowledge of Radiation

The first category of questions was used to probe how the target groups understand the science of radiation (Table II). The professionals as a whole are more educated than the villagers, so it was expected they would agree and have a lower perceived risk relative to the laypeople in the sample. The respondents were asked how much they agreed or disagreed with the following statements.

1. All radioactive material remains toxic for thousands of years.
2. The human body has the capability to repair tissue damage caused by exposure to radiation.
3. A suntan is caused by radiation damage to human skin.

Our ANOVA analysis of summary scores of the statements showed that all three populations were significantly different from one another. Further *post hoc* analysis of means indicates that we cannot reject the null hypothesis that the scientists and the physicians are not different from each other in their knowledge of radiation. The difference between scientists and physicians is not significant and we conclude that, on average, they score the same on knowledge of radiation.

3.2.3. Perceptions of the Potential Health Effects from Radiation Exposure

In preliminary interviews with the public, the villagers tend to attribute any illness obtained in the village, from an upset stomach to a brain tumor, to nuclear testing and radiation exposure. The statements in Group II (Table II) were designed to better understand the differences between how the villagers and professionals viewed the health impacts from such radiation exposure.

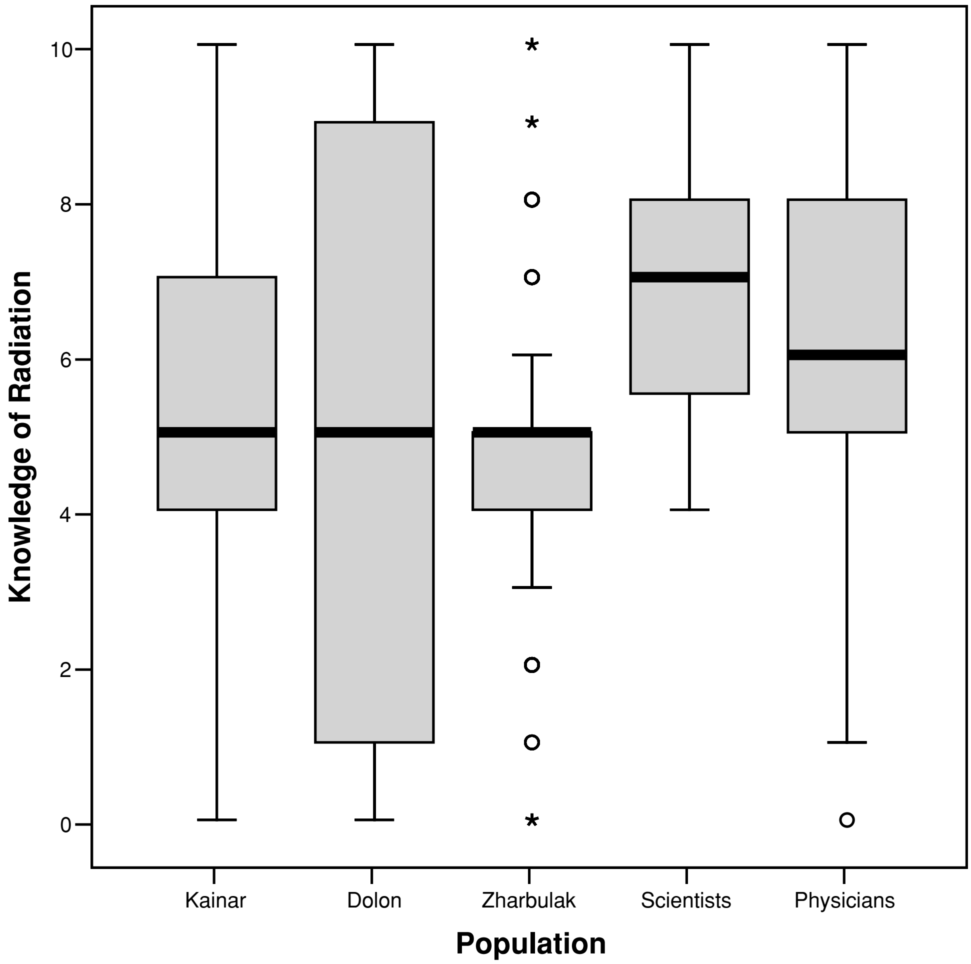

Fig. 4. Self-rating knowledge of radiation and nuclear power where 0 = "not knowledgeable at all" and 10 = "very knowledgeable" for each of the target populations.

1. If a person is exposed to any amount of radiation, then they are likely to suffer serious adverse health effects.
2. If a person is exposed to a carcinogen, then he/she is likely to get cancer.
3. Women exposed to radiation while pregnant are very likely to give birth to children with mental and physical defects

According to our ANOVA analysis of summary scores, all three respondent populations are significantly different in their opinion of health impacts. The villagers and physicians are very concerned about the health impacts of radiation exposure, which is evidenced by their elevated summary score in comparison to other categories of questions. Again, the villagers are more risk averse, followed by the physicians and then the scientists.

3.2.4. Perceptions of Dose-Response Relationships

In the exposure and health effect statements above, no doses are mentioned. During preliminary interviews, several scientists expressed the opinion that they too had been exposed to radiation during nuclear testing, but their health was fine because the doses were not that high. In their opinion, the poor health of villagers can be partially attributed to other factors, such as diet. Meanwhile, many of the villagers believe that their bodies have adapted to chronic low-dose radiation exposure, and they might get sick if they leave the region. To distinguish how widespread these opinions were among both the experts and laypeople, the respondents were asked about the positive nature of radiation exposure. The summary scores for dose response (Table II) are meant to probe how the different groups view dose when developing their concept of risk perception. The results from the following statements were included in the summary score for dose.

1. Even if the dose is the same, man-made radiation is more toxic to humans than naturally-occurring radiation.
2. With radiation, it is not how much exposure that is a problem, it is any exposure at all that is a problem.
3. There is no safe level of exposure to radiation.
4. Small doses of radiation can actually improve one's health.

In the ANOVA analysis, the three target populations are statistically different, but *post hoc* analysis of means demonstrates that the scientists and physicians do not reject the null hypothesis, similar to the scientific knowledge section. The villagers are significantly different in their opinions than the professionals.

3.2.5. Perceptions of Radiation Exposure in Kazakhstan

Another topic of interest is how respondents perceive the impact of radiation from nuclear testing in Kazakhstan and how the perceptions compare with another Soviet nuclear disaster, the accident at the Chernobyl Nuclear Power Plant in the Ukraine (Table II). The respondents were asked about their agreement or disagreement with the following statements.

1. In Kazakhstan, most cases of cancer in humans are known to be caused by man-made radiation.
2. People in this country underestimate the risks associated with radiation.
3. The radioactive fallout from the accident at Chernobyl affected more people than the radioactive fallout from nuclear testing in Kazakhstan.

Again, the ANOVA analysis demonstrates that the respondent populations are statistically different, but *post hoc* analysis relates the professional groups to one another, who are significantly different from the villagers.

3.2.6. Perceptions of the Mechanics of Nuclear Testing

The final set of questions asks respondents to give their opinion regarding the local and global impacts of nuclear testing in Kazakhstan (Table II). The following statements were probed.

1. Nuclear testing in Kazakhstan has affected people throughout the world because the radiation released into the atmosphere has spread elsewhere.
2. Radiation from nuclear testing is more concentrated near the explosion site.
3. The radioactive fallout from nuclear testing is only harmful to people who are close enough to see or feel the explosion.
4. The radioactive fallout from nuclear testing is only harmful when the bomb is exploded on the surface.

The statistical analysis from the final set of summary questions is similar to the results above. Our ANOVA analysis is significantly different between the three groups, but further analysis shows that the professionals are very similar and different from the villagers.

3.3. Discussion

The theoretical grouping of survey statements for summary scores appears to fit the risk perceptions of the different populations, with the health effects statements eliciting stronger responses from the villagers and physicians while the radiation in Kazakhstan statements elicited stronger responses from the scientists. As expected, the villager responses demonstrate a higher fear of radiation effects in comparison to the professionals. The physicians in turn demonstrate a greater fear of radiation than the scientists, except for their responses to the impacts of testing questions, which are statistically the same. We expect the villagers to have a higher risk aversion to radiation exposure due to the unknown nature of radiation exposure. We also expect scientists to agree with the general consensus among international scientists regarding the effects of radiation exposure. What is interesting here is that the physicians, who also have scientific training, fall in between these two categories as far as their risk perception is concerned.

One interesting point to note is that the percentage of "don't know/no response" answers is always an order of magnitude higher for the villagers versus the professionals. This is almost universally consistent throughout this section of the survey, with the exception of the set of statements regarding radiation exposure and potential health effects. With these statements, the scientists and the villagers have similar frequencies of "don't know" answers. This is probably because the scientists focus more on the physics of radiation, and do not interact with the health impacts from radiation exposure on a daily basis like the doctors. Overall, the more educationally specialized cohorts were more confident with their knowledge of radiation during interviews, so it was expected that they would answer "don't know" less than the villagers. This is consistent with the professionals' answers for the initial self-rated question about their knowledge of nuclear energy and radiation, as they exhibited overall higher scores than the villagers.

The fact that the villagers have a higher perception of risk with regard to the health effects and dose-response relationship related to radiation exposure than the professionals corresponds with preliminary interviews. The villagers tend to think that any exposure to radiation will cause illness, regardless of the dose. The villagers who live near the SNTS have a higher incidence of cancer, birth defects, and other illnesses in comparison to similar populations elsewhere.[33] These results are similar to previous studies where researchers have found that laypeople have a view that if they are exposed to a dangerous chemical, then they will likely be harmed. For example, Krewski *et al*. found the same results for laypeople with regard to potentially carcinogenic chemicals.[13] Laypeople would completely avoid exposure to the chemicals because they thought any exposure would cause cancer.

Similar to the questions about scientific knowledge, the physicians tend to agree more with the villagers than do the scientists and exhibit higher perceptions of risk due to radiation exposure. Even though the professionals exhibit homogeneous means in *post hoc* tests, the physicians still have a higher perception of risk than the scientists for both the health effects and dose-response categories. The majority of the patients that the doctors treat live near the SNTS, so it must appear that radiation exposure often causes health problems, no matter what the dose is. One of the scientific debates regarding radiation exposure is the threshold effect. The main question is whether or not there can be negative health effects from any dose of radiation, or whether there is a threshold such that any dose below the threshold is considered to be "safe." Recently, a National Research Council report was published that stated that low doses of radiation can cause health problems, although the risk is low.[8] The results of this survey suggest that the villagers and physicians in Kazakhstan are more in agreement with this report finding than the scientists in Kazakhstan.

Overall, the findings of this survey are similar to those determined in previous studies. When Kraus *et al*. surveyed toxicologists and the public regarding doses of potentially carcinogenic chemicals, they found that the public did not take into consideration the dose when making their risk selection, but the experts considered it.[12] After the survey was completed in Kazakhstan, focus groups were facilitated to better understand some of the data from the survey. According to the way many villagers conceptualize radiation exposure, radiation is something that stays with a person who has been exposed and causes harm regardless of the dose. Unlike the scientific view of radiation, villagers tend to be less concerned about the accumulation of radiation dose. As a result, some villagers are willing to put themselves in potentially harmful situations, such as grazing their animals on the SNTS or scavenging contaminated scrap metal to sell to metal collectors, despite the fact that they do not know exactly which areas are contaminated and which are clean. Because they have already been exposed to radiation, the villagers think that these extra doses will not make a difference. In addition, the villagers cannot avoid exposure, as radiation has permeated their environment and they are exposed to small amounts of radiation through their food, water, and air.

With regard to understanding the technical details of nuclear testing, the professional cohorts are better informed than the laypeople. For example, the respondents were asked whether radioactive fallout is harmful only to those who see or feel a nuclear explosion. The more educationally specialized cohorts tended to disagree with this statement, versus the villagers who were likely to agree. During the testing period, people who did not see or feel the explosion were exposed when the radioactive cloud moved over their town or city. This is similar for other questions that are a part of this summary section. Because the villagers were exposed to radioactive material without their knowledge and consent for so many years, they are suspicious of all radiation-related topics and think of them as very risky.

Overall, even though the professional cohorts were often statistically similar for a set of summary questions in this survey in comparison to the villagers, the physicians always had a higher perception of risk than the scientists. The results are similar to those found by Mertz *et al*., in that the risk perceptions of senior managers in a chemical company were lower than members of the British Toxicological Society, which were, in turn, lower than the Canadian public.[11] The senior managers can be likened to the scientists in this study and the members of the British Toxicological Society are similar to the doctors. The difference in the physicians versus scientists might also be explained by a study by Barke and Jenkins-Smith who found that life scientists tend to view the risk from nuclear energy and waste as much higher than experts in the physics and engineering fields.[15] The majority of the scientists surveyed in Kazakhstan had a physics background, in comparison to the doctors who studied the life sciences.

3.4. Conclusions

Throughout the knowledge of radiation and nuclear power portion of the survey, certain trends can be observed between the different groups studied: villagers, scientists, and physicians. Our hypothesis that the villagers had a higher perception of risk than the more educated cohort was confirmed. The summary scores for the physicians and villagers were more similar when perceptions of risk have to do with the health of people living near the test site, such as the health impacts and dose-response sections. The physicians differed from the other professional cohort, in that the scientists appeared to have an attitude that "a little bit of radiation exposure cannot hurt you."

The difference between the two groups of professionals is most likely because the scientists and doctors have different frames of reference. The scientists tend to think in terms of the scientific laws. If they know about the physics or chemistry of radiation, then the theories do not change without extensive experimentation. The physicians are different in that they have daily contact with patients who have been impacted by the nuclear testing, so they personally see the effects of radiation exposure. In contrast to the scientific laws, the health impacts are highly variable because different cancers develop depending on length of time after radiation exposure. Overall, the doctors have a more intimate knowledge of how people are impacted by the testing, but might not know as much about the physical principles behind radiation and nuclear power.

Overall, this study shows disconnects between the perceptions of risk of the scientific community, the physicians, and the villagers in the Semipalatinsk region of Kazakhstan. The public assumes that any exposure to radiation is bad and will cause illness, although some participate in potentially risky activities, such as grazing livestock or gathering scrap metal on the SNTS. When health impacts are involved, physicians tend to side more with the villagers, but they show similarities with the scientists as well. Finally, the scientists have been exposed to radiation throughout the testing period, and yet their perception of risk tends to be low.

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