

A review of the long-term psychological effects of radiation exposure in the cases of the atomic bombings of Hiroshima and Nagasaki and the Chernobyl nuclear accident

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Abstract

The unique history of nuclear weapons and nuclear power have created a host of unintended knock-on consequences to individuals and societies across the world through their development and deployment. This paper reviews the cases of the atomic bombings of Hiroshima and Nagasaki and the nuclear accident at Chernobyl for long-term effects on human psychological and social processes in victims and their families. Key aspects to the psychology of the atomic bomb experience were the phenomenon of “silence” in survivors and an anxiety about the possible unknown health and genetic effects of exposure, with relatively few issues observed in descendants. Children, women, clean-up workers, and migrants are known to be vulnerable or at-risk populations for mental health issues in Chernobyl. Implications for future research in this domain are discussed.

Keywords: atomic bomb survivors; Chernobyl victims; mental health; radiation disaster; intergenerational transmission

Introduction

Over 70 years have passed since humans possessed the ability to harness the energy of the atom. In 1945, Hiroshima and Nagasaki became the first cities in history to experience the consequences of nuclear technology in the form of the atomic bomb. Nuclear weapons proliferated during the Cold War arms race between the United States of America and the former Soviet Union. In 1954, the lagoon known as Bikini Atoll near the Marshall Islands was subject to thermonuclear weapons testing. The nuclear fallout from tests affected island residents, but also caught a Japanese tuna fishing vessel known as the Lucky Dragon No. 5 (*Daigo Fukuryū Maru*) in the wake, exposing the twenty-three fishermen aboard to doses of radiation that resulted in substantial treatment for the exposure and one death. Attempts to manage the atom eventually led to successful uses of nuclear energy for commercial purposes through the development of nuclear power plants, but have implicated considerable public health crises in the process, namely the 1979 release of radionuclides from a partial nuclear meltdown accident at Three Mile Island (TMI) in Pennsylvania, U.S.A, and the 1986 Chernobyl nuclear accident in the former Soviet Union territory of Ukraine. Most recently,

the consequences of nuclear power plant incidents have been seen in the ongoing recovery from the widespread dispersal of radionuclides caused by the hydrogen explosion of the Fukushima Daiichi Nuclear Power Plant, which was triggered by the 2011 Great East Japan Earthquake and Tsunami. The long-term impacts of these events are related to the knock-on effects of contamination or exposure to radioactivity as a threat to human health and the environment, which can lead to the breakdown of affected communities and prolonged psychological and social consequences.

The purpose of this review is to outline the preponderance of research and perspectives on the consequences of radiation disasters in general and to give a detailed summary of the findings related to the psychology of both the aftermath of the atomic bombings of Hiroshima and Nagasaki and the nuclear accident at Chernobyl. Further emphasis will be placed on the long-term psychological effects imposed by radiation disasters, especially regarding their impact on successive generations, the role of risk perception and risk factors, and implications for future research in these domains.

1. The Atomic Bomb Exposure Context of Hiroshima and Nagasaki

1.1 The physical and psychological impacts of the atomic bomb

On August 6th, 1945, the first ever targeted use of a nuclear weapon in history was dropped on Hiroshima. A few days later, on August 9th, the second ever atomic bomb deployed in an act of war was dropped on the city of Nagasaki. The aftermath resulted in the deaths of an estimated 140,000 people in Hiroshima and approximately 70,000 people in Nagasaki. Characteristic damage from the catastrophic explosion of the bombs included the extensive collapse of the built environment from the blast and ensuing widespread fires, severe injuries from the blast and burns from thermal rays, and health conditions caused by radiation exposure such as Acute Radiation Syndrome (ARS). Symptoms of intense fever, nausea, and diarrhea, were reported to have arisen in victims shortly after the event transpired. Hiroshima City medical records from 1950 showed an increase in patients with leukemia, and others from 1955 showed an increase in the frequency of malignant tumors related to thyroid cancer, breast cancer, and lung cancer after the bombing. Medical research related to the atomic bomb has been primarily concerned with cancer risk in atomic bomb victims, or *hibakusha* (Shimizu, Kato and Schull, 1990), the morbidity rate of leukemia (Preston et al., 1994), atomic bomb microcephaly from prenatal exposure (Miller & Blot, 1972), and numerous other physical health issues.

The impact of the atomic bombs was not limited to the destruction of the physical landscape, but also took the form of various psychosocial hardships endured by survivors, to include the loss of friends and family and the experience of prejudice and social discrimination. Many *hibakusha* have expressed their feelings about the atomic bomb survivor experience through

literature and poetry, but nonprofit organizations have pointed out that actual psychological research and treatment for them has been relatively scarce, especially given the severity of the suffering and world historical significance of the bombing (Ohta et al., 2000; Honda et al., 2002; Sawada, 2004). Sawada (2004) discovered that one major reason for this was due to the “Press Code for Japan” rules issued by the United States General Headquarters, who were in control of postwar transitioning until 1952. Historians have noted that the acting government had a hand in censoring official publications to intentionally obfuscate the aftermath of the atomic bombs as an extreme preventive measure against inciting nationalist protests to the American occupation. Even after the censorship order was lifted, researchers continued to focus on the biological and physical mechanisms behind the emergence of atomic bomb disease, with special attention to children born with microcephaly by atomic bomb survivors and effects to future generations. The next section outlines the albeit limited literature on the psychiatric and psychological research about atomic bomb survivors, their lasting mental health issues, and studies on their second and third generation descendants.

1.2 Psychiatric and psychological research with atomic bomb survivors

Several studies were conducted within the first ten years after the bombing. Okumura & Hikita (1949) reported as early as four months into the initial phase that heightened startle responses were observed in a subset of *hibakusha*, and that some appeared to have developed psychiatric and neurotic symptoms in later phases. Furthermore, Kubo (1951) accumulated interview surveys four years after the bombing and noted psychological and behavioral reactions immediately from the time it occurred up until the end of the war nine days later. His report explains a detailed, sequential account by *hibakusha* of witnessing a sudden and intense “flash”, followed by a state of momentary “blankness”, until a dreaded flurry of “panic” set in. Like many eyewitness testimonies of the event, this report proved valuable for our understanding of the thought processes that accompanied the atomic bomb experience.

Konuma, Furutani, and Kubo (1953) conducted a survey of atomic bomb survivors from Hiroshima 8 years after the bombing, and Nishikawa and Tsuki (1961) reported an 11-year post-bombing follow-up of medical examinations of survivors in Nagasaki. Konuma et al. (1953) found that approximately half of those still living near the epicenter of the blast in Hiroshima reported a generalized fatigue throughout their body, a fear of sudden lights and sounds, and other signs that contemporary psychologists might recognize as post-traumatic stress symptoms. Nishikawa and Tsuki (1961) confirmed that a portion of the atomic bomb survivors in Nagasaki were experiencing symptoms of neurosis, and surmised that the factor of exposure to radiation might be directly involved in a neurotic disorder. It is from these reports that the existence of neurotic symptoms in a subset of *hibakusha* was verified and that an underlying link between radiation and neurotic disorder was established.

In addition, psychiatrist of the extremes, Robert J. Lifton, made notable efforts to assess and record the psychodynamic implications of the *hibakusha* experience in his research. In his work, *Death in Life: Survivors of Hiroshima*, Lifton (1967) wrote about the psychological transitions that *hibakusha* described in their experiences about the time of the bombing through in-depth interviews over the course of seventeen years. Lifton described *hibakusha* as suffering from a kind of *death imprint*, *survivor guilt*, *psychic numbing*, and *struggle for meaning*, among other observations, and noted that the sheer singular nature of the atomic bomb experience and its “sense of special knowledge” was sometimes perceived as uniquely dehumanizing, which perhaps made it more difficult for *hibakusha* to come to terms with aspects of the experience over the long-term. Lifton went on to make similar observations about other traumatic experiences throughout the world, especially in his work with Vietnam veterans in the United States, where he testified in congressional hearings to recognize them as a class of symptoms which were initially rejected for political reasons. In 1978, Lifton and another colleague by the name of Chaim Shatan, successfully managed to lobby with the American Psychological Association to coin the diagnosis “post-traumatic stress disorder” (PTSD) in the DSM-II (Stein, 2015).

The construct of PTSD more formally made its way to Japan after the occurrence of the Great Hanshin-Awaji Earthquake in 1995, and it was then that the traumatic stress perspective was finally applied to the mental lives of atomic bomb survivors. Ohta, Mine, Wakasugi, Yoshimine, Himuro, Yoneda, Yamaguchi, Mikita, and Morikawa (2000) used the Clinician Administered PTSD Scale (CAPS) criteria and structured interviews to begin the process of reporting the morbidity rate of PTSD, and afterwards the Japanese Ministry of Health, Labor and Welfare (MHLW), Nagasaki Prefecture, and Hiroshima City conducted an organized study within the PTSD framework. The MHLW (2001) carried out a survey of the General Health Questionnaire (GHQ) and the Impact of Events Scale-Revised (IES-R) to *hibakusha* living within 12 kilometers of the hypocenter in Nagasaki. While the use of the scales was generally concerned with overall physical health, mental health items were still within purview, and in a comparison between those who experienced the bomb and those who did not, those who did reported a poorer perception of their overall health condition, a longer medical history for physical illnesses, a greater frequency of perceived symptoms, lower ability to function well as a member of society due to their health condition, and an attitude that the atomic bomb experience is probably related to their increased medical visits and poorer perception of their present health status. From the convergence of this data on decreases in various standards of health, it was concluded that the cause of these issues was unlikely to be due to the radiation exposure from the atomic bombing itself, but rather driven from anxiety about the consequences of being an atomic survivor. This anxiety was particularly articulated in responses by *hibakusha* like, “I was probably exposed to a harmful level of radiation,” and “I think they might discover that I will suffer from aftereffects in the future.” It was also inferred that these anxious

thoughts and feelings by the survivors themselves might reflect some aspect of their experiences with social discrimination (Honda et al., 2002).

The results of a survey carried out by officials from Hiroshima City (2010) showed that within cohorts of *hibakusha*, individuals who experienced direct exposure to “black rain” compared to controls reported more negative mental health issues like depression and anxiety and a greater tendency towards PTSD. The report also found that even into present day, a portion of atomic bomb survivors still experience traumatic reactions from the event. Also, while the majority of the trauma reactions were related to the tragic circumstances surrounding the bombing, radiation-related illnesses and their incumbent anxiety, confusion, and prejudice all shared a common theme as “unspoken” or “unspeakable” aspects of the postwar condition of atomic bomb survivors. It is now understood that the veil of silence on these topics functioned to obscure the transgressions of the atomic aftermath and has affected survivors over the course of their lives, as recent results of surveys have shown that some survivors still suffer from traumatic reactions tied to the atomic bomb experience today.

As the surveys from Hiroshima City have indicated, there are numerous aspects of their experience that *hibakusha* are not inclined to discuss with others. Sawada (2011) pointed out that many hide or remain deliberately silent about the fact that they are survivors out of a fear of the social consequences. Members of society, in turn, sense this reticence and become silent on the matter, incidentally reinforcing and “doubling” the silence. Sawada aptly recognized that this phenomenon in atomic bomb survivors bears resemblance to the one described in scholarship on Holocaust survivors known as the “conspiracy of silence” (Danieli, 1998), and can even occur within families to form a kind of “double wall” (Bar-on, 1995).

1.3 Research on second and third generation descendants of atomic bomb survivors

Early in the aftermath, there were great fears about the effects of radiation exposure from the atomic bombing on children, especially regarding the possibility that genetic effects or damage may be passed on to the unborn. An enormous and still ongoing set of epidemiological undertakings to investigate this and other possibilities known as the Life Span Study, Adult Health Study, and F1 Studies were conducted by the joint Japan-U.S. initiative known as the Radiation Effects Research Foundation (RERF; formerly the Atomic Bomb Casualty Commission) as early as the late 1940s. The RERF and other research institutes have investigated effects on the survivors of Hiroshima and Nagasaki and their progeny with follow-up studies. In recent reports by Grant, Furukawa, Sakata, Sugiyama, Sadakane, Takahashi, Utada, Shimizu, and Ozasa (2015) using the massive data set of follow-up studies from 62 years since the bombing, it was confirmed that there is no evidence of harmful physical health effects in the second-generation offspring of atomic bomb survivors of Hiroshima and Nagasaki who were exposed to radiation. Numerous studies from other sources have

corroborated this point, and more specifically stipulate that clear evidence of genetic influences on the second generation has not been demonstrated at the present time (National Research Council, 2006).

While research on the physical and biological effects of radiation and its influence on genetic mechanisms have made great strides toward our understanding and shown that harmful etiological effects to successive generations have not been scientifically proven, there remains a relative lack of mental health research and subsequent poverty of the psychological understanding of this domain, and thus it is still unclear if the consequences of radiation exposure have contributed to harmful *psychological* effects to successive generations. Lifton (1967) explained that in some cases *hibakusha* internalized their fear of the emergence of the long-term effects of radiation and that this physically apparent fear can continue throughout the whole of the lifespan. In this manner, the cognitions and behaviors associated with harboring this fear are not limited to the survivors themselves but might also implicate their descendants through possible influences on developmental processes. In other words, the effects of radiation are not only physical, but also psychological in terms of the fear and anxiety that they entail, which may extend to the mental lives of their offspring. Thus, the precise ways that deep-seated transgenerational fears and anxieties are transmitted and manifest themselves remains an important question in the psychology of atomic bomb survivors.

There are currently only four widely published reports on the topic of the possible secondary transmission of psychological issues from the atomic bombing, two in English and two in Japanese.

Tatara (1998) postulated that the second-generation descendants of atomic bomb survivors might be the earliest subjects of such psychological effects. It was suggested that parents who were survivors feared that their children would experience social discrimination and hid the fact of their atomic bomb experience from their surrounding communities. However, as this study was focused on the anxiety of atomic bomb survivors as parents, it did not investigate the subjective psychological experience of second-generation descendants themselves.

Using the model of Holocaust survivors developed by Bar-On (1995), Sawada (2011) conducted interviews with three generations of atomic bomb survivors (*hibakusha*, their children, and grandchildren). On the one hand, the results showed that a chief issue in the psychology of atomic bomb survivors was an anxiety about atomic bomb diseases and their fear of propagating them, but on the other, having the ability to raise children seems to have been a crucial factor for *hibakusha* to rebuild their lives after the war. It was also found that the second generation of *hibakusha* had not heard much about the atomic bomb experience from their parents, seldom identified as being part of the "second generation of atomic bomb", possessed a strong interest in atomic bomb and peace issues, and had almost no experiences of discrimination or prejudice. The parental experience of the atomic bomb was also not shown to be directly tied to identity or

personality formation processes in descendants. In fact, some cases reported that they might have been positively influenced by their upbringing out of respect for their parents' or grandparents' way of life after the war. While the sample of participants was very limited, this study by Sawada (2011) provides valuable insight on the psychological influence of the experience of the atomic bomb through three generations of families, and notably shed light on what might be considered positive or resilient aspects of growing up with a *hibakusha* family member. Future research would benefit from a broadened scope of interviewees, a larger sample size, and a quantitative approach to investigate the interesting observations drawn by this narrative-focused study.

Tomoike (2007) was the first to implement a quantitative pilot study of health anxiety in second and third generation descendants of Nagasaki atomic bomb survivors. A total of 68 outpatient examinees were recruited from a Nagasaki clinic as participants and filled out questionnaires about their current perception of their health condition and levels of anxiety. No difference in anxiety or concerns related to health was found between those who were second and third generation descendants of *hibakusha*. However, it was reported that among those who were aware of the possible genetic effects of radiation exposure by virtue of being descendants of atomic bomb survivors, and even among those who believed they could not judge either way for themselves, it was confirmed that those who had come down with some form of major illness became worried that it was linked to or the result of the exposure running in their family.

Ben-Ezra et al. (2012) conducted a cross-sectional study of fear of radiation exposure and PTSD symptoms (IES-R) in a convenience sample of 140 Japanese participants a month after the disasters of March 11, 2011, led to the Fukushima nuclear disaster. They divided the sample into two groups: grandchildren of Hiroshima and Nagasaki which comprised 34 individuals and a comparison group of 88 individuals who were unrelated to *hibakusha*. Grandchildren of Japanese living in Hiroshima and Nagasaki showed a higher fear of radiation exposure and a higher level of PTSD symptoms compared to the others, and there were no significant differences between the groups in age, gender, marital status, or distance from Fukushima. These results from an albeit relatively small sample suggest that anxiety might increase in third-generation *hibakusha* descendants compared to non-descendant controls from news of accidents related to radiation.

Psychological studies of the descendants of atomic bomb survivors have only been carried out on relatively small samples, as seen in the work by Ben-Ezra et al. (2012) and Tomoike (2007). However, they have established a vein of potential hypotheses for studies in this domain. Future research should investigate larger samples of second and third generation descendants of atomic bomb survivors and pay special attention to the actual state of their anxiety about radiation-related genetic effects, examine the “silence” between survivors and society about the bomb observed by Sawada (2011) and how that has likely affected families, and explore the mechanisms of health anxiety or the intergenerational transmission of mental health issues in order to broaden our

psychological understanding of the implications of the atomic bomb experience.

2. Comparison to the Chernobyl Nuclear Disaster Context

2.1 The magnitude of the Chernobyl accident

The explosion at the Chernobyl nuclear power plant occurred on April 26, 1986, and remains the most severe accident in the history of the nuclear power plant industry. It caused a release of radioactive material that resulted in unprecedented and devastating consequences for humans and the environment. More than 300,000 people were evacuated from contaminated areas in Belarus, the Russian Federation, and Ukraine, and at the time of this study five million people reportedly still reside in affected communities (The Chernobyl Forum, 2006).

2.2 The physical health impact of the Chernobyl accident

According to the international collaboration effort known as “The Chernobyl Forum” of 2005 which convened 20 years after the accident and comprehensively reported the mortality of related diseases, a total of 50 emergency workers died due to ARS, physical injuries, or various other causes from the incident. Between 1992 and 2002, more than 4,000 thyroid cancer cases were diagnosed in people who were children and adolescents in 1986, and by 2002, 15 had died due to the progression of the disease. These findings indicated a dramatic increase in thyroid cancer incidence in children and adolescents. Additionally, at the time of this report, it was thought that an increase of a few percent in possible cancer mortality might occur due to radiation exposure among the 600,000 people who received more significant exposure (i.e. clean-up workers in 1986-87, evacuees, and those residing in the area closest to the accident), though this prediction was roughly estimated. This percentage increase could mean up to 4,000 additional deaths due to cancer, in addition to approximately 100,000 cancer deaths due to other causes.

At the time of writing, epidemiological studies have yet to indicate a radiation-induced increase with clear and reliable evidence, except for an increase in thyroid cancer among children and adolescents. Nevertheless, even if clear and convincing evidence has not been provided scientifically, physical health concerns caused by radiation exposure might have affected the mental health of residents in the exposed area.

2.3 Psychological distress of residents in the affected regions

Most studies of the psychosocial impact of the Chernobyl accident are systematic studies assessing psychiatric disorder and stress-related symptomatology of those who remained in and around the contaminated areas and those who emigrated to foreign countries.

Ginzburg (1991) reported the consequences of a series of studies conducted by the

International Atomic Energy Agency (IAEA). In 1989, three years after the accident, the IAEA examined the medical and psychological health of residents in contaminated areas and villagers in non-contaminated areas. The IAEA clinicians concluded that they could not identify any health disorders directly related to radiation exposure in either the contaminated or control areas. However, in both the contaminated and non-contaminated areas, they identified significant non-radiation related health disorders among the adult population, and also reported that almost half the adults in both villages were unsure if they had a radiation-related illness. These findings indicated that the residents in both the contaminated and nearby non-contaminated areas showed high levels of psychological distress related to radiation exposure, despite there being no evidence of an increase in physical health disorders directly related to radiation exposure at that time.

Havenaar, Rumyantzeva, Brink, Bout, Engeland and Koeter (1997) studied the mental health effects of the Chernobyl disaster 6 years after the accident. They compared the psychological distress of residents in the contaminated area with those in a non-contaminated area using a self-report questionnaire and psychiatric interviews. The respondents from the contaminated area showed significantly higher scores on most of the psychiatric symptom scales, namely the GHQ, and those for depression and somatization. However, a higher prevalence of DSM-III-R psychiatric disorder was shown only among women with children under 18 years of age in the contaminated area, while no differences were found among men.

Thus, the mental health effects of the Chernobyl accident have been demonstrated at a subclinical level in population studies. Long-term mental health effects have also been found. Survivors who lived in the contaminated area at the time of the accident showed higher psychological distress than control groups even 10 years (Cwikel et al., 1997), 15 years (Foster & Goldstein, 2007), and 18 years after the accident (Longanovsky et al., 2008).

2.4 Psychological development of children exposed to radiation

One of the vital concerns related to the Chernobyl accident involved the developing brains of affected children who were in *utero* at the time. Several studies were conducted to compare mental retardation or emotional problems in affected children with control groups.

The World Health Organization (WHO) designed a pilot study known as the “Brain Damage in Utero Project” and examined all children born within a year after the accident whose mothers were evacuated from within 30 km of the reactor site and children born in uncontaminated areas. The results showed more prevalence of mental retardation and an upward trend in behavioral disorders and emotional problems in the exposed children than controls. In addition, a higher incidence of borderline nervous and psychological disorders was found in parents of exposed children than controls. However, the WHO did not conclude that radiation exposure was attributed to higher rates of mental retardation and psychological disorders in exposed children, because other

factors such as parental stress and worries might have affected the results (WHO, 1995).

Kolominsky, Igumnov, and Drozdovitch (1999) compared psychological development of children at the aged 6-7 years and 10-11 years who were in utero at the time of the accident and a control group. The affected children showed higher rates of speech-language disorders, emotional disorders, and lower scores in mean IQ than the control group. Additionally, there were more cases of borderline IQ. However, a positive correlation was found between the IQ of children and parents' education. High personal anxiety in parents was associated with emotional disorders in children. The author concluded that adverse psychosocial and sociocultural factors played an important role in the higher rates of psychological impairment in exposed children.

Nyagu, Loganvsky, Loganvskaja, Respin, and Nechaev (1998) examined children who were in utero at the time of the Chernobyl accident and whose mothers were evacuated to Kiev and compared them to a control group of classmates using the Wechsler Intelligence Scale for Children (WISC), electroencephalography (EEG), and clinical methods. The results showed that acutely exposed children had lower scores in mean Verbal IQ, higher rates of disorders of psychological development, and behavioral and emotional disorders compared to the control group. Although the authors suggested a relationship between prenatal radiation exposure and brain damage, the methodology was criticized on the grounds that it lacked transparency of sampling, testing, or a statistical control of parental intelligence and education (Bromet & Havenaar, 2007).

Thus, several studies found significant differences in the incidence of mental retardation and psychological disorders and IQ scores between exposed children and controls. However, prenatal radiation exposure due to the Chernobyl accident has not been shown to directly affect the brain development of children at a young age or *in utero*. Future research is needed that incorporates parental factors such as intelligence, educational level, stress level or concerns.

2.5 Risk factors: Vulnerability

Several studies revealed vulnerability factors related to the psychological impact of the Chernobyl accident. Females and adults with children appear to be especially vulnerable (Havenaar et al., 1997; Viinamäki et al., 1995; Foster & Goldstein, 2007).

Viinamäki, Kumpusalo, Myllykangas, Salomaa, Kumpusalo, Kolmakov, Ilchenko, Zhnkowsky, and Nissinen (1995) conducted a study 7 years after the accident to compare the mental health of residents in the high-fallout area with a control area using the GHQ. The results showed that women living in the contaminated area showed higher GHQ scores than the female control group, while there were no significant differences between men. In addition, the findings indicated that a deficiency in social support was an independent risk factor for mental well-being, especially for women in the contaminated area.

Other studies demonstrated that having children was also a risk factor. These studies

indicated that mothers with children under 18 years of age had higher risks of psychiatric disorders (Havenaar et al., 1997), and having children was associated with greater current symptomatology in both men and women (Foster & Goldstein, 2007). As described above, a dramatic increase in thyroid cancer in children and young adults occurred. The relationship between radiation exposure from the accident and the developing brains of children and babies *in utero* has not been consistently established, but it is a substantial concern for Chernobyl survivors. These concerns for effects on physical health and brain development caused by radiation exposure might have affected parents' mental health.

Other vulnerability factors related to psychological distress were as follows: Age (Foster & Goldstein, 2007); not having a partner, being in a poor financial situation, and having a subjectively poor perception of one's health status (Viinamäki et al., 1995).

2.6 Risk factors: Disaster-related emigration to other regions or countries

Even if inhabitants of the contaminated area prevented themselves from being exposed to more radiation by resettling to other regions or countries, their psychological distress has been shown to last for a long period. Several studies demonstrated the experience of the Chernobyl disaster impacted both the mental and physical health of the Chernobyl survivors, even after emigration (Cwikel, Abdelgani, Goldsmith, Quastel and Yvelson, 1997; Foster & Goldstein, 2007; Remennick, 2002).

Cwikel, Abodelgani, Goldsmith, Quastel, and Yvelson (1997) conducted a two-year follow-up study of immigrants to Israel from exposed areas. In the first wave that occurred 8 years after the accident, psychological symptoms, including PTSD, depression, anxiety, and somatization, were significantly higher in those from exposed areas than control areas. In the second wave of migrants 10 years after the accident, all the psychological symptoms decreased over time except for somatization, which remained at the same level. The result also showed a direct correlation between the number of chronic conditions and psychological symptoms.

In addition, immigrants from the exposed region might face other difficulties along with resettlement, such as socio-economic problems, a decline in standard of living, acculturation, accommodation, or social stigma.

Foster and Goldstein (2007) detected a correlation between difficulty in achieving American acculturation and current depression and anxiety. Remennick (2002) reported that victims of Chernobyl showed higher levels of depression, sense of stigma, and cancer-related anxiety compared to other Russian immigrants. In addition, they tended to use more health services but with less satisfaction. These findings indicated accommodation and achievement were more difficult for Chernobyl survivors than other immigrants when confronted with relocation and considerable changes in living conditions (Remennick, 2002).

2.7 Risk factors: Level of exposure

One of the most important risk factors affecting the mental health of Chernobyl survivors is radiation exposure level. As described above, two studies focusing on immigrants from exposed regions were conducted that classified them in terms of the geographical proximity to the epicenter of the Chernobyl nuclear power plant and compared their physical and mental health.

Foster and Goldstein (2007) found that geographical proximity to the epicenter was associated with all mental health outcomes, to include depression, anxiety, and PTSD symptoms. Cwikel et al. (1997) reported three or four chronic conditions in 57% of the liquidators (clean-up workers) in 47% of survivors in the most exposed area, and in 49% of survivors in less exposed areas, whereas only 30% of those in the comparison group reported such high levels of morbidity.

Notably, liquidators were the most seriously impacted group in terms of physical and mental health. Koscheyev, Martens, Kosenkov, Lartzev, and Leon (1993) conducted a study using the Minnesota Multiphasic Personality Inventory (MMPI) to assess the psychological status and psychological reactions in chief operators working at the Chernobyl power plant at four time points: 3 months, 5-6 months, 1 year, and 1 year and 7-8 months after the accident. The MMPI scores on health concerns, depression, and other psychological distress significantly increased over time in the Chernobyl group. Additionally, the percentage of those workers with one or more elevated clinical scale scores increased over time for the Chernobyl group. A significant increase occurred over time in the proportion of workers with at least one clinical scale score in the abnormal range. For those workers remaining at the power plant, the uncertainty surrounding whether it was safe to be there might have increased stress levels. Also, utilizing volunteers at later times after the accident who were generally less well-adjusted may have affected stress levels. Nevertheless, it was determined that higher levels of stress and somatic concerns occurred over time.

Loganovsky, Havenaar, Tintle, Guey, Kotov, and Bromet (2008) conducted a study 18 years after the accident to assess the long-term psychological effects of Chernobyl in a sample of clean-up workers and a control group of people who were living in the same regions but had never been recruited as clean-up workers. The results showed that clean-up workers experienced a higher rate of depression and suicidal ideation after the Chernobyl disaster compared to the control group. In the year before interviews were taken, rates of depression, PTSD, and headaches were reported to have elevated. Clean-up workers who experienced disorders within the past 12 months had significantly more work absences than affected controls. The level of radiation exposure affected the severity of somatic and PTSD symptoms at the time of the study. Significantly more impairment occurred in the most highly exposed workers, especially in PTSD symptoms, compared to two less exposed groups.

These results seem to suggest that workers have a greater susceptibility to psychiatric

disorders and the most exposed workers appear to harbor greater anxiety concerning health issues.

2.8 Cognitive beliefs about being exposed to radiation

Two studies indicated that cognitive beliefs about radiation exposure are a key factor associated with mental health. Havenaar, Wilde, Bout, Drottz-Sjöberg and Van Den Brink (2003) analyzed cognitive factors using the data from a study they previously reported in 1997. The result showed that people in a contaminated area had more concerns about the Chernobyl accident for almost all cognitive variables, *risk perception*, *credibility of information*, and *sense of control*, compared to those who lived in non-contaminated areas. As a result of multivariate linear models, the findings indicated that cognitive variables such as *risk perception* and *sense of control* were important mediating factors in explaining the mental health differences between the exposed and non-exposed regions. Foster and Goldstein (2007) investigated the mental health impact on immigrants who emigrated from Chernobyl to the United States. The findings indicated that one of the cognitive variables, *belief in exposure to radiation*, had a significant effect on all psychiatric symptoms. Respondents who had a belief that they were exposed to radiation showed higher levels of depression, anxiety symptoms, and post-traumatic sequelae than those without such a belief.

As noted earlier, it is difficult at the current time to accurately verify all the impaired physical health issues attributed to radiation exposure with clear and reliable evidence. However, the belief and uncertainty of being exposed to radiation appears to be a factor in psychological distress in victims of Chernobyl, regardless of whether or not they were actually exposed to a radiation level which could have adversely affected their physical health. This belief could have affected victims of Chernobyl for a prolonged period, and may be continuing to affect their mental well-being.

In sum, the long-term psychological effects of the Chernobyl accident and risk factors of psychiatric disorders have been established by many systematic, well-designed, cross-sectional, and population-level studies. However, while international efforts and organizations have worked to formally quantify some aspects of the mental health effects of the Chernobyl disaster, most have been either resigned to studies of risk or more focused on environmental issues, acute psychiatric sequelae, and physical health epidemiology, thus more longitudinal research is needed to understand the long-term psychological consequences from an empirical viewpoint.

General Summary

This review covered the available literature on the long-term mental health consequences reported by survivors and their families as witnesses and victims of the atomic bombings of Hiroshima and Nagasaki and the nuclear disaster at Chernobyl. Poor subjective health outcomes have been reported by atomic bomb survivors in their later years, and it is possible that this could

be attributed to anxiety caused by radiation exposure. The fear and actual experience of prejudice and discrimination in society were also associated with mental health outcomes, and the plausible influences of the phenomenon of silence – a seldom researched aspect of the *hibakusha* experience – remains an important subject that deserves attention. Studies about how survivors have passed their experience on to subsequent generations have been insufficient, and future research should elucidate the details of intergenerational transmission of trauma, if they exist, through an organized approach. In addition, it was found that some descendants of atomic bomb survivors appear to have been positively affected by their associated survivor’s way of life (Sawada, 2011). Well-designed studies of such positive impacts through topics such as resilience or the framework of post-traumatic growth, as well as more refined research on the negative impacts of the experience of disasters related to radiation exposure would prove to be a boon to the current understanding of this domain.

Many of the studies about the Chernobyl accident were systematically and elegantly designed studies performed by international coalitions. Many indicators of the long-term psychological effects of the Chernobyl accident have been established through their efforts. Additionally, women and adults with children were found to be particularly vulnerable risk subgroups. Emigration, exposure level, and cognitive beliefs about radiation exposure were also detected as disaster-related risk factors for mental health issues from Chernobyl.

Taken together, the consequences of the atomic bomb experience in Hiroshima and Nagasaki and the disaster at Chernobyl show some commonalities regarding the pervasive uncertainty onset by actual and perceived radiation exposure. Survivors and victims of both groups demonstrated that the uncertainty and cognitive beliefs about being exposed were associated with psychological distress. Specifically, Havenaar et al. (1997) asserted that the significant long-term impact of Chernobyl on psychological well-being and health-related quality of life was due to a form of illness behavior and chronic stress. Their paper described a process in which victims who were aware that they experienced radiation exposure expected some sort of bodily change from it, and that chronic expectation of a negative result led them to appraise ostensibly ordinary physical sensations as symptoms of disease, thereby causing many victims to perceive their current health as subpar and their future health as bleak (Havenaar et al., 1997; Jourdain, 2009). Kim et al. (2011) also observed that aspects of “persistent distress” in the atomic bomb survivors of Nagasaki stemmed from a lack of knowledge regarding radiation effects and a fear of learning about their potential risk. In this way, the presence of a cognitive belief in radiation exposure and its inherent uncertainty seems to be one of the most important risk factors in explaining how and why those who experienced radiation exposure have suffered for a prolonged period. This finding from review also supports the observations made by Vyner (1988) in his work, *Invisible Trauma: The Psychosocial Effects of Invisible Environmental Contaminants*, who outlined up to twelve types of uncertainty faced by those affected by toxic exposures, including but not limited to: the dose received, the

significance of that dose, its latency, etiology, diagnosis, prognosis, and treatment, how to cope adaptively, and who is responsible for financing the health costs of their exposure. Through these factors, the anxiety caused by the belief in radiation exposure might be characterized by an uncertainty about its safety and a risk appraisal about its effects on physical health.

Risk perception emerged as an important mediating factor in the psychological outcomes of Chernobyl. Due to decades of work on risk, media, and stigma by Slovic (2013), the psychology of the acute phase of toxic incidents is understood to undergo a mechanism known the “social amplification of risk”, but as the present review suggests, the chronic stages remain less clear. Similar to the case of information suppression in the atomic bomb aftermath, important details from the early years after the Chernobyl incident are shrouded in secrecy due to deliberate efforts by the former Soviet state (Shlyakhter & Wilson, 1992). Recently, there have been efforts to better understand the Chernobyl experience since the fall of the Soviet Union in deep ethnographic work such as *Life Exposed: Biological Citizens After Chernobyl* (Petryna, 2013). However, a more fine-grained understanding of the details of the Chernobyl experience, namely the precise mechanisms of the victims’ anxiety and the essence of their traumatic experiences, requires more extensive research from the perspective of psychology. For instance, it is still not understood to what extent Chernobyl victims expected that radiation might affect their future physical health (i.e., the aftereffects of radiation), how parents’ anxiety from the disaster has affected the mental health of their children, and how victims characterize and communicate their experience to their families and the people around them (e.g., the possible effects of stigma or self-stigma). Thus, research based on the narratives of victims is needed to gain better insight into the reality of their plight, distill the essence of their traumatic experiences, and make sense of the important key factors related to their psychological distress.

Sense of control was another critical mediating factor in explaining the mental health differences between people from the exposed and non-exposed regions affected by Chernobyl. Indeed, Reich and Goto (2015) aptly pointed out that a profound loss of autonomy is associated with exposure events, stating that the “apocalyptic disruptions” of the people affected by nuclear disasters are not amenable to any choices to which they could exert any meaningful control, but are in fact the consequences of social and political decisions made by outside entities. A comprehensive review of emergency radiation disaster management systems by Dainiak et al. (2011) appealed to the study of sense of control in their proposal that psychological support for nuclear disasters should serve to manage distress, lessen stress and anxiety, and minimize uncertainty by focusing on “calming, connecting, and promoting self-efficacy.” The necessity of augmenting sense of control through various mechanisms such as self-efficacy in response radiation disasters has been suggested but remains an open research question for future studies.

Long-term psychological impacts of radiation exposure were identified in both historical

cases discussed in this review. Excess radiation exposure is fundamentally tied to a longer-term of human development as many of the feared dose-related aftereffects to somatic cells are understood to potentially occur in middle age, when individuals are particularly susceptible to cancer. While there is no evidence of germline mutations from the atomic bomb exposure that would cause harmful effects to the physical health of future generations, psychological elements of the exposure experience have been shown to last throughout the lives of those affected, and the possibility that mental health issues might affect later generations has been raised. A few studies incorporating the descendants of atomic-bomb survivors in Hiroshima and Nagasaki indicated that successive generations generally did not have health anxiety concerning radiation exposure, but this anxiety could emerge or become exacerbated if they hear news about nuclear power plants. In studies about the Chernobyl accident, findings indicated that high personal anxiety in parents was associated with high rates of emotional disorders in children. This could also mean that parental psychological distress associated with radiation exposure could be affecting successive generations in some way. Future research is needed to better understand the psychological impact of the experience of radiation exposure on descendants.

Limitations and Future Directions

It should be noted that this review was limited to the cases of Hiroshima, Nagasaki, and Chernobyl, and did not encompass psychological phenomena across the entire history of radiation-related incidents or nuclear exposure events, nor did it speculate about possibly emerging long-term psychological issues in the context of the ongoing recovery from the Fukushima nuclear disaster. Further research and reviews of these issues should consider the literature on events such as the 1987 orphan source incident which led to a public health crisis of radioactive contamination in Goiania, Brazil, the experiences of atomic veterans from various Western nations who were exposed to radiation during atmospheric nuclear tests (Jourdain, 2009), and the current epidemiological research being conducted by the Fukushima Health Management Survey (Maeda et al., 2014; Reich & Goto, 2015). The RERF and other institutions related to radiation disaster management in Japan and abroad have planned studies on the long-term mental health of people affected by these events, but such projects have only just begun. It is nonetheless encouraging that the psychology of radiation disaster – and particularly the field of radiation disaster recovery – is a burgeoning area of research that will hopefully address or expound upon some of the phenomena discussed in this review.

References

- Bar-On, D. (1995). Fear and hope: Life-stories of five Israeli families of Holocaust survivors, three generations in a family. *Cambridge, MA: Harvard University Press, 434, 351-365.*
- Ben-Ezra, M., Palgi, Y., Soffer, Y., & Shrira, A. (2012). Mental health consequences of the 2011

- Fukushima nuclear disaster: are the grandchildren of people living in Hiroshima and Nagasaki during the drop of the atomic bomb more vulnerable?. *World psychiatry*, 11(2), 133-133.
- Bromet, E. J., & Havenaar, J. M. (2007). Psychological and perceived health effects of the Chernobyl disaster: a 20-year review. *Health physics*, 93(5), 516-521.
- The Chernobyl Forum. (2006). Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. (<https://www.iaea.org/sites/default/files/chernobyl.pdf>)
- Cwikel, J., Abdelgani, A., Goldsmith, J. R., Quastel, M., & Yvelson, I. I. (1997). Two-year follow up study of stress-related disorders among immigrants to Israel from the Chernobyl area. *Environmental Health Perspectives*, 105(Suppl 6), 1545.
- Dainiak, N., Gent, R. N., Carr, Z., Schneider, R., Bader, J., Buglova, E., ... & Hauer-Jensen, M. (2011). Literature review and global consensus on management of acute radiation syndrome affecting nonhematopoietic organ systems. *Disaster medicine and public health preparedness*, 5(3), 183-201.
- Danieli, Y. (1998). *International handbook of multigenerational legacies of trauma*. Springer Science & Business Media.
- Foster, R. P., & Goldstein, M. F. (2007). Chernobyl disaster sequelae in recent immigrants to the United States from the former Soviet Union (FSU). *Journal of Immigrant and Minority Health*, 9(2), 115-124.
- Grant, E. J., Furukawa, K., Sakata, R., Sugiyama, H., Sadakane, A., Takahashi, I., .. & Ozasa, K. (2015). Risk of death among children of atomic bomb survivors after 62 years of follow-up: a cohort study. *The Lancet Oncology*, 16(13), 1316-1323.
- Ginzburg, H.M. (1993). The psychological consequences of the Chernobyl Accident-Findings from the International Atomic Energy Agency Study. *Public Health Reports*, 108(2); 184-192.
- Havenaar, J. M., Rummyantzeva, G. M., van den Brink, W., Poelijoe, N. W., Van den Bout, J., van Engeland, H., & Koeter, M. W. (1997). Long-term mental health effects of the Chernobyl disaster: an epidemiologic survey in two former Soviet regions. *American Journal of Psychiatry*, 154(11), 1605-1607.
- Havenaar, J. M., De Wilde, E. J., Van Den Bout, J., Drottz-Sjöberg, B. M., & Van Den Brink, W. (2003). Perception of risk and subjective health among victims of the Chernobyl disaster. *Social science & medicine*, 56(3), 569-572.
- Honda, S., Shibata, Y., Mine, M., Imamura, Y., Tagawa, M., Nakane, Y., & Tomonaga, M. (2002). Mental health conditions among atomic bomb survivors in Nagasaki. *Psychiatry and clinical neurosciences*, 56(5), 575-583.
- Hiroshima City Health and Welfare Bureau (2010). Survey report on the awareness of health status

- in people who experienced the atomic bomb. *Genbaku taikenshatō kenkō ishiki chōsa hōkokusho*. (In Japanese) (<http://www.city.hiroshima.lg.jp/www/contents/1271828954409/index.html>)
- Japanese Ministry of Health, Labor and Welfare (2001). Research on the evaluation of health effects related to PTSD. (<http://www.mhlw.go.jp/houdou/0108/h0813-1.html#san3>) (In Japanese).
- Jourdain, R.L. (2009). "Psychological fallout": the effects of nuclear radiation exposure. Doctoral thesis of Massey University, New Zealand.
- Kim, Y., Tsutsumi, A., Izutsu, T., Kawamura, N., Miyazaki, T., & Kikkawa, T. (2011). Persistent distress after psychological exposure to the Nagasaki atomic bomb explosion. *The British Journal of Psychiatry*, 199(5), 411-416.
- Konuma, M., Furutani, M., & Kuvo, S. (1953). Diencephalic syndrome as a delayed A-bomb effect. *Japan Med J*, 1547, 4853-4860 (in Japanese)
- Kolominsky, Y., Igumnov, S., & Drozdovitch, V. (1999). The psychological development of children from Belarus exposed in the prenatal period to radiation from the Chernobyl atomic power plant. *Journal of Child Psychology and Psychiatry*, 40(2), 299-305.
- Koscheyev, V. S., Martens, V. K., Kosenkov, A. A., Lartzev, M. A., & Leon, G. R. (1993). Psychological status of Chernobyl nuclear power plant operators after the nuclear disaster. *Journal of Traumatic Stress*, 6(4), 561-568.
- Kubo, Y. (1951) A Study of A-bomb sufferers' behavior in Hiroshima: a socio-psychological research on A-bomb and A-energy. *Japanese Journal of Psychology*, 22(2), 103-110. (In Japanese)
- Lifton, R. J. (1967). *Death in life: Survivors of Hiroshima*. New York: Basic Books.
- Loganovsky, K., Havenaar, J. M., Tintle, N. L., Guey, L. T., Kotov, R., & Bromet, E. J. (2008). The mental health of clean-up workers 18 years after the Chernobyl accident. *Psychological medicine*, 38(04), 481-488.
- Maeda, M., & Oe, M. (2014). Disaster behavioral health: psychological effects of the Fukushima nuclear power plant accident. In *Radiation disaster medicine* (pp. 79-88). Springer International Publishing.
- Miller, R., & Blot, W. (1972). Small head size after in-utero exposure to atomic radiation. *The Lancet*, 300(7781), 784-787.
- National Research Council. (2006). *Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2* (Vol. 7). National Academies Press.
- Nishikawa, T., & Tsuiki, S. (1961). Psychiatric examination of those injured in the atomic bomb blast. *Nagasaki Igakkai zasshi= Nagasaki medical journal*, 36, 717.
- Nyagu, I.N., Loganovsky, K.N., & Loganovskaja, T. K. (1998). Psychophysiologic aftereffects of prenatal irradiation. *International journal of psychophysiology*, 30, 303-311.

- Ohta, Y., Mine, M., Wakasugi, M., Yoshimine, E., Himuro, Y., Yoneda, M., ... & Morikawa, T. (2000). Psychological effect of the Nagasaki atomic bombing on survivors after half a century. *Psychiatry and clinical neurosciences*, 54(1), 97-103.
- Okumura, N., & Hikita, H. (1949). Results of psycho-neurological study on atomic bomb survivors. *Kyushu Neuropsychiatry*, 1, 50-52.
- Radiation Effects Research Foundation. Radiation Health Effects, Late effects on survivors, Psychological effects. (http://www.rerf.jp/radefx/late_e/psycholo.html)
- Petryna, A. (2013). *Life exposed: biological citizens after Chernobyl*. Princeton University Press.
- Preston, D. L., Kusumi, S., Tomonaga, M., Izumi, S., Ron, E., Kuramoto, A., Kamada, N., Dohy, H., Matsui, T., Nonaka, H., Thompson, D. E., Soda, M. & Thompson, D. E. (1994). Cancer incidence in atomic bomb survivors. Part III: Leukemia, lymphoma and multiple myeloma, 1950-1987. *Radiation research*, 137(2s), S68-S97.
- Reich, M.R. & Goto A. (2015). Towards long-term responses in Fukushima. *The Lancet*, 386 (9992): 498-500.
- Remennick, L. I. (2002). Immigrants from Chernobyl-affected areas in Israel: the link between health and social adjustment. *Social Science & Medicine*, 54(2), 309-317.
- Sawada, A., Chaitin, J., & Bar-On, D. (2004). Surviving Hiroshima and Nagasaki—experiences and psychosocial meanings. *Psychiatry: Interpersonal and biological processes*, 67(1), 43-60.
- Sawada, A. (2011). Issues of A-Bomb Survivors and their Effects on Second and Third Generations through a Narrative Research on Three Generations of A-Bombing, *Studies in philosophical anthropology*, 123-147. (In Japanese)
- Shimizu, Y., Kato, H., & Schull, W. J. (1990). Studies of the mortality of A-bomb survivors: 9. Mortality, 1950-1985: part 2. Cancer mortality based on the recently revised doses (DS86). *Radiation research*, 121(2), 120-141.
- Shlyakhter, A., & Wilson, R. (1992). Chernobyl: the inevitable results of secrecy. *Public Understanding of Science*, 1(3), 251-259.
- Slovic, P., Flynn, J., & Kunreuther, H. (2013). *Risk, media and stigma: Understanding public challenges to modern science and technology*. Routledge.
- Stein, J. L. (2015). Examining Post-Traumatic Stress Disorder and the Plight of Vietnam Veterans. *Iowa Historical Review*, 5(1), 7-22.
- Tatara, M. (1998). The second generation of Hibakusha, atomic bomb survivors. In *International handbook of multigenerational legacies of trauma* (pp. 141-146). Springer U.S.
- Tomoike, T. (2007). About the Consciousness of the 2-3rd Hibakushas' Health : The Present Condition of the Self-consciousness Especially in the Relation with Heredity Caused by Atomic Bomb(Social Welfare) *Nagasaki International University Review*, 7, 197-204. (In

Japanese)

- Viinamäki, H., Kumpusalo, E., Myllykangas, M., Salomaa, S., Kumpusalo, L., Kolmakov, S., ... & Nissinen, A. (1995). The Chernobyl accident and mental wellbeing—a population study. *Acta Psychiatrica Scandinavica*, *91*(6), 396-401.
- Vyner, H. M. (1988). The psychological dimensions of health care for patients exposed to radiation and the other invisible environmental contaminants. *Social Science & Medicine*, *27*(10), 1097-1103.
- World Health Organization. (1996). *Health consequences of the Chernobyl accident. Results from the IPHECA pilot projects and related national programmes. Summary report from WHO 1995* (No. NRPA--1996: 3). World Health Organization.
- Yevelson, I. I., Abdelgani, A., Cwikel, J., & Yevelson, I. S. (1997). Bridging the gap in mental health approaches between east and west: the psychosocial consequences of radiation exposure. *Environmental health perspectives*, *105*(Suppl 6), 1551.