

Low Dose/Dose Rate Radiation Exposure and Human Mental Health

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The literature review on human epidemiological studies suggests that low dose ionizing radiation (LDIR) (≤ 100 mSv) or low dose rate ionizing radiation (LDRIR) (< 6 mSv/H) exposure may affect mental health depending on age, sex, races and radiation components, sources including nuclear war, fallout from nuclear weapon test, nuclear power plant accidents, space radiation, high background radiation, genetics, lifestyle, other environmental exposures, sociodemographics, diagnostic accuracy. A study conducted on the coastal Kerala population which is known to be receiving fifteen times the normal permissible dose of radiation has shown Down's syndrome and related abnormalities [1]. However, this finding was not supported by Koya, *et al.* [2] who indicated that the prevailing high-level natural radiation (> 1 mSv/year) in the study area did not appear to increase the risk of either mental retardation or cleft lip/palate among offspring of parents staying in the area. Prenatally exposed survivors (exposed in the 8th through the 25th week) of the atomic bombings of Hiroshima and Nagasaki had abnormal neuronal migration, small head size as well as mental retardation and seizure [3-6]. These survivors had an increased frequency of severe mental retardation (SMR), a diminution in intelligence quotient (IQ) score and in school performance and an increase in the occurrence of seizures. Otake and Schull [7] pointed out that the period of susceptibility to mental retardation coincided with that for proliferation and migration of neuronal elements from near the cerebral ventricles to the cortex. Mental retardation could be the result of interference with this process, and the exposures at 8 - 15 wk to 0.01 - 0.02 Gy (1 - 2 rad) doubled the frequency of severe mental retardation. This estimate was based on small numbers of mentally retarded atomic-bomb survivors. The threshold for those exposed 8 through 15 weeks after fertilization appears to be in the 100 to 200 mGy fetal-dose range in this vulnerable gestational period [8]. The increased prevalence of Down's syndrome cases in West Berlin [9,10] and in Republic of Belarus [11] has also been reported to be causally related to a short period of exposure to ionizing radiation as a result of the Chernobyl reactor accident. Elevated mental disorders [12], neural tube defects, conjoined twins and teratomas, microcephaly and microphthalmia [13] were also reported in prenatally irradiated children after Chernobyl disaster. Based on computerised EEG, a clinical neuropsychiatric examination, and IQ tests, Loganovskaja and Loganovsky [14] hypothesized that the cerebral basis of mental disorders in the prenatally irradiated children was the malfunction of the left hemisphere limbic-reticular structures, particularly in those exposed at the most critical period of cerebrogenesis (16 - 25 weeks of gestation). There were dose-related cognitive and neurophysiological abnormalities in prenatally exposed children following exposure to fetal doses > 20 mSv and thyroid doses in utero > 300 mSv in the 8th and later weeks of gestation, as well as fetal doses > 10 mSv and thyroid doses in utero > 200 mSv at 16 - 25 weeks of gestation [15]. The left hemisphere was more vulnerable to prenatal irradiation than the right [16]. Heiervang, *et al.* [17,18] assessed individuals exposed to radiation prenatally using a broad neuropsychological test battery, and observed that neuropsychological performance was significantly weaker in the adolescents exposed prenatally compared to the controls on measures of verbal working memory, verbal memory, and executive functioning when controlling for possible confounders. It supports the hypothesis that the Chernobyl accident has a specific effect on the neuropsychological functioning of those exposed prenatally to low-dose ionizing radiation in utero during the most sensitive gestational period. So far, the cognitive and academic outcomes of infants exposed to low dose radiation are still in debate. In a cohort study of adult Swedish population who received low dose radiotherapy for cutaneous haemangioma before age 18 months, Hall, *et al.* [19] reported that low doses of ionizing radiation to

the brain in infancy influenced cognitive abilities in adulthood. After exclude confounding factors, they suggested that embryo and infant brain was sensitive to low dose radiation exposure, and radiation exposure at these stages may affect their life time learning and memory. With increased abusive use of X-ray computed tomography (CT scan) for medical diagnosis and radiotherapy, the hospital stockpile of nuclear waste is increased tremendously and is now the largest man-made source of radiation exposure to the general population, which contributes about 14% of the total annual exposure worldwide from all sources. Increased construction of nuclear power plants worldwide and subsequently potential nuclear accidents, occupational radiation exposure, frequent-flyer risks, manned space exploration and possible radiological terrorism have made low dose ionizing radiation or low dose rate ionizing radiation research much more imperative and urgent nowadays than ever before.

Human population group	Radiation source	Dose exposed	Endpoint biomarkers	Endpoint biomarker changes and types of cells monitored	References
Inhabitants in coastal Kerala, Indian	Background (thorium-containing monazite minerals)	15 - 30 mGy/year (Control: 1 mGy/year)	Genetic anomaly and mental health	Increased genetic anomalies and high prevalence of Down's syndrome and other forms of mental retardation, especially born to mothers aged 30-39- year-old.	[1]
Survivors of prenatal exposure to A-bomb attack	A-bomb	Prenatal (8-15wks of gestational age) exposure doses from 10 to 20mGy	Mental retardation	The frequency of severe mental retardation was doubled	[7]
Survivors of prenatal exposure to Chernobyl fall-out in Germany	Chernobyl fall-out	Not clear	Trisomy 21 (Down's syndrome)	Higher prevalence of Down's syndrome	[9]
Survivors of prenatal exposure to Chernobyl fall-out in Ukraine	Chernobyl fall-out	A whole fetus: 7 ± 2 mSv, Thyroid: 100-1200 mSv	Psychophysiological effect	Elevated mental disorders	[12]
All infants born in Rivne between 2000 and 2006, 250 km west of the Chernobyl atomic power plants	Chernobyl fall-out	No data	Malformations of brain development	The higher rate of neural tube defects, microcephaly and microphthalmia	[13]
Prenatally irradiated children born from 26 April 1986 to 26 February 1987 by pregnant women evacuated from the 30-km exclusion zone of the Chernobyl NPP	Chernobyl fall-out	19.3 ± 12.1 mSv	Neuropsychiatric development	A significant increase of mental and behavioural disorders	[14-16]
Adolescents exposed prenatally to radiation from Chernobyl	Chernobyl fall-out	No data	Cognitive outcomes	A significantly weaker on measures of verbal working memory, verbal memory, and executive functioning	[17,18]
Swedish population irradiated before age 18 months, psychological test done in adult	Mainly X-rays and γ-rays	52mGy (average)	Cognitive outcomes	Low radiation dose adversely affects intellectual development	[19]

Table 1: Chronic low dose/dose rate radiation exposure on mental health.

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