Exposure to low-dose radiation in occupational settings and ischemic heart disease: a systematic review and meta-analysis

Supplementary material

Search Strategy

Limits: 1990-2022; English; search done on October 20, 2022

PubMed:

((((ionizing[Text Word] OR ((low [Text Word] OR moderate*[Text Word]) AND (dose[Text Word] OR dosage[Text Word]))) AND radiation[Text Word])) OR (Alpha particles[Text Word] OR beta particles[Text Word] OR gamma rays[Text Word] OR gamma radiation[Text Word] OR x-rays[Text Word] OR radon[Text Word])) AND ((occupation*[Text Word] OR employ*[Text Word] OR job[Text Word] OR vocation*[Text Word])) AND (myocardial infarction[Text Word] OR angina[Text Word] OR ((heart[Text Word] OR aortic[Text Word] OR aorta[Text Word] OR cardiac[Text Word] OR cardiomyopath*[Text Word] OR myocardial[Text Word] OR coronary[Text Word]) AND (disease*[Text Word] OR aneurysm[Text Word] OR occlusion[Text Word] OR stenosis[Text Word] OR thrombosis[Text Word] OR vasospasm[Text Word])) OR (cardiovascular disease[Text Word] OR CVD[Text Word] OR (ischemic [Text Word]) OR (stroke [Text Word])))

Scopus:

TITLE-ABS-KEY ("myocardial infarction" OR angina OR ((heart OR aortic OR aorta OR cardiac OR cardiomyopath* OR myocardial OR coronary OR cardiovascular OR cvd OR ischemic OR stroke) AND (disease* OR aneurysm OR occlusion OR stenosis OR thrombosis OR vasospasm))) AND TITLE-ABS-KEY (occupation*) OR TITLE-ABS-KEY (employ*) OR

TITLE-ABS-KEY (job*) OR TITLE-ABS-KEY (vocation*) AND TITLE-ABS-KEY (((ionizing OR ionising OR ((low OR moderate) AND (dose OR dosage))) AND radiation) OR "Alpha particles" OR "beta particles" OR "gamma rays" OR "gamma radiation" OR x-rays OR radon)

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TS= (("myocardial infarction" OR angina OR ((heart OR aortic OR aorta OR cardiac OR cardiomyopath* OR myocardial OR coronary OR cardiovascular disease OR CVD OR ischemic OR stroke) AND (disease* OR aneurysm OR occlusion OR stenosis OR thrombosis OR vasospasm))) AND ((occupation*) OR (employ*) OR (job*) OR (vocation*)) AND (((ionizing OR ((low OR moderate) AND (dose OR dosage))) AND radiation) OR "Alpha particles" OR "beta particles" OR "gamma rays" OR "gamma radiation" OR x-rays OR “radon”))

Table S1. Characteristics of included studies

Study ID	Study design	Population	Country	Time period of exposure	Follow-up	Size of cohort	Exposure(s) type and organ	Mean (range) exposure dose (Sv/Gy)	Measures of association	Outcome(s)
Anderson 2021 (36)	Cohort	Uranium enrichment workers	US	1948 - 2003	To 2011	23,731	Internal dose to the lung (mGy); External dose to the lung (mGy)	0.044 (0 to 0.592)	RR, ERR/mGy	IHD, cerebrovascular disease (mortality)
Atkinson 2004 (46)	Cohort	Atomic Energy Authority workers	UK	1946 - 1995	To 1997	51,367	External whole body dose (including neutrons and tritium where relevant) (mSv)	0.01888 (<0.01 to >0.2)	SMR, RR	IHD (mortality)
Azizova 2015 (34)	Cohort	Mayak nuclear	Russia	1948-1982	To 2008	22,377	External whole body gamma dose and external dose to the liver from alpha radiation (Gy)	0.51 (0 to >4.5) 0.43 (<0.1 to >3.0)	RR	IHD (incidence)
Azizova 2018 (31)	Cohort	Mayak nuclear workers	Russia	1948-1982	To 2008 (Mayak)	22,374 (Mayak)	External whole body gamma dose (Sv), internal alpha dose to the liver from plutonium (Gy)	0.52 (0 to 84)	RR, ERR/Sv, ERR/Gy	Circulatory disease, IHD, cerebrovascular disease (mortality)
Azizova 2022 (30)	Cohort	Mayak nuclear	Russia	1948-1982	To 2018	22,377	External dose (Gy) to the liver, internal dose to the liver from alpha radiation (Gy) and internal alpha dose from internal exposure to plutonium	0.43 (<0.1 to >3.0)	RR, EER/Gy	Circulatory disease, including IHD and cerebrovascular disease mortality
Boice 2022a (37)	Cohort	Los Alamos laboratory (nuclear weapons)	US	1943-1980	To 2017	26,328	External and internal whole body dose and specific dose or 14 organs including heart.	0.0135 (0 to 0.897) (Heart)	SMR, ERR/Gy, HR	All heart disease, IHD, cerebrovascular disease (mortality)
Boice 2022b (38)	Cohort	Medical radiation workers	US	1965-1994	To 2016	109,019	External dose from x- and gamma radiation (mGy); whole body and organ-specific for lung, red bone marrow, and heart	0.0146 (0 to 1.27) (Heart)	SMR, EER/100mGy by radiation dose to heart	All heart disease, ischemic heart disease, rheumatic heart disease, cerebrovascular disease (mortality)
Boice 2022c (39)	Cohort	Nuclear power plant workers	US	1957-1984	To 2011	135,193	External dose from gamma radiation (mGy); whole body and organ-specific for lung, esophagus, colon, brain, bone marrow, and heart.	0.0439 (0 to 1.1) (Heart)	SMR, EER/100mGy by radiation dose to heart	All heart disease, ischemic heart disease, cerebrovascular disease (mortality)
Bouet 2018 (16)	Cohort	Uranium millers	France	1968-2013	To 2013	1,291	No dosimetry reported.		SMR	IHD, cerebrovascular disease (mortality)

Study ID	Study design	Population	Country	Time period of exposure	Follow-up	Size of cohort	Exposure(s) type and organ	Mean (range) exposure dose (Sv/Gy)	Measures of association	Outcome(s)
Cha 2020 (20)	Cohort	Medical diagnostics	South Korea	2007 - 2016	To 2016	11,500	Internal dose to the heart (mGy)	0.0062 (0.000 0 to 0.0729)	RR, ERR/100 mGy	Circulatory disease (all), circulatory disease (except cerebrovascular and others), hypertension, IHD, cerebrovascular disease, others (incidence)
Doody 2000 (42)	Cohort	Radiological technologists (nuns)	US	1926 – unclear	To 1995	1,103	No dosimetry reported.		SMR	Circulatory disease (all), IHD, cerebrovascular disease (mortality)
Gillies 2017 (6)	Cohort	Nuclear workers (INWORKS)	France, UK, US	As early as 1944, as late as 2005	To 2004, 2001, 2005, respectiv ely	308,297	External whole body dose (mSv)	0.0252 (0 to 1.932)	ERR/Sv	Circulatory disease, IHD, cerebrovascular disease (mortality)
Golden 2022 (40)	Cohort	Uranium processing (Mallinckrodt)	US	1942 – 1966	To 2012	2,514	External and internal dose for uranium and radium (mGy) for lung, brain, heart, kidney, colon, red bone marrow and lymph nodes	0.0475 (0 to 0.738) (Heart)	SMR, HR, ERR and HR at 100 mGy	All heart disease, cerebrovascular disease, IHD (mortality)
Kreuzer 2013 (47)	Cohort	Wismut uranium miners & millers	Germany	1946 – 1989	To 2008	58,982	External whole body dose from gamma radiation (mSv)	0.0407 (0 to 0.909)	RR, ERR/Sv	All cardiovascular disease, IHD, AMI, cerebrovascular diseases (mortality)
Kreuzer 2015 (43)	Cohort	Wismut uranium millers	Germany	1946 – 1990	To 2008	4,054	External dose (Sv), long-lived radionuclides, Radon (WLM)	0.0407 (0 to 0.909)	SMR, ERR/100WL M, ERR/Sv, ERR/ 100kBqh/m3	All cardiovascular disease, IHD, cerebrovascular disease (mortality)
Lane 2010 (44)	Cohort	Eldorado Uranium workers	Canada	1932-1980	To 1999	17,660	External gamma dose and Radon Decay Products (WLM)	0.0522 males, 0.0344 females.	SMR, SIR, ERR/100WL M	IHD, Stroke, and other cardiovascular diseases (mortality)
Metz-Flamant 2013 (48)	Cohort	Nuclear workers	France	1950 – 1994	To 2004	59,021	External whole body from x- and gamma radiation dose (mSv)	0.0225 (0 to 0.6056)	ERR/Sv	All circulatory diseases, IHD, cerebrovascular diseases, other circulatory diseases (mortality)

Study ID	Study design	Population	Country	Time period of exposure	Follow-up	Size of cohort	Exposure(s) type and organ	Mean (range) exposure dose (Sv/Gy)	Measures of association	Outcome(s)
Navaranjan 2016 (15)	Cohort	Uranium miners & millers	Canada	1954 – 1996	To 2007	28,546	Cumulative exposure to radon decay products (WLM)	21.0 WLM for males, 0.2 WLM for females.	SMR, ERR/ 100WLM	All circulatory disease, Major cardiovascular disease, IHD, cerebrovascular disease (mortality)
Rage 2018 (17)	Cohort	Uranium miners (adding Jouac)	France	1957 – 2001	To 2007	5,400	External dose from gamma rays (mGy), radon (WLM), and uranium ore dust (kBqm-3h)	0.0218 (0.0001 to 0.0995)	SMR, ERR/ 100WLM	All circulatory system diseases, IHD, cerebrovascular disease, other circulatory diseases (mortality)
Rajaraman 2016 (55)	Cohort	Radiological technologists (fluoroscopy)	US	1950 – 2008	To 2008	68,926	No dosimetry reported.		HR	All heart diseases, IHD, myocardial infarction, hypertension (mortality)
Villeneuve 2007a (56)	Cohort	Fluorspar miners	Canada	1950 - 1990	To 2001	1,742	Radon (WLM)	43.6 WLM/year (0 to >2,000)	RR	IHD (called coronary heart disease in this paper), circulatory disease, cerebrovascular disease, AMI (mortality)
Villeneuve 2007b (45)	Cohort	Fluorspar miners	Canada	1950 - 1990	To 2001	1,742	Radon (WLM)	43.6 WLM/year (0 to >2,000)	SMR	Circulatory diseases, coronary heart disease, cerebrovascular disease (mortality)
Vrijheid 2007 (41)	Cohort	Nuclear power	15 countries *	As early as 1943 to as late as 2000	As early as 1984 to as late as 2000	275,312	External dose to colon or lung (Sv)	0.0207 (0.0 to >0.5) (colon)	SMR, ERR/Sv, RR at 100mSv	IHD, heart failure, DVT, cerebrovascular diseases, other circulatory diseases (mortality)
Wang 2009 (21)	Cohort	Medical diagnostics	China	1950-1980	To 1995	27,011	External whole body dose from X-rays (mGy)	0.189 (0 to 0.673)	RR	Circulatory disease, IHD, cerebrovascular disease (mortality)

Study ID	Study design	Population	Country	Time period of exposure	Follow-up	Size of cohort	Exposure(s) type and organ	Mean (range) exposure dose (Sv/Gy)	Measures of association	Outcome(s)
Zablotska 2013 (35)	Cohort	Uranium processing workers	Canada	1932-1980	To 1999	3,000	External whole body gamma radiation dose (mSv), radon exposure (WLM)	0.1344 (0 to 5.0988). 15.9 WLM (0.0-627.6)	SMR, RR, ERR/Sv	Hypertensive disease, IHD, cerebrovascular disease, other CVD (mortality and incidence)
Zhang 2019 (49)	Cohort	Radiation workers	UK	1955-2011	To 2011)	174,541	External whole body dose (mSv)	0.0232 (0 to >0.5)	mSv dose, ERR/Sv	Heart diseases (mortality)

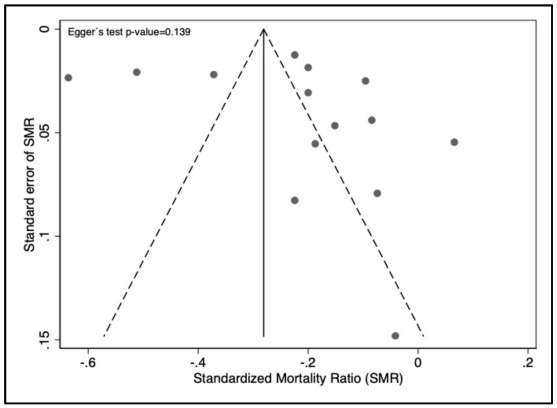
* Australia, Belgium, Canada, Finland, France, Hungary, S. Korea, Lithuania, Slovakia, Spain, Sweden, UK, US, Switzerland

Figure S1. Details of the OHAT Risk of Bias assessment by study

	Selection	Confounding	Attrition/ e	Detection	Outcome	Selective repor	Other (statistica	Any other	Summary score
Anderson 2021	+	-	++	-	++	++	++	++	Tier 2
Atkinson 2004	+	-	+	+	++	++	++	++	Tier 2
Azizova 2018	++	-	+	+	+	++	++	++	Tier 2
Azizova 2015b	++	+	+	+	++	++	++	++	Tier 1
Azizova 2022a	+	-	-	-	+	++	+	++	Tier 2
Boice 2022a	-	-	++	++	++	++	++	++	Tier 2
Boice 2022b	+	-	-	-	+	+	+	++	Tier 2
Boice 2022c	+	-	+	-	+	+	+	++	Tier 2
Bouet 2018	-	-	++	-	++	++	++	++	Tier 2
Cha 2020	+	++	++	-	+	++	++	++	Tier 2
Doody 2000	-	-	++	--	++	+	++	++	Tier 2
Gillies 2017	+	-	-	-	++	++	++	++	Tier 2
Golden 2022	-	-	+	-	++	++	++	++	Tier 2
Kreuzer 2013	+	-	++	-	+	++	++	++	Tier 2
Kreuzer 2015	+	-	++	-	+	+	++	++	Tier 2
Lane 2010	+	+	-	--	+	++	+	++	Tier 2
Metz-Flamant 2013	+	-	++	+	+	++	++	++	Tier 2
Navaranjan 2016	-	--	+	+	++	+	++	++	Tier 2
Rage 2018	-	-	++	-	++	++	++	++	Tier 2
Rajaraman 2016	-	+	-	--	-	+	++	++	Tier 2
Villeneuve 2007	+	+	+	+	++	++	++	++	Tier 1
Villeneuve 2007b	+	-	++	--	+	++	+	++	Tier 2
Vrijheid 2007	+	-	+	-	+	++	+	++	Tier 2
Wang 2009	+	-	+	-	+	++	++	++	Tier 2
Zablotska 2013	-	-	-	-	+	+	++	++	Tier 2
Zhang 2019	+	-	+	+	++	++	++	++	Tier 2

Figure S2. Funnels plots for studies assessing the association between ischemic heart disease mortality and low dose occupational radiation exposure

a) Studies reporting Standardized Mortality Ratio (SMR)



b) Studies reporting excess or relative risk per Sievert (EER/Sv)