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1. Reviews and meta-analyses

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2. Residential exposure

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3. Occupational exposure

3.1 Effect of Occupational Extremely Low-Frequency Electromagnetic Field Exposure on the Thyroid Gland of Workers: A Prospective Study

Fang, Y. (2022). Current Medical Science, 42(4), 817-823. <https://doi.org/10.1007/s11596-022-2610-8>

Background and objective: The aim of this study was to investigate the biological effects of occupational extremely low-frequency electromagnetic field (ELF-EMF) exposure on the thyroid gland. **Methods:** The authors conducted a prospective analysis of 85 workers (exposure group) exposed to an ELF-EMF (100 μ T, 10–100 Hz) produced by the electromagnetic aircraft launch system and followed up on thyroid function indices, immunological indices, and color Doppler images for 3 years. Additionally, 116 healthy volunteers were randomly selected as controls (control group), the thyroid function of whom was compared to the exposure group.

Results: No significant difference was observed in thyroid function between the exposure and control groups. During the follow-up of the exposure group, the serum free triiodothyronine (FT3) level was found to slowly decrease and free thyroxine (FT4) level slowly increase with increasing exposure time. However, no significant difference was found in thyroid-stimulating hormone (TSH) over the three years, and no significant difference was observed in the FT3, FT4 and TSH levels between different exposure subgroups. Furthermore, no significant changes were observed in thyroid autoantibody levels and ultrasound images between subgroups or over time.

Conclusion: Long-term exposure to ELF-EMF may promote thyroid secretion of T4 and inhibit deiodination of T4 to T3. ELF-EMF has no significant effect on thyroid immune function and morphology.

3.2 ELF-MF Exposure, Actual and Perceived, and Associated Health Symptoms: A Case Study of an Office Building in Tel Aviv-Yafo, Israel

Raz-Steinkrycer, L.S., Dubnov, J., Gelberg, S., Jia, P., Portnov, B.A. (2022). Sustainability, 14, 11065. <https://doi.org/10.3390/su141711065>

Background and objective: Empirical studies link exposure to extremely low frequency magnetic fields (ELF-MFs) to several health symptoms. However, it is unclear whether these symptoms are associated with actual or perceived exposure. In this study the authors attempted to answer this question by studying the health complaints of employees working in a multi-story office building located near a major high-voltage power line.

Methods: ELF-MF measurements were conducted in the building using a triaxial sensor coil device on all 15 floors. In parallel, questionnaires were administered to evaluate the prevalence of various health symptoms among the employees. Multivariate logistic regressions were used next to quantify the associations between actual and perceived ELF-MF exposure and the employees' health complaints. Results: The analysis revealed that feelings of weakness, headache, frustration, and worry were associated with both measured and perceived ELF-MF exposure ($p < 0.01$), while perceived ELF-MF exposure was also found to be associated with eye pain and irritation (OR = 1.4, 95% CI = 1.2–1.6), sleepiness (OR = 1.3, 95% CI = 1.1–1.5), dizziness and ear pain (OR = 1.2, 95% CI = 1.0–1.4).

Conclusion: The authors conclude that high-voltage power lines produce both physiological and psychological effects in nearby workers, and, hence, proximity to such power lines should become a public health issue.

Several limitations of the present study need to be mentioned. First, the ELF-MF exposure of study participants might not be only from the power line, but also from various other EMF sources (such as mobile phones, computers, monitors, etc.), or they may have multiple sensitivities to, for example, odor or noise. Moreover, the authors could not examine EMF-ELF exposure in the workers' homes. Furthermore, due to technical limitations, measurements on different floors of the building were made on different days, which might have introduced some variation.

4. Human Experimental Studies

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5. Exposure Assessment

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6. Leukaemia Studies

6.1 Commercial outdoor plant nurseries as a confounder for electromagnetic fields and childhood leukemia risk.

Nguyen, A., Crespi, C.M., Vergara, X., Kheifets, L. (2022). *Environmental Research*, 212, 113446. <https://doi.org/10.1016/j.envres.2022.113446>

Background and objective: Close residential proximity to powerlines and high magnetic fields exposure may be associated with elevated childhood leukemia risks as reported by prior studies and pooled analyses. Magnetic fields exposure from high-voltage powerlines is associated with proximity to these powerlines and consequently with any factor varying with distance. Areas underneath powerlines in California may be sites for commercial plant nurseries that can use pesticides, a potential childhood leukemia risk factor. The objective of this study is to assess if potential pesticide exposure from commercial plant nurseries is a confounder or interacts with proximity or magnetic fields exposure from high-voltage powerlines to increase childhood leukemia risk.

Methods: A comprehensive childhood leukemia record-based case-control study with 5788 cases and 5788 controls (born and diagnosed in California, 1986–2008) was conducted. Pesticide, powerline, and magnetic field exposure assessment utilized models that incorporated geographical information systems, aerial satellite images, site visits and other historical information.

Results: The relationship for calculated fields with childhood leukemia (odds ratio (OR) 1.51, 95% confidence interval (CI) 0.70–3.23) slightly attenuated when controlling for nursery proximity (OR 1.43, 95% CI 0.65–3.16) or restricting analysis to subjects living far (>300 m) from nurseries (OR 1.43, 95% CI 0.79–2.60). A similar association pattern was observed between distance to high-voltage powerlines and childhood leukemia. The association between nursery proximity and childhood leukemia was unchanged or only slightly attenuated when controlling for calculated fields or powerline distance; ORs remained above 2 when excluding subjects with high calculated fields or close powerline proximity (OR 2.16, 95% CI 0.82–5.67 and OR 2.15, 95% CI 0.82–5.64, respectively). The observed relationships were robust to different time periods, reference categories, and cut points.

Conclusion: Close residential proximity to nurseries is suggested as an independent childhood leukemia risk factor. These results do not support plant nurseries as an explanation for observed childhood leukemia risks for powerline proximity and magnetic fields exposure, although small numbers of subjects concurrently exposed to high magnetic fields, close powerline proximity and plant nurseries limited the ability to fully assess potential.

6.2 Unconventional Oil and Gas Development Exposure and Risk of Childhood Acute Lymphoblastic Leukemia: A Case–Control Study in Pennsylvania, 2009–2017.

Clark, C.J., Johnson, N.P., Soriano Jr, M., Warren, J.L., Sorrentino, K., Kadan-Lottick, N.S., Sayers, J.E., Ma X., Deziel, N.C. (2022). *Environmental Health Perspectives*, 130(8). <https://doi.org/10.1289/EHP11092>

Background and objective: The most common form of childhood leukemia, in a large regional sample using UOGD-specific metrics, including a novel metric to represent the water pathway. **Methods:** The authors conducted a registry-based case–control study of 405 children ages 2–7 y diagnosed with ALL in Pennsylvania between 2009–2017, and 2,080 controls matched on birth year. The authors used logistic regression to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the association

between residential proximity to UOGD (including a new water pathway-specific proximity metric) and ALL in two exposure windows: a primary window (3 months preconception to 1 y prior to diagnosis/reference date) and a perinatal window (preconception to birth).

Results: Children with at least one UOG well within 2km of their birth residence during the primary window had 1.98 times the odds of developing ALL in comparison with those with no UOG wells [95%confidenceinterval(CI):1.06,3.69]. Children with at least one vs. no UOG wells within 2 km during the perinatal window had 2.80 times the odds of developing ALL(95%CI:1.11,7.05). These relationships were slightly attenuated after adjusting for maternal race and socio-economic status [odds ratio (OR)=1:74 (95%CI:0.93,3.27) and OR=2:35 (95%CI:0.93,5.95)], respectively). The ORs produced by models using the water pathway-specific metric were similar in magnitude to the aggregate metric.

Conclusion: This study including a novel UOGD metric found UOGD to be a risk factor for childhood ALL. This work adds to mounting evidence of UOGD's impacts on children's health, providing additional support for limiting UOGD near residences.

6.3 Parental occupational exposure to combustion products, metals, silica and asbestos and risk of childhood leukaemia: Findings from the Childhood Cancer and Leukaemia International Consortium (CLIC).

Onyije, F.M., Olsson, A., Erdmann, F., Magnani, C., et al. (2022). Environment International 167, 107409. <https://doi.org/10.1016/j.envint.2022.107409>

Background and objective: Parental occupational exposures around conception (father) or during pregnancy (mother) have been hypothesized as potential predisposing factors for childhood leukaemia.

Methods: the authors investigated parental exposure to several known occupational carcinogens and childhood leukaemia risk. They conducted a pooled analysis using case-control data from four European countries (3362 childhood leukemia cases and 6268 controls). Parental occupational exposures to polycyclic aromatic hydrocarbons (PAH), diesel engine exhaust (DEE), chromium, nickel, crystalline silica, and asbestos were assessed by a general population job-exposure matrix. The authors estimated odd ratios (ORs) and 95% confidence intervals (CIs) using unconditional logistic regression models for all childhood leukaemia combined, by leukaemia type (ALL and AML) and by ALL subtype (B-lineage and T-lineage).

Results: The authors found an association between high paternal occupational exposure to crystalline silica and childhood ALL (OR 2.20, CI 1.60-3.01) with increasing trend from no exposure to high exposure ($P = <0.001$), and also for AML (OR 2.03, CI 1.04-3.97; P for trend = 0.008). ORs were similar for B- and T-lineage ALL. For ALL, ORs were also slightly elevated with wide confidence intervals for high paternal occupational exposure to chromium (OR 1.23, CI 0.77-1.96), and DEE (OR 1.21, CI 0.82-1.77). No associations were observed for paternal exposures to nickel, PAH and asbestos. For maternal occupational exposure the authors found several slightly elevated odds ratios but mostly with very wide confidence intervals due to low numbers of exposed mothers.

Conclusion: This is a first study suggesting an association between fathers' occupational exposure to crystalline silica and an increased risk of childhood leukaemia in their offspring. As this association was driven by certain occupations (field crop farmers and miners) where other potentially relevant exposures like pesticides and radon may also occur, more research is necessary.

6.4 Risk of Cancer in Children of Parents Occupationally Exposed to Hydrocarbon Solvents and Engine Exhaust Fumes: A Register-Based Nested Case–Control Study from Sweden(1960–2015)

Rossides, M., Kampitsi, C., Tälback, M., Mogense, H., et al. (2022). *Environmental Health Perspectives*, 130(7). <https://doi.org/10.1289/EHP11035>

Background and objective: It remains unclear whether parental occupational exposure to hydrocarbon solvents (HCS) or engine exhaust fumes (EEF) is associated with higher risks of cancer in the offspring. This study aims to estimate relative risks of childhood cancers associated with maternal or paternal exposure to aliphatic/alicyclic, aromatic, or chlorinated HCS or gasoline/diesel EEF.

Methods: The authors conducted a case–control study in which individuals <20y old, born 1960–2014, were identified from the Swedish National Cancer Register (1960–2015) at first cancer diagnosis and matched to population controls (1case:25controls) on birth year and sex. Maternal and paternal occupation around the child’s birth was retrieved for 9,653 cases and 172,194 controls and 12,521 cases and 274,434 controls, respectively, using information from six censuses and a nationwide register. Using the Swedish job-exposure matrix (SWEJEM), the authors assessed exposure to HCS and EEF (any or higher/lower). Odds ratios (ORs) and 95% confidence intervals (CIs) of 15 childhood cancer subtypes were estimated using conditional logistic regression models adjusted for several confounders.

Results: Maternal exposure to aromatic HCS was associated with non-Hodgkin lymphoma (OR=1.64;95%CI:1.05,2.58), aliphatic/alicyclic HCS with germ cell tumors (OR=1.52; 95%CI:0.89,2.59), and gasoline/diesel EEF with astrocytoma (OR=1.40; 95%CI:1.04,1.88), myeloid leukemia (OR=1.53; 95%CI:0.84,2.81), lymphomas (OR=1.60; 95%CI:0.85,3.02 for Hodgkin; OR=1.44; 95%CI:0.71,2.91 for non- Hodgkin), and epithelial tumors (OR=1.51; 95%CI:0.93,2.44). Paternal exposure to gasoline EEF was associated with Hodgkin lymphoma (OR=1.21; 95%CI:1.01,1.44) and soft tissues sarcomas (OR=1.22; 95%CI:1.00,1.48). No notable difference was observed between higher and lower exposure.

Conclusion: These findings suggest that occupational exposure to HCS or EEF, especially in the mother, may increase the risk of some childhood cancers. They add to the growing literature on adverse effects from HCS and EEF in the child, but replication of these associations in other populations is warranted.

6.5 Occupational exposure to pesticides in mothers and fathers and risk of cancer in the offspring: A register-based case-control study from Sweden (1960–2015)

Rossides, M., Kampitsi, C., Tälback, M., Mogense, H., et al. (2022). *Environmental Research* 214, 113820. <https://doi.org/10.1016/j.envres.2022.113820>

Background and objective: Maternal and paternal occupational exposure to pesticides was linked to leukemia in the offspring in some previous studies. Risks for other cancers, particularly from maternal exposure, are largely unknown.

Methods: The authors examined the association between maternal and paternal exposure to pesticides and childhood cancer in a Swedish register-based case-control study (1960–2015). Cancer cases <20 years old were identified from the Cancer Register (n = 17313) and matched to controls (1:25) on birth year and sex. Employment history of each biological parent around the child’s birth was retrieved from six censuses and a nationwide register, and exposure to any of herbicides, insecticides, and fungicides was evaluated using the Swedish job-exposure matrix (SWEJEM) in 9653/172194 mothers and 12521/274434 fathers of cases/controls. Adjusted odds ratios (OR) and 95% confidence

intervals (CI) were estimated from conditional logistic regression models for any cancer, leukemia, lymphoma, central nervous system [CNS], and other solid tumors.

Results: The authors found an OR of 1.42 (95% CI 0.78, 2.57; 12 exposed cases) for lymphoma and 1.30 (95% CI 0.88, 1.93; 27 exposed cases) for other solid tumors associated with maternal occupational exposure to pesticides. No associations were observed between maternal exposure and leukemia or CNS tumors, or paternal exposure and any of the cancers examined, except for a potential association between pesticides exposure and myeloid leukemia (OR 1.15 [95% CI 0.73, 1.79; 22 exposed cases]). Conclusion: Although these findings merit further investigation, they indicate that parental exposure to pesticides may lead to higher risks of childhood cancer even in settings of low exposure.

6.6 Cancer risks among studies of medical diagnostic radiation exposure in early life without quantitative estimates of dose

Little, M.P., Wakeford, R., Bouffler, S.D. et al. (2022). Science of the Total Environment 832, 154723. <http://dx.doi.org/10.1016/j.scitotenv.2022.154723>

Background and objective: There is accumulating evidence of excess risk of cancer in various populations exposed at acute doses below several tens of mSv or doses received over a protracted period. There is also evidence that relative risks are generally higher after radiation exposures in utero or in childhood.

Methods: The authors reviewed and summarized evidence from 89 studies of cancer following medical diagnostic exposure in utero or in childhood, in which no direct estimates of radiation dose are available. In all of the populations studied exposure was to sparsely ionizing radiation (X-rays).

Results: Several of the early studies of in utero exposure exhibit modest but statistically significant excess risks of several types of childhood cancer. There is a highly significant ($p < 0.0005$) negative trend of odds ratio with calendar period of study, so that more recent studies tend to exhibit reduced excess risk. There is no significant inter-study heterogeneity ($p > 0.3$). In relation to postnatal exposure there are significant excess risks of leukaemia, brain and solid cancers, with indications of variations in risk by cancer type ($p = 0.07$) and type of exposure ($p = 0.02$), with fluoroscopy and computed tomography scans associated with the highest excess risk. However, there is highly significant inter-study heterogeneity ($p < 0.01$) for all cancer endpoints and all but one type of exposure, although no significant risk trend with calendar period of study.

Conclusions: Overall, this large body of data relating to medical diagnostic radiation exposure in utero provides support for an associated excess risk of childhood cancer. However, the pronounced heterogeneity in studies of postnatal diagnostic exposure, the implied uncertainty as to the meaning of summary measures, and the distinct possibilities of bias, substantially reduce the strength of the evidence from the associations the authors observe between radiation imaging in childhood and the subsequent risk of cancer being causally related to radiation exposure.