

Powerwatch Childhood Cancer Articles

The Powerwatch Childhood Cancer set of articles article is separated into 11 sections, each of which can be individually downloaded, or you can download it as one document.

It is a 'work in progress' incorporating new information whenever time permits.

Section 4

Childhood Cancer and Non-Ionising Radiation

The complete set:

1. Childhood incidence and types of cancer
2. Genetics and parental exposure
3. Ionising radiation
4. Non-ionising radiation – electromagnetic fields (EMFs)
5. Chemical and infections
6. Other possible causative factors
7. Types of childhood cancer – Astrocytoma to kidney cancer
8. Types of childhood cancer – Leukaemia to thyroid cancer
9. Challenges affecting survivors of childhood cancer
10. The needs of parents, family and GPs of childhood cancer survivors
11. References

Freely downloadable from:

<http://www.powerwatch.org.uk/library/index.asp>

Section 4 - Childhood cancer and EMFs

As discussed in section 2, only about 10% of childhood cancers are inherited. Mostly are multi-factorial, involving an initiatory event and at least one promotional event. Precisely how many sequential co-operating mutations are required to produce overt, clinical cancer is not entirely clear, but the relatively short latency, especially in infancy and childhood suggests that only a few are needed in comparison with most adult carcinomas that are thought to evolve over decades.

The increase in incidence of childhood leukaemia during the 20th century suggests that changes in environmental factors, including lifestyle, are at least partly responsible.

Excessive exposure to non-ionising radiation has been linked to an increased risk of developing cancer. SCENHIR (the Scientific Committee on Emerging and Newly Identified Health Risks) in 2009, concluded that their previous assessment that ELF magnetic fields were a possible carcinogen and might contribute to an increase in childhood leukaemia was still valid, taking into consideration the subsequent epidemiological and animal studies. Environmental agents can also contribute to cancer by increasing the genotoxic potential of other agents, interfering with the DNA repair processes, allowing a cell with DNA damage to survive and stimulating the cell division, resulting in alteration of the normal functions of the cell.

Eden's summary of the aetiology of childhood leukaemia ([2010](#)) said "*environmental factors for which some evidence exists include non-ionising electromagnetic radiation and electric fields.*"

Here we look at non-ionising radiation (electromagnetic fields or EMFs) which has been implicated by a significant amount of scientific research in the development of childhood cancer, either as cancer initiator or promoter.

ELF (power-frequency or PF) magnetic field exposure

One of the eminent scientists in this field, Anders Ahlbom (Sweden), speaking in Berlin at a WHO/ICNIRP international scientific workshop entitled "[Risk-factors for Childhood Leukaemia](#)", in May 2008, said: "*There is relatively strong epidemiological evidence that ELF magnetic fields are a causal factor in the development of childhood leukaemia. The evidence is stronger than that for passive smoking and lung cancer*".

Schüz ([2011](#)), a very cautious scientist, in an overall review, concluded that the assessment that ELF-MF are a possible carcinogen and may cause childhood leukaemia remains valid.

Röösli ([2013](#)) suggests that, if causal, 1-4% of all childhood leukaemia cases could be attributed to low-frequency magnetic fields.

In a meta-analysis of 11,699 cases of childhood leukaemia, magnetic field levels equal to, or higher than 0.2 μ T was associated with childhood leukaemia (Zhao [2014](#)). A study by Bunch ([2014](#)) reported no increased risks in recent years from overhead powerlines, but this was a [seriously flawed study](#).

Kheifets & Oksuzyan (2008) outlined some of the difficulties in studying the link between EMFs and childhood leukaemia. She suggested that more revealing studies might include those of highly exposed children living in flats next to built-in transformers or electrical equipment rooms (that is based on an assumption that the higher the exposure, the greater the risk, a viewpoint not shared by everybody) or, an investigation of possible joint effects of environmental exposures and genetic cofactors.

Parental occupational exposure to ELF EMFs

In a study of children whose mothers were occupationally exposed to low levels of powerfrequency magnetic fields during pregnancy, Infante-Rivard & Deadman (2003) found a slightly increased risk of developing ALL between 0-9 years. Pearce (2007) found that paternal occupational exposure to EMFs prior to the child's conception resulted in a significant increased risk of acute lymphoblastic leukaemia (ALL) for boys aged less than 6, though the strength of this association is weakened as the research team looked at ionising radiation exposure as well, which has been linked to male susceptibility to cancer. Criticisms have been made of studies that rely on estimated field levels, as being unreliable due to the variation in exposure of different jobs, and neither was home exposure assessed.

A small increase in risk of ALL (Reid 2011) and a larger one with childhood cancer (Smulevich 1999, Keegan 2012) with maternal or paternal exposure any time before the birth, was linked to extremely low frequency electromagnetic fields (ELF EMFs).

Children under 5 had an increased risk of brain tumours if their mothers or fathers were employed as electrical workers (Cordier 2001) or electric power installers (Olshan 1999). Li (2009) suggests a possible association between maternal occupational ELF-EMF exposure shortly before and during pregnancy (including among sewing machine operators), and astroglial tumours in their children.

The evidence is mixed as to whether EMFs directly damage DNA, although indirect effects such as from the bystander effect (in which unirradiated cells exhibit irradiated effects as a result of signals received from nearby irradiated cells), may be responsible. It is possible that the way EMF exposure has been measured may be responsible for the mixed results obtained experimentally. Kavet (2011) suggests that contact current could be responsible for the association of childhood leukaemia with magnetic fields.

Though experiments may be contradictory or inconclusive, nevertheless, it is suggested that EMFs could act by:

- Directly increasing the level of harmful **free radicals** within the body
- Affecting **other cellular processes** (including direct, or indirect tumour promotion), some of which may not even have been investigated as yet
- Decreasing the level of the protective hormone **melatonin**
- Acting in a synergistic way with respect to **other pollutants**, making them more harmful

ELF free radical effects

In body tissue free radicals are dangerous high-energy particles that damage cells and can both cause and accelerate the progression of cancer. Timmel & Henbest ([2004](#)) were the first to show that exposure to EMFs can increase the yield of free radicals by more than 60%. The theory was reviewed by Simkó & Mattson ([2004](#)), who concluded that EMFs cause a general increase in the levels of free radicals, which could explain the diverse and often inconsistent nature of observed effects of EMFs, free radicals being intermediaries in many processes. DNA damage could arise as a result of persistently elevated free radical concentrations, caused by long-term EMF exposure, or via the radical pair mechanism by which magnetic fields increase the lifetime of free radicals, allowing more DNA damage to occur (Rollwitz [2004](#), Henshaw 2008).

Melatonin effects

The hormone melatonin, is thought to protect the body from cancer

- by neutralising free radicals
- by inhibiting the uptake of growth factors by cancer cells
- by increasing the likelihood of cancer cells undergoing apoptosis (cell death), and
- by inhibiting the growth of blood vessels in tumours.

The production of melatonin at night (when the majority of melatonin is produced by the body's pineal gland) has been found to be reduced significantly by light at night and magnetic fields associated with the electricity supply (Henshaw & Reiter [2005](#), Erren [2005](#)). Lupke ([2004](#), [2006](#)) suggested that EMFs reduced the anti-oxidative protection from melatonin.

Badr ([1999](#)) found that melatonin protects cells from genetic damage. Melatonin helped prevent oxidative damage to the human haemopoietic system (Vijayalaxmi [1995](#), [1996](#), [1999](#)) and in animal foetuses (Wakatsuki [1999](#), Okatani [2001](#)). Melatonin levels are particularly high during pregnancy (Nakamura [2001](#)), so any change in these levels may result in some of the *in utero* damage which cause the 'first hit' which ultimately leads to cancer.

Professor Henshaw, Scientific Director of CHILDREN with CANCER UK, said "*Low-frequency magnetic fields can suppress production of melatonin, which, in pregnant women, will deprive the foetal brain of the protective hormone.*"

A variety of bone marrow cells have been shown to produce melatonin (Tan [1999](#), Conti [2000](#), Carrillo-Vico [2004](#)). Whilst the specific function of melatonin in these cells remains unknown, its suppression could have clear implications for cancer initiation and/or progression. A reduction in melatonin in the leukocyte precursor cells would be expected to enhance free radical-mediated DNA damage, thereby increasing the likelihood of these cells becoming carcinogenic.

Melatonin reduces the growth of HL-60 myeloid leukaemia cells *in vitro* (Henshaw 2008).

Light at Night

Evidence suggests that increasing exposure to light at night (LAN) and the consequent disruption of circadian rhythms, especially via reduction in nocturnal pineal melatonin, is a significant factor in the increasing incidence of breast cancer in recent decades in industrialised countries (Blask [2005](#)). Whether LAN features in childhood cancer risk is not known. Electric light exposure at night can disrupt the circadian rhythm and many other physiological processes that are under circadian control. Because of this, Stevens ([2012](#)) suggests that ill-timed electric light exposure to pregnant women, to neonates, infants, and small children may increase cancer risk in those children.

Synergistic effects

Airborne pollutant particles are known to have a significant effect on health and a number of studies have reported an association between childhood cancer and exposure to traffic pollution, or particularly benzene (Lagorio [2013](#)). The strong electric fields associated with high voltage power lines may affect the charge on the chemicals found in traffic pollution, making them more likely to be absorbed by the body. This effect can be observed up to 7 kilometres downwind of a high voltage powerline (Fews [1999a](#)). The older the cable and the wetter the weather the more charged ions are emitted (Fews [1999b](#)). Very small particles are particularly hazardous because of their ability to penetrate deeply into the lung and pass into the bloodstream (Seaton [1995](#)). These small particles are in the size range where electrical charging can significantly increase lung deposition on inhalation. The report by Draper ([2005](#)) found increased risk of leukaemia in children born within 600 metres of National Grid 400 and 275 kilovolt power lines. This distance is clearly too far away to be a direct EMF effect, but could validate the ion polarisation theory.

Maternal use of a sauna close to conception or in the first trimester, and paternal use in the 3 months before the pregnancy, use of an electric blanket, or any heat source have been linked to an increased risk of medulloblastoma. Heat and magnetic field exposure would both have been involved (Bunin [2006](#)), and both may have contributed.

Mair (2008) also suggested that EMFs could be mutagenic on their own, or could potentiate ionizing radiation mutations.

Brain and CNS tumours

Women who worked in low-frequency magnetic environments when pregnant, such as machinists, hairdressers, nurses and dry cleaners were twice as likely to have babies that developed brain tumours (Li [2009](#)).

In a meta-analysis of 13 studies (Mezei [2008](#)), there was a very slightly elevated risk of brain tumours with exposure to magnetic field levels in the home over 0.2 microtesla (μT), with a greater risk at levels of 0.3 or 0.4 μT . A more recent study not included in the meta-analysis found a positive association between exposure to residential magnetic fields above 0.4 microtesla and the risk of brain tumours (Saito [2010](#)).

Preston-Martin ([1996](#)) found no association, but she concluded that the prevalence of high fields in Los Angeles homes was too low even to detect a **moderate** effect. Gurney &

van Wijngaarden ([1999](#)) concluded that electromagnetic fields (EMFs) played no causal role in brain cancer development, and Kheifets (who has been repeatedly funded by the power industry), in a pooled analysis of 10 studies, found no association ([2010](#)).

Leukaemia

There is disagreement as to whether the relationship between EMF exposure and an increased risk of childhood leukaemia is a causal one, or whether there is a coincidental association with some other, as yet undiscovered, factor. However, the relative risk is surprisingly consistent, even though epidemiology is a bit of a blunt instrument to detect causal factors in a multi-factorial illness. Even Public Health England (former HPA-RPD), the International Agency for Research on Cancer (IARC, 2001) and the World Health Organisation (WHO) have all agreed that EMFs are a potential carcinogen (Class 2B) and that precaution is warranted.

The California EMF Programme report (Neutra 2002), has been recognised as one of the more definitive documents of recent times. The authors concluded that EMFs increased the risk of childhood leukaemia. The International Agency for research on Cancer (IARC) classified magnetic fields as a “possible human carcinogen”, though this was not sufficient to influence public health policy according to Kheifets ([2006](#)). The results of one Canadian study by Green ([1999](#)), based on personal measured fields rather than spot measurements found a significant increase in risk of childhood leukaemia at 0.14 microtesla (even lower than most of the published literature, which seems to show a consensus at 0.3 – 0.4 microtesla), though there was no association with living near high voltage powerlines. Teepen & van Dijck ([2012](#)) suggested that the risk of childhood leukaemia increased by 40-70% when children were exposed to EMF levels above 0.3 μ T. They advised reducing exposure from power lines near densely populated areas and schools.

An influential report (www.bioinitiative.org) by Hardell & Sage ([2008](#)) concluded that in view of the association between electromagnetic fields and childhood leukaemia, a new lower public safety limit for habitable space adjacent to all new or upgraded power lines should be applied. A new lower limit should also be used for existing habitable space for children and/or women who are pregnant.

Kheifets ([2011](#)) pointed out some of the difficulties in making sense of the measured levels and childhood leukaemia risk using various statistical tests, and we suggest that it may be as appropriate (if not more so) to take into account peak-level exposure and maternal exposure during pregnancy. Most studies are based on average levels, thus excluding what may be the most important metric, irrespective of analysis procedure.

It is possibly that if magnetic fields are causative, it may be the rotating quality of the fields that is responsible. This is rarely measured.

More than 25 epidemiological studies around the world have investigated the association between childhood leukaemia and EMF exposure. They have found an increased risk of childhood leukaemia with proximity to high voltage powerlines, substations or high residential magnetic fields (Lin & Lee [1994](#), Boikat & von Manikowsky [1996](#), Kaatsch [1996](#), Thériault & Li [1997](#), Linet [1997](#), Michaelis [1997](#), [1998](#), Dockerty [1998](#), Li [1998](#),

McBride [1999](#), UKCCS [1999](#), Angelillo & Villari [1999](#), Bianchi [2000](#), Abdul Rahman [2008](#), Kheifets [2010](#), Kroll [2010](#), Teepen & van Dijck [2012](#), Sermage-Faure 2013, Pedersen 2014), showing up to 5 times higher (Malagoli [2010](#), Wünsch-Filho [2011](#)) or more (Sohrabi [2010](#)), especially with a diagnosis of ALL under the age of 6 (Green [1999](#)). Not all studies have found an association (Tynes & Haldorsen [1997](#), Kleinerman [2000](#)), and some of these studies used wire codes and calculated fields rather than measured fields from specific sources of EMFs. A study by Lowenthal ([2007](#)) found that living within 300 metres of high voltage powerlines within the first 15 years of life tripled the risk of developing a lymphoproliferative or myeloproliferative disorder in later life; and Draper ([2005](#)), in the largest single study of childhood cancer and powerlines, reported an increased risk in children whose birth address was within 600 metres of a high voltage power line. The risk was increased 5-fold if the child lived there for the first 5 years of life. This may be due to the air ionisation effect referred to above, which is an electric field effect. Henshaw (2008) who proposed the air ionisation effect, suggested that about 11% of childhood leukaemia cases may be linked to magnetic fields. Swanson ([2006](#)) suggests the increased risk could be due to magnetic fields, corona ions, the characteristics of the areas power lines pass through, bias or chance, and Jeffers ([2007](#)) adds that population mixing in housing developments which followed the construction of the lines, could also be involved.

Schüz ([2001](#)) suggested that night-time levels were of particular importance, though when he made a further analysis of his findings ([2007](#)) his conclusions were less clear. Schüz also looked at residential exposure to magnetic fields at 16.7 Hz from the electrified railway system in Germany, and found a moderate but statistically non-significant association with childhood leukaemia (Schüz [2001](#)).

Exposure to various electrical appliances, both during pregnancy and in childhood were looked at by Hatch ([1998](#)) who found a link with childhood ALL and maternal use (during pregnancy), or child use, of some household electrical appliances.

A review of 152 articles (Pelissari [2009](#)) suggested that *“an association may exist between exposure to low frequency magnetic fields and acute lymphoblastic leukemia in children, but this association is weak, preventing the observation of consistency in the findings.”* The authors concluded that ALL should be the focus of future studies as this seems to be the subtype with the most likely association.

Yang ([2008](#)) found genetic markers that showed that those carrying this gene variant were four times more likely to develop childhood leukaemia if they also live within 100 metres of power lines or transformers, compared to those with a fully functioning version of the gene. This groundbreaking piece of research indicates a potential for identifying individual susceptibility. For those already genetically susceptible (children with some congenital syndromes, such as Down syndrome), exposure to magnetic fields seemed to increase the risk of developing leukaemia (Mejia-Aranguré [2007](#)).

Individual studies are often limited because of the relative rarity of childhood leukaemia and the relatively low number of children exposed to high levels of EMFs. Three reports which have pooled the data from individual studies, have found an increase in risk with exposure to magnetic fields of 0.3 – 0.4 microtesla (Ahlbom [2000](#), Greenland [2000](#),

Wartenberg [2001](#)). This level was confirmed by further studies (Kabuto [2006](#), Feizi & Arabi [2007](#)).

It seems unlikely that there is a straightforward answer to whether EMFs *cause* cancer. We believe there is increasing evidence that they may play a definite role in affecting the body's ability to cope with pre-cancerous cell damage. There almost certainly will be other factors, such as chemical and other physical exposures (Juutilainen [2006](#)) involved in the final outcome of a diagnosis of leukaemia.

Maslanyj ([2010](#)) concluded that taking a precautionary approach with respect to the proximity of powerlines to children was an appropriate one in view of the consistent association with childhood leukaemia in the research. He suggested that low-cost intervention to reduce exposure is timely, accepting that this recommendation was a controversial one as this measure may not fully alleviate the risk, due to other possible interpretations of the data. He did, however, comment that EMF links with Alzheimer's disease may be worth taking into account.

Meanwhile, unaccountably, there seems to be mixed opinion as to whether to recommend more precautionary limits to EMF exposure, bearing in mind that precautions are appropriate when there is uncertainty. If a relationship between the two were *proven*, then it would be the time for legislation. Calvente ([2010](#)) called for an urgent reconsideration of exposure limits for both low frequency and static magnetic fields based on a review of experimental and epidemiological research into the link with childhood leukaemia.

The Stakeholder Advisory Group on ELF EMF (SAGE), the official Department of Health working group which was set up to recommend policy about powerlines to government, produced its First Interim Assessment in April 2007. They concluded that banning the building of new homes and schools within 60 metres of power lines is the best available option for reducing deaths from childhood leukaemia and possibly other diseases. The report fell short of recommending this as government policy because of fierce disagreements within the group. It said that such a policy, if implemented by the government would have a dramatic effect on property prices within power line corridors. It put the cost of restricting development at £1bn. Michael Jayne of the Royal Institution of Chartered Surveyors (RICS) called on the Government to take precautionary measures in order to ensure that the health risk is minimised by preventing the building of residential properties within specified distances of power lines.

Neuroblastoma

De Roos ([2001](#)) found that paternal exposure to battery-powered forklifts was positively associated with neuroblastoma in the child and there was also a weak association between 0.4 μ T paternal, but not maternal, magnetic field exposure and neuroblastoma.

Other non-ionising radiation and electric and magnetic field exposure

Söderberg ([2002](#)) found a slightly elevated risk for AML, but not ALL in children who had been exposed to high magnetic fields from infant incubators.

Changes in magnetic field level above 1.6 microtesla, such as can be found when travelling in electric trains, have been linked with an increased risk of miscarriage (Li [2002](#)). It is possible that the magnetic fields may also change DNA in ways that may not be destructive enough to result in a miscarriage, but may have health implications.

Ultraviolet light is part of the EMF spectrum. Mahé ([2011](#)) found that taking part in outdoor sports increases the risk of developing UV-induced skin lesions in childhood. However, it is also worth remembering that lack of vitamin D, the best source of which is sunlight, is responsible for many health problems, too.

Static fields

Very little has been done to identify whether exposure to static fields may be related to the risk of leukaemia. Bowman ([1995](#)) suggested that childhood leukaemia may be related to the combined effects of the earth's static magnetic fields and low levels of ELF magnetic fields resulting in various molecular ion resonances. The earth's static magnetic fields vary from country to country and could be significant in the disparity between study results, if it did, indeed, have a role.

Adverse effects of EMF exposure during treatment for cancer

It has also been suggested that exposure to EMFs may adversely affect the outcome of treatment for childhood leukaemia. The Regina Elena National cancer Institute in Italy carried out some EMF measurements because of the equipment used in some treatments. The author (Di Nallo [2008](#)) concluded that EMF measurements were recommended because of the vulnerability of patients with cancer, their long stay near the equipment and the day-long exposure, which represent additional risk factors, necessitating a prudent avoidance strategy, possibly even for staff as well as patients.

Effects of EMFs on survival after treatment

Exposure to magnetic fields appeared to decrease the survival time of children in remission from leukaemia, at over 0.3 microtesla (Foliart [2006](#)), or over 0.1 microtesla (Svendsen [2007](#)), though a further study by Foliart ([2007](#)) concluded that elevated magnetic field levels were not associated with factors that predicted poor survival.

Hocking & Gordon ([2003](#)) also found an association between living near to TV transmitters and decreased length of survival after leukaemia diagnosis.

Radio-frequency radiation exposure

Older TV and radio masts transmitted analogue signals. No link was found between the radiation from AM radio transmitters and the incidence of brain tumours (Ha [2007](#)).

The situation has now changed with the arrival of digital radio and TV and the omnipresent telecommunications (mobile phone) masts. There are also other sources of digital signal transmission (digital cordless phones, WiFi, etc) that are being increasingly situated within houses, schools, offices, leisure facilities, etc. that is increasing the general public's exposure to radiofrequency radiation significantly.

It has been suggested by many scientists that digital signals may well have a greater biological impact on living systems than analogue signals; this possible impact includes not only people, but also animals and plants. If this is so, we would expect to see increasing evidence of health problems associated with exposure, though this may not include an increase in childhood cancer risk.

Navarro (2003) and R Santini ([2002](#), [2003](#)) found evidence of ill-health as a result of living near to mobile phone masts, but they were not specifically looking at cancer incidence. Two studies on adult cancer incidence near masts found significant increases (Wolf & Wolf 2004, Eger 2004) and the Wolf study found a ten-fold increase in female cancer. Neither looked at childhood cancer incidence.

Brain and CNS tumours

People have expressed concern about the use of mobile phones and brain tumours, but this is a relatively new technology. Children have only just begun to use them extensively and brain & CNS tumours can take some time to develop and be diagnosed. Meanwhile, this uncertainty may influence whether we discourage our young people from exposing themselves to such a potential hazard, especially as in May 2011, The International Agency for Research on Cancer (IARC) classified radiofrequency RF as a possible human carcinogen.

As well as the risk from phones, people have wondered whether the radio-frequency emissions from the mobile phone network of masts and other sources may also result in an increased risk of tumours in children who live nearby.

Professor Stefaan van Gool, who is a clinic supervisor at the children's Haematology/oncology department at Louvain University hospital in Belgium and treats children with brain cancer says, *"Cordless baby alarms, toys and phones expose children to daily radiation. Although the intensity is less than a mobile phone, children are more susceptible to the effects. A lot of young people have WiFi at school, so their exposure is continual."* He continues *"There is irrefutable proof of the harmful effects of electromagnetic radiation. It should actually be the responsibility of the operators and the industry to demonstrate that they are not harmful"*

Leukaemia

There have been some studies that have found increases in leukaemia risk as a result of living in proximity to radio or TV transmitters (Maskarinec [1994](#), Hocking [1996](#), Dolk [1997a](#), [1997b](#), Michelozzi [2001](#), [2002](#)), that mean we cannot be complacent about the effects of RF signals. The study authors concluded that there was a small increased risk in adult and childhood leukaemia for those who lived within 2 kilometres (Ha [2007](#)), but the confidence levels were low due to the small number of cases involved. One study showed no such increase in risk (Merzenich [2008](#)), and Elliott ([2010](#)) found no link between childhood cancer and maternal exposure to base stations. Elliott has a tendency to find negative links between the environment and health problems, including the fact that he found no evidence for the reality of Gulf War Syndrome; not everybody concurs with his findings.

Neuroblastoma

De Roos ([2001](#)) found that maternal and paternal occupational exposure to a broad grouping of sources that produce radiofrequency radiation was associated with an increased incidence of neuroblastoma in the children.

Skin cancer

Paediatric melanoma is rare, but increasing in incidence. Solar and artificial (sunbed) UV-exposure is the main risk factor for the development of epithelial skin cancer as well as for malignant melanoma. UV exposure in childhood and adolescence is especially important (Greinert & Boniol [2011](#)).

The UK has the highest incidence of skin cancers in children and adolescents. In Europe, melanomas are more common in adolescents in the North and West and skin carcinomas in the South and East. Between 1978 and 1997 the annual increase in incidence for adolescent cancers has been 4.1% for melanoma and 2.5% for skin carcinoma (de Vries [2006](#)). The number of children affected was significantly smaller than the number of adolescents. The study authors suggest that the aetiology between childhood and adolescent skin cancers may be different, or it may also be that parental care with respect to skin screening is more influential for children than for adolescents.

Musselman & Spector ([2011](#)) found a link between sunlight exposure and risk of childhood cancer, possibly due to the role of vitamin D as a regulator of cell growth and differentiation and there was an inverse relationship between NHL risk and sun exposure (Petridou [2007](#)).

Conclusion

At a World Health Organisation / International Commission for Non-Ionising Radiation Protection (ICNIRP) workshop in May 2008 on "[risk factors for childhood leukaemia](#)", Anders Ahlbom reviewed the epidemiological data looking at childhood leukaemia and electromagnetic fields.

He said "Generally the exposure measures have been too crude, however this would tend to decrease the estimated association rather than increase it. Significant confounding is most unlikely - there would have to be a very large new factor that has not already been considered. Selection bias is possible, but unlikely to be a large effect given the number of very different pooled studies. It will not be due to chance.

The evidence that ELF magnetic fields are a causal factor in the development of childhood leukaemia is stronger than that for passive smoking and lung cancer."

We believe that childhood cancer is unlikely to be *caused* by exposure to electromagnetic fields, but there seems sufficient evidence that they may have a promotional effect that we think taking a precautionary stance, minimising exposure, is the best course, whilst further research takes place. In 2010, The US President's Cancer Panel emphasised that children are far more vulnerable to environmental toxins and radiation than adults. The panel requests more research from ELF to RF to clarify the cancer risk and also long-term monitoring of the exposure.

References

- Abdul Rahman Hi** et al 2008 - *A case-control study on the association between environmental factors and the occurrence of acute leukemia among children in Klang Valley, Malaysia* Asian Pac J Cancer Prev 9(4):649-52 PMID: 19256754
- Ahlbom A** et al 2000 - *A pooled analysis of magnetic fields and childhood leukaemia* Br J Cancer 83(5):692-8 PMID: 10944614
- Angelillo IF & P Villari** 1999 - *Residential exposure to electromagnetic fields and childhood leukaemia: a meta-analysis* Bull World Health Organ 77(11):906-15 PMID: 10612886
- Badr FM** et al 1999 - *Radioprotective effect of melatonin assessed by measuring chromosomal damage in mitotic and meiotic cells* Mutat Res 444(2): 367-372 PMID: 10521676
- Bianchi N** et al 2000 - *Overhead electricity power lines and childhood leukemia: a registry-based, case-control study* Tumori 86(3):195-8 PMID: 10939597
- Blask DE** et al 2005 - *Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats* Cancer Res 65(23):11174-84 PMID: 16322268
- Boikat U & S von Manikowsky** 1996 - *[Prevention during building construction against electromagnetic fields caused by high voltage electric lines--principles and risk evaluation]* Gesundheitswesen 58(3):147-53 PMID: 8645899
- Bowman JD** et al 1995 - *Hypothesis: the risk of childhood leukemia is related to combinations of power-frequency and static magnetic fields* Bioelectromagnetics 16(1):48-59 PMID: 7748203
- Bunch KJ** et al 2014 - *Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962-2008* Br J Cancer Feb 6 [Epub ahead of print] PMID: 24504371
- Bunin GR** et al 2006 - *Maternal supplement, micronutrient, and cured meat intake during pregnancy and risk of medulloblastoma during childhood: a children's oncology group study* Cancer Epidemiol Biomarkers Prev 15(9):1660-7 PMID: 16985028
- Calvente I** et al 2010 - *Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: a systematic review* Sci Total Environ 408(16):3062-9 PMID: 20451240
- Carrillo-Vico A** et al 2004 - *Evidence of melatonin synthesis by human lymphocytes and its physiological significance: possible role as intracrine, autocrine and /or paracrine substance* FASEB J 18(3):537-9 PMID: 14715696
- Conti A** et al 2000 - *Evidence for melatonin synthesis in mouse and human bone marrow cells* J Pineal Res 28: 193-202 PMID: 10831154
- Cordier S** et al 2001 - *Parental occupations and childhood brain tumors: results of an international case-control study* Cancer Causes Control 12(9):865-74 PMID: 11714115
- AJ** et al 2001 - *Parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring* Epidemiology 12(5):508-17 PMID: 11505168
- de Vries E** et al 2006 - *Skin cancer incidence and survival in European children and adolescents (1978-1997). Report from the Automated Childhood Cancer Information System project* Eur J Cancer 42(13): 2170-82 PMID: 16919779
- Di Nallo AM** et al 2008 - *Monitoring of people and workers exposure to the electric, magnetic and electromagnetic fields in an Italian National Cancer Institute* J Exp Clin Cancer Res 27:16 PMID: 18598357
- Dockerty JD** et al 1998 - *Electromagnetic field exposures and childhood cancers in New Zealand* Cancer Causes Control 9:299-309 PMID: 10622301
- Dolk H** et al 1997a - *Cancer incidence near radio and television transmitters in Great Britain. II. All high power transmitters.* Am J Epidemiol. 145:10-17 PMID: 8982017
- Dolk H** et al 1997b - *Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter* Am J Epidemiol. 145:1-9 PMID: 8982016
- Draper G** et al 2005 - *Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study*, BMJ, 330(7503):1290 PMID: 15933351
- Eden T** 2010 - *Aetiology of childhood leukaemia* Cancer Treat Rev 36(4):286-97 PMID: 20223594
- Elliott P** et al 2010 - *Mobile phone base stations and early childhood cancers: case-control study* BMJ 340:c3077 PMID: 20570865

- Erren T** 2005 - *Could visible light contribute to the development of leukaemia and other cancers in children?*, Med Hypotheses 64(4):864-71 PMID: 15694708
- Feizi AA & MA Arabi** 2007 – *Acute childhood leukemias and exposure to magnetic fields generated by high voltage overhead power lines – a risk factor in Iran* Asian Pac J Cancer Prev 8(1):69-72 PMID: 17477775
- Fews AP** et al 1999a – *Corona ions from powerlines and increased exposure to pollutant aerosols* Int J Radiat Biol 75:1523-1531 PMID: 10622258
- Fews AP** et al 1999b – *Increased exposure to pollutant aerosols under high voltage power lines* Int J Radiat Biol 75(12):1505-1521 PMID: 10622257
- Foliart DE** et al 2007 – *Magnetic field exposure and prognostic factors in childhood leukaemia* Bioelectromagnetics 28(1):69-71 PMID: 16988997
- Foliart DE** et al 2006 – *Magnetic field exposure and long-term survival among children with leukaemia* Br J Cancer 94(1):161-4 PMID: 16404370
- Green LM** et al 1999 – *Childhood leukemia and personal monitoring of residential exposures to electric and magnetic fields in Ontario, Canada* Cancer Causes Control 10(3):233-43 PMID: 10454069
- Green LM** et al 1999 - *A case-control study of childhood leukemia in southern Ontario, Canada, and exposure to magnetic fields in residences* Int J Cancer 82(2):161-70 PMID: 10389746
- Greenland S** et al 2000 - *A pooled analysis of magnetic fields, wire codes and childhood leukaemia*. Epidemiology 11:624-634 PMID: 11055621
- Greinert R & M Boniol** 2011 - *Skin cancer--primary and secondary prevention (information campaigns and screening)--with a focus on children & sunbeds* Prog Biophys Mol Biol 107(3):473-6 PMID: 21906618
- Gurney JG & E van Wijngaarden** 1999 – *Extremely low frequency electromagnetic fields (EMF) and brain cancer in adults and children: review and comment* Neuro Oncol 1(3):212-20 PMID: 11550314
- Ha M** et al 2007 – *Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer* Am J Epidemiol 166(3):270-9 PMID: 17556764
- Hardell L & C Sage** 2008 – *Biological effects from electromagnetic field exposure and public exposure standards* Biomed Pharmacother 62(2):104-9 PMID: 18242044
- Hatch EE** et al 1998 – *Association between childhood acute lymphoblastic leukemia and use of electrical appliances during pregnancy and childhood* Epidemiology 9(3):234-45 PMID: 9583414
- Henshaw DL and RJ Reiter** 2005 - *Do magnetic fields cause increased risk of childhood leukaemia via melatonin disruption?* Bioelectromagnetics Suppl 7:S86-97 PMID: 16059923
- Hocking B & I Gordon** 2003 – *Decreased survival for childhood leukemia in proximity to television towers* Arch Environ Health 58(9):560-4 PMID: 15369273
- Hocking B** et al 1996 - *Cancer incidence and mortality and proximity to TV towers* Med J Aust. 165:601–605 PMID: 8985435
- Infante-Rivard C & JE Deadman** 2003 – *Maternal occupational exposure to extremely low frequency magnetic fields during pregnancy and childhood leukaemia* Epidemiology 14(4): 437-41 PMID: 12843769
- Jeffers D** 2007 - *Transmission lines, EMF and population mixing* Radiat Prot Dosimetry 123(3):398-401 PMID: 17110386
- Juutilainen J** et al 2006 – *Do extremely low frequency magnetic fields enhance the effects of environmental carcinogens? A meta-analysis of experimental studies* Int J Radiat Biol 82(1):1-12 PMID: 16546898
- Kaatsch P** et al 1996 – *Case control study on childhood leukemia in Lower Saxony, Germany. Basic considerations, methodology, and summary of results* Klin Padiatr 208(4):179-85 PMID: 8776704
- Kabuto M** et al 2006 – *Childhood leukaemia and magnetic fields in Japan: a case-control study of childhood leukaemia and residential power-frequency magnetic fields in Japan* Int J Cancer 119(3): 643-50 PMID: 16496405
- Kavet R** et al 2011 - *The Relationship between Residential Magnetic Fields and Contact Voltage: A Pooled Analysis* Radiat Res 176(6):807-15 PMID: 21988611
- Keegan TJ** et al 2012 - *Case-control study of paternal occupation and childhood leukaemia in Great Britain, 1962-2006* Br J Cancer 107(9):1652-9 PMID: 22968649
- Kheifets L** et al 2011 – *Exploring exposure-response for magnetic fields and childhood leukemia* J Expo Sci Environ Epidemiol 21(6):625-33 PMID: 20606705

- Kheifets L** et al 2010 – *Pooled analysis of recent studies on magnetic fields and childhood leukaemia* Br J Cancer 103(7):1128-35 PMID: 20877339
- Kheifets L** et al 2010 – *A pooled analysis of Extremely Low-Frequency Magnetic Fields and Childhood Brain Tumors* Am J Epidemiol 172(7):752-61 PMID: 20696650
- Kheifets L & S Oksuzyan** 2008 - *Exposure assessment and other challenges in non-ionizing radiation studies of childhood leukaemia* Radiat Prot Dosimetry 132(2):139-47 PMID: 18940819
- Kheifets L** et al 2006 – *Public health impact of extremely low-frequency electromagnetic fields* Environ Health Perspect 114(10):1532-7 PMID: 17035138
- Kleinerman RA** et al 2000 – *Are children living near high-voltage power lines at increased risk of acute lymphoblastic leukemia?* Am J Epidemiol 151:512-515 PMID: 10707920
- Kroll ME** et al 2010 - *Childhood cancer and magnetic fields from high-voltage power lines in England and Wales: a case-control study* Br J Cancer 103(7):1122-7 PMID: 20877338
- Lagorio S** et al 2013 - *Exposure to benzene and childhood leukaemia: a pilot case-control study* BMJ Open 3(2) PMID: 23444447
- Li CY** et al 1998 – *Risk of leukaemia in children living near high-voltage transmission lines* J Occup Environ Med 40(2): 144-7 PMID: 9503290
- Li D-K** et al 2002 - *A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage* Epidemiology 13(1): 9-20 PMID: 11805581
- Li P** et al 2009 – *Maternal occupational exposure to extremely low frequency magnetic fields and the risk of brain cancer in the offspring* Cancer Causes Control 20(6):945-55 PMID: 19224378
- Lin RS & WC Lee** 1994 – *Risk of childhood leukaemia in areas passed by high power lines* Rev Environ Health 10(2): 97-103 PMID: 8047676
- Linnet MS** et al 1997 – *Residential exposure to magnetic fields and acute lymphoblastic leukemia in children* N Engl J Med 337(1):1-7 PMID: 9203424
- Lowenthal RM** et al 2007 – *Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study* Intern Med J 37(9):614-9 PMID: 17543004
- Lupke M** et al 2006 – *Gene expression analysis of ELF-MF exposed human monocytes indicating the involvement of the alternative activation pathway* Biochim Biophys Acta 1763(4):402-12 PMID: 16713449
- Lupke M** et al 2004 – *Cell activating capacity of 50 Hz magnetic fields to release reactive oxygen intermediates in human umbilical cord blood-derived monocytes and in Mono Mac 6 cells* Free Radic Res 38(9):985-93 PMID: 15621717
- Mahé E** et al 2011 - *Outdoor sports and risk of ultraviolet radiation-related skin lesions in children: evaluation of risks and prevention* Br J Dermatol 165(2):360-7 PMID: 21574980
- Malagoli C** et al 2010 – *Risk of hematological malignancies associated with magnetic fields exposure from power lines: a case-control study in two municipalities of northern Italy* Environ Health 9(1):16 PMID: 20353586
- Maskarinec G** et al 1994 - *Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations.* J Environ Pathol Toxicol Oncol. 13:33–37 PMID: 7823291
- Maslanyj M** et al 2010 – *A precautionary public health protection strategy for the possible risk of childhood leukaemia from exposure to power frequency magnetic fields* BMC Public Health 10(1):673 PMID: 21054823
- McBride ML** et al 1999 – *Power-frequency electric and magnetic fields and risk of childhood leukemia in Canada* Am J Epidemiol 149(9):831-42 PMID: 10221320
- Mejia-Arangure JM** et al 2007 – *Magnetic fields and acute leukemia in children with Down Syndrome* Epidemiology 18(1):158-61 PMID: 17099322
- Merzenich H** et al 2008 – *Childhood Leukemia in Relation to Radio Frequency Electromagnetic Fields in the Vicinity of TV and Radio Broadcast Transmitters* Am J Epidemiol 168(10):1169-78 PMID: 18835863
- Mezei G** et al 2008 – *Assessment of selection bias in the Canadian case-control study of residential magnetic field exposure and childhood leukaemia* Am J Epidemiol 167(12):1504-10 PMID: 18483123
- Mezei G** et al 2008 – *Residential magnetic field exposure and childhood brain cancer: a meta-analysis* Epidemiology 19(3):424-30 PMID: 18379430

- Michaelis J** et al 1998 – *Combined risk estimates for two German population-based case-control studies on residential magnetic fields and childhood acute leukemia* Epidemiology 9:92-94 PMID: 9430275
- Michaelis J** et al 1997 – *Childhood leukemia and electromagnetic fields: results of a population-based case-control study in Germany* Cancer Causes Control 8(2):167-74 PMID: 9134240
- Musselman JR & LG Spector** 2011 – *Childhood cancer incidence in relation to sunlight exposure* Br J Cancer 104(1):214-20 PMID: 21102587
- Nakamura Y** et al 2001 – *Changes of serum melatonin level and its relationship to feto-placental unit during pregnancy* J Pineal Res 30(1):29-33 PMID: 11168904
- Navarro EA** et al 2003 - *The microwave syndrome: a preliminary study in Spain* Electromagn Biol Med. 22:161–169
- Neutra** et al 2002 - *California EMF Program report - An Evaluation of the Possible Risks From Electric and Magnetic Fields (EMFs) From Power Lines, Internal Wiring, Electrical Occupations and Appliances*
- Okatani Y** et al 2001 – *Melatonin protects against oxidative mitochondrial damage induced in rat placenta by ischemia and reperfusion* J Pineal Res 31(2):173-8
- Olshan AF** et al 1999 - *Neuroblastoma and parental occupation* Cancer Causes Control 10(6):539-49 PMID: 10616823
- Pearce MS** et al 2007 - *Paternal occupational exposure to electro-magnetic fields as a risk factor for cancer in children and young adults: a case-control study from the North of England* Pediatr Blood Cancer 49, 280-6
- Pedersen C** et al 2014 - *Distance from residence to power line and risk of childhood leukemia: a population-based case-control study in Denmark* Cancer Causes Control 25(2):171-7 PMID: 24197706
- Pelissari DM** et al 2009 – *Magnetic fields and acute lymphoblastic leukemia in children: a systematic review of case-control studies* Cad Saude Publica 25 Suppl 3:S441-52
- Petridou ET** et al 2007 - *Sun exposure, birth weight, and childhood lymphomas: a case control study in Greece* Cancer Causes Control 18(9):1031-7 PMID: 17653828
- Preston-Martin S** et al 1996 – *Los Angeles study of residential magnetic fields and childhood brain tumors* Am J Epidemiol 143(2):105-19
- Reid A** et al 2011 - *Risk of childhood acute lymphoblastic leukaemia following parental occupational exposure to extremely low frequency electromagnetic fields* Br J Cancer 105(9):1409-13 PMID: 21915123
- Rollwitz J** et al 2004 – *Fifty-hertz magnetic fields induce free radical formation in mouse bone marrow-derived promonocytes and macrophages* Biochim Biophys Acta 1674(3):231-8
- Röösl M** 2013 - *[In Process Citation]* Ther Umsch 70(12):733-8 PMID: 24297859
- Saito T** et al 2010 – *Power-Frequency Magnetic Fields and Childhood Brain Tumors: A Case-Control Study in Japan* J Epidemiol 20(1):54-61
- Santini MT** et al 2005 – *Extremely low frequency (ELF) magnetic fields and apoptosis: a review* Int J Radiat Biol 81(1): 1-11
- Santini R** et al 2003 - *Symptoms experienced by people in vicinity of base stations: II/Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors.* Pathol Biol (Paris). 51:412–415.
- Santini R** et al 2002 - *Investigation on the health of people living near mobile telephone relay stations: I/Incidence according to distance and sex* Pathol Biol (Paris). 50:369–373.
- Schüz J** et al 2011 - *Exposure to extremely low-frequency magnetic fields and the risk of childhood cancer: update of the epidemiological evidence* Prog Biophys Mol Biol 107(3):339-42 PMID: 21946043
- Schüz J** et al 2007 – *Nighttime exposure to electromagnetic fields and childhood leukemia: an extended pooled analysis* Am J Epidemiol 166(3):263-9
- Schüz J** et al 2001 - *Residential magnetic fields as a risk factor for childhood acute leukaemia: results from a German population-based case-control study* Int J Cancer 91(5):728-35
- Schüz J** et al 2001 – *Childhood acute leukaemia and residential 16.7 Hz magnetic fields in Germany* Br J Cancer 84(5):697-9
- Seaton A** et al 1995 – *Particulate air pollution and acute health effects* Lancet 345: 176-178

- Sermage-Faure C** et al 2013 - Childhood leukaemia close to high-voltage power lines--the Geocap study, 2002-2007 *Br J Cancer* 108(9):1899-906 PMID: 23558899
- Simko M & Mattson MO** 2004 – *Extremely low frequency electromagnetic fields as effectors of cellular responses in vitro: possible immune cell activation* *J Cell Biochem* 93(1): 83-92
- Smulevich VB** et al 1999 – *Parental occupation and other factors and cancer risk in children: I. Study methodology and non-occupational factors* *Int J Cancer* 83:712-17 PMID: 10597183
- Smulevich VB** et al 1999 – *Parental occupation and other factors and cancer risk in children: II. Occupational factors* *Int J Cancer* 83(6):718-22
- Söderberg KC** et al 2002 - *Childhood leukemia and magnetic fields in infant incubators* *Epidemiology* 13(1):45-9
- Sohrabi MR** et al 2010 - *Living near overhead high voltage transmission power lines as a risk factor for childhood acute lymphoblastic leukemia: a case-control study* *Asian Pac J Cancer Prev* 11(2):423-7 PMID:20843128
- Stevens RG** 2012 - *Does electric light stimulate cancer development in children?* *Cancer Epidemiol Biomarkers Prev* 21(5):701-4 PMID: 22354903
- Svensden AL** et al 2007 – *Exposure to magnetic fields and survival after diagnosis of childhood leukemia: a German cohort study* *Cancer Epidemiol Biomarkers Prev* 16(6):1167-71
- Swanson J** et al 2006 - *Power-frequency electric and magnetic fields in the light of Draper et al. 2005* *Ann N Y Acad Sci* 1076:318-30 PMID: 17119212
- Tan DX** et al 1999 – *Identification of highly elevated levels of melatonin bone marrow: its origin and significance* *Biochim Biophys Acta* 1472:206-214
- Teepen JC & JA van Dijck** 2012 - *Impact of high electromagnetic field levels on childhood leukemia incidence* *Int J Cancer* 131(4):769-78 PMID: 22437882
- Thériault G & C Li** 1997 - *Risks of leukaemia among residents close to high voltage transmission electric lines* *Occup Environ Med* 54(9): 625-8
- Timmel CR & Henbest KB** 2004 – *A study of spin chemistry in weak magnetic fields* *Philos Transact A Math Phys Eng Sci* 362(1825): 2573-2589
- Tynes T & T Haldorsen** 1997 – *Electromagnetic fields and cancer in children residing near Norwegian high-voltage power lines* *Am J Epidemiol* 145:219-226
- UKCCS Investigators** 1999 – *Exposure to power-frequency magnetic fields and the risk of childhood cancer* *Lancet* 354:1925
- Urayama KY** et al 2011 – *Early life exposure to infections and risk of childhood acute lymphoblastic leukemia* *Int J Cancer* 128(7):1632-43 PMID: 21280034
- Vijayalaxmi** et al 1999 - *Melatonin and protection from whole-body irradiation: survival studies in mice* *Mutat Res* 425(1): 21-27
- Vijayalaxmi** et al 1996 - *Melatonin and radioprotection from genetic damage: In vivo/in vitro studies with human volunteers* *Mutat Res* 371(3-4): 221-228
- Vijayalaxmi** et al 1995 - *Marked reduction of radiation-induced micronuclei in human blood lymphocytes pretreated with melatonin* *Radiat Res* 143(1): 102-106
- Wakatsuki A** et al 1999 – *Melatonin protects against ischemia and reperfusion-induced oxidative lipid and DNA damage in fetal rat brain* *J Pineal Res* 26(3):147-52
- Wartenberg D** 2001 - *Residential EMF Exposure and Childhood Leukaemia: Meta-analysis and population attributable risk* *Bioelectromagnetics Suppl* 5: S86-104
- Wünsch-Filho V** et al 2011 – *Exposure to magnetic fields and childhood acute lymphocytic leukemia in São Paulo, Brazil* *Cancer Epidemiol* 35(6):534-9 PMID: 21840286
- Yang Y** et al 2008 - *Case-only study of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1 and XPD) and low-frequency electromagnetic fields in childhood acute leukemia* *Leuk Lymphoma* 49(12):2344-50 PMID: 19052983
- Zhao L** et al 2014 - *Magnetic fields exposure and childhood leukemia risk: A meta-analysis based on 11,699 cases and 13,194 controls* *Leuk Res* 38(3):269-274 PMID: 24388073