Residential and occupational exposure to 50 Hz magnetic fields and malignant melanoma: a population based study

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Aims: To test the hypothesis that exposure to electromagnetic fields from high voltage power lines increases the incidence of cutaneous malignant melanoma in adults aged 16 and above.

Methods: Nested case-control study. The study population comprised subjects aged 16 and above who had lived in a residence situated in a broad corridor around a high voltage power line in 1980, or one of the years from 1986 to 1996. The cases were incident cases that were diagnosed in 1980–96 and reported to the Cancer Registry of Norway. Two controls were matched to each case by year of birth, sex, municipality, and first year entering the cohort. Time weighted average exposure to residential magnetic fields generated by the power lines was calculated for the exposure follow up from 1 January 1967 until diagnosis by means of a computer program, in which distance from residency to the line, line configuration, and current load were taken into account. Exposure was analysed using cut off points at 0.05 and 0.2 microtesla (μT). Exposure to magnetic fields at work was classified by an expert panel who assessed magnetic field exposure by combining branch and occupation into one of three levels: <4 hours, 4–24 hours, and >24 hours per week above background (0.1 μT). The categories were cumulated over the occupationally active years for the exposure follow up from 1 January 1955 until diagnosis, and cut off points at 18 and 31 category-years were evaluated.

Results: Analysis of the two upper residential magnetic field categories showed an odds ratio of 2.01 (95% CI 1.09 to 3.69) and 2.68 (95% CI 1.43 to 5.04) for women, and an odds ratio of 1.70 (95% CI 0.96 to 3.01) and 1.37 (95% CI 0.77 to 2.44) for men, respectively. Occupational exposure (95% CI 1.09 to 3.69) and 2.68 (95% CI 1.43 to 5.04) for women, and an odds ratio of 1.70 (95% CI 0.96 to 3.01) and 1.37 (95% CI 0.77 to 2.44) for men, respectively. Occupational exposure showed no significant association with cutaneous malignant melanoma, and analysis of both residential and occupational exposure simultaneously, showed no additional effect.

Conclusion: The present study provides some support for an association between exposure to calculated residential magnetic fields and cutaneous malignant melanoma, but because of the lack of a biological hypothesis and the known strong association between solar radiation and melanoma, no firm conclusions can be drawn and further studies would be of interest.

Solar ultraviolet radiation (UVR) is a well established risk factor for cutaneous malignant melanoma (CMM), but many factors are still obscure. A recent report from Norway indicated that sun exposure at any age is of importance for the lifetime risk of CMM. The study also showed that it was half as hazardous to be born in the northern part than in the southeastern part of Norway.

Since 1979, a large number of studies have reported increased cancer risk in children and adults exposed to extremely low frequency magnetic fields; of particular interest have been leukaemia, brain tumours, and more recently breast cancer. Recently, an International Agency for Research on Cancer (IARC) working group evaluated extremely low frequency (ELF) magnetic fields as possibly carcinogenic to humans, based on the statistical association of higher level residential magnetic fields and increased risk for childhood leukaemia.2 No consistent evidence was found for other cancer sites in children and adults in relation to such exposure.

Few studies have addressed CMM in relation to residential electromagnetic field exposure. A study from Finland reported a non-significant increased incidence rate ratio of melanoma in adults living close to power lines.3 Studies of workers in the telecommunications, electronics, and electric utility industries have reported increased risk of melanoma,4 but an alternate explanation for this finding has been exposure to polychlorinated biphenyls5; other studies addressing CMM and exposure to magnetic fields at work have yielded mixed results.6 A recent report linked uveal melanoma to a history of employment in occupations involving use of selected radio frequency radiation transmitting devices.7 An increased risk of CMM has also been reported in airline crew, but although they are exposed to cosmic radiation and electromagnetic fields, the most likely explanation for the risk shown is increased exposure to solar radiation.8

The study of melanoma was a priori motivated by the hypothesis proposed by Stevens, in which electromagnetic fields may contribute to hormone related cancers.9 According to the hypothesis, reduced melatonin production in exposed individuals will be accompanied by an increase in oestrogen secretion by the ovary and prolactin secretion by the pituitary gland. Reports have indicated that melanoma cells have both melatonin and oestrogen receptors.10,11 Animal studies addressing the role of 50/60 Hz magnetic fields in carcinogenesis have indicated interactions between such exposure and melatonin, but the experimental evidence is still insufficient for any firm conclusions to be drawn, and results from animal and human studies investigating possible suppressing effects of ELF magnetic fields on melatonin have yielded equivocal results.12

The aim of this study was to test the hypothesis that exposure to 50 Hz residential and occupational magnetic fields of

Abbreviations: CI, confidence interval; CMM, cutaneous malignant melanoma; ELF, extremely low frequency; GIS, geographical information systems; OR, odds ratio; TWA, time weighted average; UVR, ultraviolet radiation
the type generated by high voltage power lines increases the risk of CMM in relation to the subjects’ calculated exposure to magnetic fields on the basis of data on line configuration and historical loads on power lines.

METHODS

Study population

The study population comprised all persons (aged 16 and above) who, at 1 November 1980, or at 1 January in at least one of the years from 1986 to 1996 had lived in a residency in a broad corridor around a high voltage power line. A person entered the cohort the first year he was registered in a residency within the corridor. The corridor around each power line was established through geographical information systems (GIS), and was chosen to be wide enough to ensure that it included both exposed and unexposed residences. The Norwegian Mapping Authority provided the coordinates of every Norwegian residence linked to its address, and the Norwegian Water Resources and Energy Directorate provided the coordinates of power lines from 33 to 420 kV. By combining this information, distance from residences to a power line was calculated within the corridor. With reference to the address code, Statistics Norway was able to identify individuals who had lived in such a residency at the above mentioned points in time.

Cases and controls

The cohort was linked to the Cancer Registry of Norway by using the unique identification number; we identified all persons diagnosed with melanoma between 1 January 1980 and 31 December 1996, aged 16 and above. For each case, two controls were selected at random from the cohort using the following criteria: alive at the time of diagnosis of the case and entering the cohort at the same year as the case, matched for sex, year of birth (±5 years), and municipality at the first point in time entering the cohort. Subsequently, Statistics Norway provided a residential history for cases and controls as far back as 1967; for the years 1967 to 1985, migration within a municipality was not registered; from 1986 to 1996 migration within a municipality was registered. By combining this information with the start year for the power line, a subject’s years in a home near a power line could be identified.

Cancer registration

The Cancer Registry has recorded all new cases of cancer in Norway since 1953. The system is based on compulsory reporting by hospital departments and histopathological laboratories. The coding of cancers is based on a modified version of the International Classification of Diseases, 7th revision (ICD-7).

Exposure to magnetic fields

Residential exposure was defined as magnetic fields generated by power lines close to dwellings. The exposure follow up was from 1 January 1967 until year of diagnosis. The calculations were performed by use of a computer program (Teslaw) developed at SINTEF Energy, Norway. The program presents the result as µT root mean square magnetic field strength. This is the sum of the vectors for the individual conductor in a given situation integrated over one period. Underground cables were not taken into account because they are not believed to be a significant source of magnetic fields. The calculations took account of height of towers, distance between phases, ordering of phases, distance between the power line and the house, and average (mean) load on the power line for each year a study subject had lived in the house. Changes of the configuration of the power lines were taken into account. Based on the fact that GIS information was somewhat crude regarding distances to power lines, we decided to collect corrected distances from economic maps (scale 1:5000) for the residencies situated in the closest half of the corridor. Distance to the power lines was defined as the distance from the closest corner of the house to the midpoint between the outer phases of a line. The historical load was estimated as the yearly average loads in amperes for each year the study subject had lived close to the line. The loads for one year were usually based on day to day records. If a record was not available, the historical load was assessed by experienced staff members of the power company on the basis of information for nearby lines and present and historical knowledge of the company’s transmission and distribution system. Time weighted average (TWA) residential exposure to magnetic fields was a priori divided into three categories, with cut off points 0.05 and 0.2 µT. The first was based on the fact that Norwegian homes in general have low exposure, the latter on the cut off used in earlier reports in the literature. The following exposure parameters were evaluated: TWA from 1 January 1967 until diagnosis, and TWA for the five years before diagnosis.

Exposure to magnetic fields at work was assessed a priori, and the method was a practical modification of the method of expert judgement used by Flynn and colleagues. The assessment was individually performed by an expert panel and is described in more detail elsewhere. A guideline, disseminated to the experts, was to assign a rank if they believed the job involved exposure above background level (0.1 µT): a rank of 1 if the level was less than four hours a week; a rank of 2 when more than four hours and less than 24 hours per week; and a rank of 3 if the job was above background level for more than 24 hours per week. The classification of a job was based on a 3–5 digit industry code and a 3 digit occupation code used at the Norwegian censuses in 1960, 1970, 1980, and 1990. For many subjects the 1990 occupation was missing; we therefore assigned the 1980 information to 1990. The exposure follow up was from 1 January 1955 until date of diagnosis, and the potentially occupationally active period was defined as the age interval 18–67. We cumulated exposure categories multiplied by the number of years. For subjects changing occupation between two censuses, we cumulated the first occupation until the midpoint between the two relevant censuses. We used the first and third quartile among the controls as cut off points. The values were 18 and 31 category-years, respectively.

Other factors

Educational level was used as indicator for socioeconomic status: 1, primary school; 2, secondary school; 3, university/college. Table 1 shows the demographic information and distribution of TWA residential magnetic field exposure for cutaneous malignant melanoma cases and controls living close to high voltage power lines in Norway, 1980–96.
A likelihood ratio test was performed.

Based on our matching of sex, age, and geographical region, we evaluated a potential difference in effect over subgroups of sex, age, and geographical regions.

For both total analysis and analysis for women showed a significantly increased risk and an increasing trend both for overall TWA exposure to residential magnetic fields and for exposure during the latest five years. For men, a significantly increased risk and an increasing trend were seen only for TWA exposure during the latest five years. Analysis evaluating magnetic fields as a continuous variable yielded the following results for both genders combined: for overall TWA exposure, OR = 3.68 (95% CI 1.85 to 7.34); for exposure in the latest five years, OR = 1.88 (95% CI 1.33 to 2.66).

Based on our matching of sex, age, and geographical region, we evaluated a potential difference in effect over subgroups of these variables, and tested the difference by introducing an interaction term between total TWA magnetic fields and the variable defining the subgroup. Results of the likelihood ratio test were as follows: sex, p = 0.05; age above and below 55 years, p = 0.85; and two geographical regions, p = 0.88.

Table 2 presents ORs for melanoma overall and by sex in relation to exposure to magnetic fields, given as total TWA and TWA during the latest five years. Since adjustment for educational level, number of dwellings, and type of residence did not affect the results, we only present the crude analysis. Both total analysis and analysis for women showed a significantly increased risk and an increasing trend both for overall TWA exposure to residential magnetic fields and for exposure during the latest five years. For men, a significantly increased risk and an increasing trend were seen only for TWA exposure during the latest five years. Analysis evaluating magnetic fields as a continuous variable yielded the following results for both genders combined: for overall TWA exposure, OR = 3.68 (95% CI 1.85 to 7.34); for exposure in the latest five years, OR = 1.88 (95% CI 1.33 to 2.66).

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Table 3 presents risk of CMM by part of body and exposure to calculated residential TWA* magnetic fields; adults living close to high voltage power line in Norway, 1980–96.

Table 4 presents odds ratios for different levels of occupational magnetic field exposure. Results are presented for both genders as well as for women and men. The analysis yielded no increasing trend or any significantly increased ORs. Analysis of subjects with exposure both at home and at work did not provide support for an additional effect of the
combined exposures (data not shown). Analysis of residential exposure ≥0.02 μT only, and removing the highly exposed at work (category × years = 18) gave the following results: for both genders combined, OR = 2.07 (95% CI 1.18 to 3.62, 29 cases); for women, OR = 2.83 (95% CI 1.25 to 6.39, 16 cases), and for men, OR = 1.71 (95% CI 0.74 to 3.93, 13 cases).

**DISCUSSION**

This study provides support for an association between residential exposure to magnetic fields and CMM, in particular for women. Occupational exposure showed no significant association with CMM, and analysis of both residential and occupational exposure simultaneously showed no additional effect.

The study was conducted within a well defined cohort, and selection bias was minimised by the use of data available at Statistics Norway. The study was not biased by differential recall of past exposure by cases and controls. We were successful in obtaining information pertinent to exposure estimation; all of the relevant data on power lines needed to calculate magnetic fields were available, and any misclassifications were probably non-differential. The urban-rural distribution of the residences and the high proportions of cases and controls from areas outside Oslo indicate that the analysis is based on a data set that represents different segments of the Norwegian population.

A previous dosimeter study among children living close to a power line in Norway showed that the magnetic fields from the line are the major source of exposure. This should also be the case for adults, in particular for those not exposed to magnetic fields at work. In comparison with other countries, such as Sweden, the contribution of ground currents to magnetic fields in homes is minor in Norway because of a different grounding system.

Based on the fact that moving within municipalities was available only for the period 1986 to 1996, study subjects with a history of moving (516 of 2421) have more reliable information on residential exposure if the moving took place in 1986 or later. No personal measurements of magnetic fields were available, and any misclassifications were probably non-differential. The urban-rural distribution of the residences and the high proportions of cases and controls from areas outside Oslo indicate that the analysis is based on a data set that represents different segments of the Norwegian population.

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