SHORT REPORT

Risk for leukaemia and brain and breast cancer among Danish utility workers: a second follow-up

Christoffer Johansen, Ole Raaschou Nielsen, Jørgen H Olsen, Joachim Schüz

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Objective: To update a study of risks for leukaemia, brain cancer and breast cancer in a Danish nationwide, population-based cohort of utility employees.
Methods: A multivariate statistical model including information on age, duration of employment, date of first employment and level of occupational exposure to electromagnetic fields was applied.
Results: No increased risk for these cancers was seen among 28 224 subjects with more than 3 months of employment in whom cancer had not been diagnosed before first employment.
Conclusion: The results do not support the hypothesis of an association between occupational exposure to magnetic fields in the electric utility industry and risks for leukaemia, brain cancer and breast cancer.

Occupational exposure to extremely low-frequency (50–60 Hz) electromagnetic fields (ELF-EMF) has been investigated as a possible cause of leukaemia and brain and breast cancer in many epidemiological studies. The Danish utility worker cohort consisted of all employees at the 99 utility companies that have supplied all of Denmark with electricity since the beginning of the past century. This nationwide cohort has been followed-up for pacemaker implantation,[1] diseases of the central nervous system,[2 3] cause-specific mortality[4] and cancer incidence.[5]

In the study reported in this paper, we used a revised job-exposure matrix to investigate the risks for leukaemia and brain and breast cancer, which are the cancers suspected a priori to be associated with exposure to EMF.

MATERIAL AND METHODS

Study group

The study group comprised all employees at the 99 public and privately owned utility companies that supply Denmark with electricity. The construction of the cohort has been described in detail elsewhere.[5] We identified 32 475 people who had been employed for at least 3 months in a Danish electric utility company during the 20th century. The information available on each employee included name, date of birth or personal identification number (a unique 10-digit number introduced in Denmark on 1 April 1968, which incorporates sex and date of birth), tasks at the company, date of first employment at any of the companies and subsequent period(s) of employment. A job-exposure matrix specific for EMF was designed that distinguished 25 job titles of workers in utility companies and 19 work areas within the industry. Experienced engineers in the utility industry assigned an average level of exposure to 50 Hz EMF during a working day to each of the 475 combinations of job title and work area. The levels of exposure to ELF-EMF were then grouped into three categories: background exposure ($\leqslant$0.099 μT), medium exposure (0.1–0.99 μT) and high exposure ($\geqslant$1.0 μT).[6] We assigned exposures of subjects on the basis of the characteristics of the first employment held; according to the company files, only 323 men and 97 women changed their job title during the period of employment. We therefore assumed that category-specific exposure levels were unchanged over the study period. We conducted an internal comparison across exposure categories applying a multiplicative Poisson regression model.

The personal identification number permits accurate linkage of information between registries, and linkage with the Central Population Register allowed verification of the personal identification numbers of 32 475 workers and provided information on vital status and migration through 2002. By this procedure, we excluded 1840 workers who died before 1 January 1978 and for whom we were not able to obtain complete information on cause of death, and four workers for whom personal data could not be verified. Finally, we excluded 2407 workers for whom we had no information on exposure, leaving 28 224 employees for inclusion in this study.

The study cohort was linked to the Danish Cancer Registry, which has been in operation since 1942. The period of follow-up for occurrence of a first primary cancer among the employees was taken from 1 April 1968 or the date of first employment, whichever came last, to the date of death, emigration or 31 December 2002, whichever came first. Only periods of employment in a utility company were considered as incurring possible exposure to ELF-EMF. Non-melanoma skin cancer was not considered to be a first primary cancer, and any cancer occurring subsequently was counted as the first primary cancer.

RESULTS

The 28 224 employees (22 436 men and 5788 women) in the study accrued 642 108 person-years of follow-up, with an average of 22.8 years. The risks for leukaemia among men (n = 70) and for breast cancer among women (n = 188) were close to unity for employees in both the medium and high exposure categories. The relative risk (RR) for brain cancer among men with high exposure was lower than that of men with background exposure (n = 24; RR = 0.69; 95% CI 0.38 to 1.25), whereas the risk for brain cancer among women was higher for those with medium exposure than for women with background exposure (n = 20; RR = 1.37; 95% CI 0.51 to 3.69; table 1). The numbers of cases of leukaemia among women and of male breast cancer were small, and these data were thus not included in the study.

DISCUSSION

In this long-term follow-up study, we found no compelling evidence for an association between cancers that have been linked with exposure to EMF in previous studies. The results confirm the negative findings for leukaemia and brain and breast cancer in our previous study.[5]

Our finding of no increased risk for leukaemia is in line with the results of other studies of occupational cancers.[7–9] Although a small case–control study in New Zealand showed an almost

Table 1 Adjusted relative risks* for leukaemia, brain cancer and breast cancer among 22 335 men and 5774 women who had been employed for at least 3 months at a utility company in Denmark between 1900 and 1993, including incident cases of cancer diagnosed from 1 April 1968 to 31 December 2002, by average estimated level of exposure to electromagnetic fields at work

Cancer (No of cases)	Background exposure (⩽0.09 μT)	Medium exposure (0.1–0.99 μT)	High exposure (⩾1.0 μT)
Person-years	128 936	343 140	170 032
Leukaemia			
Men (70)	1.0	0.97 (0.51 to 1.85)	1.04 (0.53 to 2.04)
Brain tumours			
Men (85)	1.0	0.80 (0.47 to 1.37)	0.69 (0.38 to 1.25)
Women (25)	1.0	1.37 (0.51 to 3.69)	No cases
Breast cancer			
Women (188)	1.0	0.77 (0.56 to 1.07)	1.04 (0.32 to 3.34)

Results are shown as RR (95% CI).
*Relative risks from a Poisson regression model with the variables occupational exposure to electromagnetic fields, age, duration of employment and calendar year as covariates.

threefold increase in risk for leukaemia among welders and flame cutters, the result was based on only 14 cases and nine controls.[10] Updates of two previous studies of cohorts in Sweden and the USA showed no increased risk for leukaemia.[11 12]

The risk for brain cancer was investigated in several studies[7 8 13–15] after publication of a Danish study in 1998 that gave overall negative results. In the study in Sweden by Håkansson *et al*,[12] an excess risk for grades I–II astrocytoma was observed among people with ''high'' and ''very high'' exposure. Likewise, in the study by Wijngaarden *et al* in the USA,[11] excess mortality from brain cancer among electricians was observed in the updated analysis. Two other Scandinavian cohort studies did not find substantial increases in the risk for brain tumours.[16 17]

In the cohort study of Håkansson *et al*,[12] no excess risk for breast cancer was observed among women. In a Norwegian study of female radio and telegraph operators, the standardised incidence ratio for breast cancer was increased by 30%.[18] Three case–control studies, with 1018 cases,[19] 843 cases[11] and 556 cases in postmenopausal women,[20] found increased risks for breast cancer among women occupationally exposed to ELF-EMF; however, no attempt was made in these studies to measure or classify occupations by potential exposure to ELF-EMF, and only relatively crude categories of exposure based on job title were used.[19 20] No increase in the risk for breast cancer was found in a recently published Swedish study of 20 400 cases of female breast cancer identified through a regional cancer registry and 116 227 population-based female controls, in which a better exposure matrix was used, based on direct measurements and including more data on the women's occupations.[21]

Our study has several advantages, including access to nationwide, population-based health registries through the personal identification number, leading to almost complete information on incident cases of cancer over decades of follow-up. The administrative nature of these registers, the fact that company employment files for the workers were established years before diagnosis of a cancer was reported to the Danish Cancer Register, and the completeness of the employment files make selection and information bias unlikely. We included only primary cancers, so that secondary cancers could not be the outcome studied. We validated the EMF exposure matrix and reassigned exposure categories to some of the cohort members.[6] We found almost twice the number of cases of breast cancer in women as in our first study, the number of brain tumours increased from 72 cases to 110 and 10 more cases of leukaemia were added. The potential bias introduced by the ''healthy worker effect'' was dealt with in the present analysis by using a statistical model, that allowed an internal comparison of risks across ELF-EMF exposure categories for the cohort of utility workers.

CONCLUSION

The results of this extended follow-up of the Danish utility cohort are in line with the overall conclusion reached by the International Agency for Research on Cancer in 2002, that there was no consistent exposure–response relationship across studies and no consistent association with specific subtypes of leukaemia and brain cancer.[22] In line with the conclusion of the most recent review,[23] we found no evidence for an association between exposure to ELF-EMF and the risk for breast cancer.

Policy implications

- The result of this study is in line with the overall evaluation by the International Agency for Research on Cancer in 2002.
- The data do not suggest a need to change the international guidelines (International Commission on Non-ionizing Radiation Protection) for occupational exposure to 50/60 Hz electromagnetic fields.

Main messages

- Occupational exposure to 50/60 Hz electromagnetic fields does not increase the risks for leukaemia, brain cancer or female breast cancer.
- This cohort study included a validated matrix for occupational exposure to electromagnetic fields, rates of primary cancers and an internal comparison model, which strengthen the overall results of the study.

Authors' affiliations
Christoffer Johansen, Ole Raaschou Nielsen, Jørgen H Olsen, Joachim Schüz, Institute of Cancer Epidemiology, Danish Cancer Society, Strandboulevarden 49, DK-2100 Copenhagen, Denmark

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Correspondence to: Dr C Johansen, Division for Cancer Epidemiology, Strandboulevarden 49, DK-2100 Copenhagen, Denmark; christof@cancer.dk

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