Original research

Malignant lymphoma and occupational exposure to extremely low frequency magnetic fields and electrical shocks: a nested case-control study in a cohort of four Nordic countries

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ABSTRACT

Background Exposure to extremely low frequency magnetic fields (ELF-MFs) and electric shocks is a common occupational risk factor in many workplaces. Recent investigations have highlighted a possible association between such exposures and lymphoma risk. This study was carried out to further explore the association between occupational exposure to ELF-MFs and electric shocks and risk of lymphoma in a large Nordic census-based cohort.

Methods We included cases of non-Hodgkin's lymphoma (NHL, n=68 978), chronic lymphocytic leukaemia (CLL, n=20 615) and multiple myeloma (MM, n=35 467) diagnosed between 1961 and 2005 in Finland, Iceland, Norway and Sweden. Cases were matched to five controls by year of birth, sex and country. Lifetime occupational ELF-MF and electric shock exposures were assigned to jobs reported in population censuses using job-exposure matrices. The risk of cancer was assessed based on cumulative exposure to ELF-MF and electric shocks. ORs with 95% CIs were estimated using logistic models adjusted for occupational co-exposures relevant to lymphomas.

Results Less than 7% of the cases experienced high levels of ELF-MF. We observed no increased risks among workers exposed to high levels of ELF-MF for NHL (OR: 0.93; CI 0.90 to 0.97), CLL (OR: 0.98; CI 0.92 to 1.05) or MM (OR: 0.96; CI 0.90 to 1.01).

Conclusion Our results do not provide support for an association between occupational exposure to ELF-MFs and electric shocks and lymphoma risk.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ While there is evidence that exposure to extremely low frequency magnetic fields (ELF-MFs) and electric shocks might increase the risk of leukaemia, only few and inconsistent findings have been reported regarding lymphoma outcomes.

WHAT THIS STUDY ADDS

⇒ The findings do not support the hypothesis that exposure to ELF-MF and electric shocks is associated with lymphoma risk.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE AND/OR POLICY

⇒ Further research into lymphoma risk associated with ELF-MFs and electric shocks should not be a research priority. Considering other established and potential negative health outcomes, these exposures practically should still be kept at low as possible.

INTRODUCTION

Exposure to extremely low frequency magnetic fields (ELF-MFs) is a common occupational risk factor in many workplaces, originating from electrical appliances and electrical motors,[1 2] power lines,[3 4] sewing machines,[5] medical equipment[6] or any other devices powered by electricity.[7] A high risk for experiencing electric shocks also has been observed in about 70% of workers with a high level of ELF-MF exposure, indicating a concurrent exposure to both occupational factors.[8]

While there are indications that exposure to ELF-MF might increase the risk of leukaemia,[9] only few and inconsistent findings have been reported regarding lymphoma.[10–13]

A case-control study of Karipidis *et al* linked the total work history of ELF-MF exposed workers to a job exposure matrix (JEM) and observed a significantly elevated OR of 1.48 for non-Hodgkin's lymphoma (NHL) among the fourth quartile exposed group (≥9.85 µT-years) compared with the first quartile (<3.92 µT-years).[11] A pooled analysis of 10 NHL case-control studies from the InterLymph Consortium among 24 occupational groups revealed a 24% elevated risk of NHL among electrical wiremen.[13] A cohort study among American electric utility workers indicated that total cumulative exposure to ELF-MF raised rate ratios to 2.9 and 4.7 for NHL among median and highly exposed workers, respectively.[14] In a case-control study, Floderus *et al* assessed the work history and performed personal monitoring of ELF-MF exposed individuals, and observed that daily mean exposure of ≥0.2 µT significantly increased the risk of chronic lymphocytic leukaemia (CLL) up to 3.7 compared with the reference group (≤0.15 µT).[15] In a cohort study by Floderus *et al*, elevated risk of multiple myeloma (MM) was not observed among medium (0.084–0.115 µT) or high (≥0.116 µT)

ELF-exposed Swedish workers.[16] A meta-analysis on the relationship between occupational ELF-MF exposure and risk of haematolymphopoietic malignancies reported the strongest relative risk of 1.35 for CLL.[9] Eriksson and Karlsson, by studying 275 MM confirmed cases in four counties in northern Sweden observed a significantly decreased risk of MM among electricians and linemen.[17]

Findings of other studies on electric utility workers, welders or other occupational groups generally did not support a relationship between ELF-MF exposure and excess risk of lymphomas.[12 18–21]

While a high exposure to ELF-MF is correlated with the risk of electric shocks,[8] this is necessary to examine the effect of each exposure separately and to disentangle the potential effects of these two exposures. Still no investigation has examined the effect of exposure to electric shocks on risk of lymphomas.

Generally, few studies were concerned with the relationship between occupational ELF-MF exposure and malignant lymphomas, and, to the best of our knowledge, there is no investigation on exposure to electric shocks and the risk of these diseases. However, due to the high correlation between exposure to ELF-MF and electric shocks, it is necessary to examine the effect of each exposure separately and to disentangle the potential effects of these two exposures. Therefore, the aim of our study was to assess the association between occupational exposure to ELF-MF and electric shocks and malignant lymphomas using a large study population with a long-term follow-up.

METHODS

Study population and malignancies

This is a nested case-control study within the Nordic Occupational Cancer (NOCCA) cohort. The NOCCA covers around 15 million adults, who participated in one or more population censuses in 1960, 1970, 1980/1981 and/or 1990, in five Nordic countries: Finland, Iceland, Norway, Denmark and Sweden.[22] Danish data were excluded from the current study because of lack of access to individual-level data. A maximum of 45 years (1961–2005) follow-up was carried out using record linkage between the cancer registries for information on cancer and national population registries for death and emigration. Methods used were described previously.[23]

The seventh revision of the International Classification of Diseases published by the WHO,[24] with country-specific modifications, served as a common coding system for all countries through the study period (online supplemental appendix I), as either the main system or as a system used in parallel with newer codes (WHO 1971,[25] WHO 1990[26]). Five controls for each case were randomly selected from the NOCCA cohort. The control subjects were alive and free of cancer on the index date (the date of diagnosis of the case), and matched by year of birth, sex and country. Participants had to be older than 20 years at the index date and have occupational information from one or more preceding censuses.

Data preparation

Occupational information was provided for study subjects from censuses of 1960, 1970, 1980 and 1990 in Sweden, 1960, 1970 and 1980 in Norway, 1970, 1980 and 1990 in Finland, and 1981 in Iceland. The heads of households filled in self-administered questionnaires on education, occupation, industry, and name and address of employer at the time of the census. Some responders to the census questionnaire did not give information on their occupational activity and were therefore recorded with missing information.

Work histories and coding were based on census records that are a snapshot of a job held by individuals at the time of the census. If two different jobs were reported in two successive censuses, we assumed that he/she changed their job in the middle of censuses. Additionally, if an individual had missing occupational codes at one census, the nearest census record was assigned to that period.

A high level of accuracy has been reported on occupational classification based on census records among these countries.[27–29] National adaptations of the Nordic Occupational Classification (NYK) were used for coding occupations in Finland, Norway and Sweden. NYK is based on the International Standard Classification of Occupations (ISCO) from 1958.[30] A national adaptation of ISCO-68 was used in Iceland for occupational coding.[31] Finally, job duration was combined based on the years of censuses and code of each occupation.

Exposure assessment

Occupational codes were linked to two JEMs to indicate ordinal ELF-MF[32 33] and electric shock[8] exposures, respectively. The ELF-MF JEM was a modified version of the JEM developed by Bowman *et al*.[33] The original ELF-MF JEM reflects the intensity of time weighted average exposure (μT) by job based on available measurement data, but does not account for the probability of exposure. To account for both the intensity and probability of exposure, geometrical mean intensities were first categorised into three levels (background, low and high) based on distributional cut points at 0.15 μT and 0.30 μT. The resulting intensity-based ratings were subsequently upgraded or downgraded by two industrial hygienists based on the estimated probability of exposure per job, and classified as three exposure levels (background, low and high).

The electric shocks JEM was based on injury data gathered from five European countries. The number of workers per occupation and country were obtained from EUROSTAT (the statistical office of the European Union).[34] Accident rates were pooled across countries with a random effects model and jobs were categorised into background, low and high electric shocks risk based on the 75th and 90th percentiles of the pooled accident rates distribution.[8]

The occupational classifications in the JEMs were based on ISCO-88 job codes and were linked to the job histories through crosswalks from NYK or ISCO-68 to ISCO-88.

Each individual occupational exposure to ELF-MF and electrical shocks was categorised into background, low or high exposure levels, taking the highest exposure levels registered in that persons work history. We also calculated the duration (in years) that a participant reported to have performed a job with low or high exposure to ELF-MF or electrical shocks during their whole working career or only high exposure to ELF-MFs or electrical shocks. To calculate the cumulative exposure, expressed in unit-years, the job duration was multiplied with weights based on the distribution of the intensity of ELF-MF exposure over the occupations to exposure rating (ie, background 0, low 1, high 4) to better reflect the log-normal exposure distribution.[8 32] Cut-off points for the continuous exposure variables were based on the distribution of exposure among a larger set of controls included in analyses of several disease outcomes. We took tertiles based on the controls of the entire data set of the project which also included cardiovascular and neurological diseases, brain cancer, leukaemia and acute myeloid leukaemia, besides NHL, CLL and MM.

We estimated cumulative exposure of persons assuming that; (1) Employment period of subjects started at age 20 years and ended at either the index date or age 60 years (effective retirement age)[35] whichever came first, (2) If the employment career of a given person included different occupations, he/she changed their occupation in the middle of the two censuses, (3) If a census had missing occupational codes, the nearest census record was assigned to that period; and (4) For Iceland, occupation of persons in the 1981 census were assigned to the whole working life.

Statistical tests and adjustment

Models were adjusted for social class and occupational exposure to solvents from ALOHA+JEM.[36] Classification of social class was based on occupational information (ISCO-88 codes) and categorised into administrators and managers, lower administrative workers, skilled and specialised workers, unskilled workers, farmers and gardeners, economically inactive/unclassifiable workers. Occupational exposure to solvents (aromatic, chlorinated and others) was estimated using the ALOHA+JEM,[36] which classifies subjects based on ISCO-88 job codes into no, low and high exposure categories.

ORs and 95% CIs were estimated using conditional logistic regression models by adding ELF-MFs and electric shocks exposure to indicate the incidence risk of lymphomas.

A series of sensitivity analyses was conducted to assess the robustness of the main results. We explored the impact of lag times on our results by comparing the fit of the models including cumulative exposure variables with 0 year, 1 year, 5 years, 10 years and 20 years of lag time. We repeated all the analyses separately by sex and by country, taking into account different windows of exposure, and excluding those participants that were economically inactive the whole working career.

RESULTS

Table 1 shows a higher proportion of male subjects for NHL (52.7%), CLL (60.1%) and MM (52.8%) among the cases. More than 50% of the cases were from Sweden.

Table 2 indicates the distributions of occupational exposure to ELF-MF and electric shocks for all cases and controls. Generally, less than 7% of cases were exposed to high levels of ELF-MF.

The risks of NHL, CLL and MM among workers highly exposed to ELF-MF (table 3) were 0.93 (CI 0.90 to 0.97), 0.98 (CI 0.92 to 1.05) and 0.96 (CI 0.90 to 1.01), respectively.

The risks of NHL, CLL and MM were 0.94 (CI 0.91 to 0.97) and 0.93 (CI 0.87 to 0.99) and 0.97 (CI 0.93 to 1.02), respectively, among workers exposed to high levels of electric shocks compared with subjects exposed to background levels (table 4).

The outcomes remained materially unchanged in sensitivity analyses considering cumulative exposure variables with 0 year, 1 year, 5 years, 10 years and 20 years of lag time, with separate analyses by sex and country, in different windows of exposure and excluding participants, who had been economically inactive their entire working career.

DISCUSSION

In this study we investigated the risk of NHL, CLL and MM among workers potentially exposed to ELF-MFs and electric shocks. There was no evidence of an association between ELF-MFs and electric shocks and the increased risk of these diseases. The current case-control study was nested in a large census-based cohort with accurate case ascertainment, complete cancer and mortality follow-up, and standardised exposure assessment for ELF-MFs and electric shocks,

Table 1 Characteristics of cases and control subjects

	Non-Hodgkin's lymphoma				Chronic lymphocytic leukaemia				Multiple myeloma			
	Cases (n=68 978)		Controls (n=344 890)		Cases (n=20 615)		Controls (n=103 075)		Cases (n=16 739)		Controls (n=177 335)	
Characteristics	N	%	N	%	N	%	N	%	N	%	N	%
Sex												
Men	36 322	52.7	181 610	52.7	12 393	60.1	61 965	60.1	18 728	52.8	93 640	52.8
Women	32 656	47.3	163 280	47.3	8222	39.9	41 110	39.9	16 739	47.2	83 695	47.2
Year of birth												
<1900	1926	2.8	9630	2.8	876	4.2	4380	4.2	1935	5.5	9675	5.5
1900–1924	36 698	53.2	183 490	53.2	13 031	63.2	65 155	63.2	23 006	64.9	115 030	64.9
1925–1949	27 447	39.8	137 235	39.8	6387	31.0	31 935	31.0	9985	28.2	49 925	28.2
1950–1960	2907	4.2	14 535	4.2	321	1.6	1605	1.6	541	1.5	2705	1.5
Country												
Finland	18 216	26.4	91 080	26.4	4353	21.1	21 765	21.1	6875	19.4	34 375	19.4
Iceland	455	0.7	2275	0.7	118	0.6	590	0.6	212	0.6	1060	0.6
Norway	12 420	18.0	62 100	18.0	4346	21.1	21 730	21.1	9413	26.5	47 065	26.5
Sweden	37 887	54.9	189 435	54.9	11 798	57.2	58 990	57.2	18 967	53.5	94 835	53.5
Social class												
Administrators and managers	20 254	29.4	99 565	28.9	6030	29.3	30 492	29.6	11 020	31.1	56 055	31.6
Lower administrative workers	16 990	24.6	81 700	23.7	4706	22.8	22 365	21.7	7677	21.6	37 558	21.2
Skilled and specialised workers	17 289	25.1	89 730	26.0	5232	25.4	27 072	26.3	8597	24.2	44 373	25.0
Unskilled workers	6301	9.1	32 449	9.4	1740	8.4	9245	9.0	3172	8.9	16 186	9.1
Farmers and gardeners	7212	10.5	36 555	10.6	2643	12.8	12 606	12.2	4403	12.4	20 444	11.5
Economically inactive/unclassifiable	932	1.4	4891	1.4	264	1.3	1295	1.3	598	1.7	2719	1.5
Solvent exposure (ever)												
Aromatic solvents	18 474	26.8	93 719	27.2	6220	30.2	30 969	30.0	9671	27.3	47 577	26.8
Chlorinated solvents	10 781	15.6	55 030	16.0	3376	16.4	17 273	16.8	5120	14.4	26 587	15.0
Other solvents	16 644	24.1	83 974	24.3	5039	24.4	25 793	25.0	7935	22.4	40 243	22.7

Table 2 Distributions of occupational exposure to extremely low frequency magnetic fields and electric shocks for cases and controls

	Non-Hodgkin's lymphoma		Chronic lymphocytic leukaemia		Multiple myeloma	
	Cases	Controls	Cases	Controls	Cases	Controls
Agent	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)
Extremely low frequency magnetic fields						
Highest level of exposure*						
Background level	41 632 (60.4)	205 054 (59.5)	12 654 (61.4)	62 874 (61.0)	22 397 (63.1)	110 680 (62.4)
Low level	23 063 (33.4)	116 584 (33.8)	6525 (31.4)	32 768 (31.8)	10 944 (30.9)	55 344 (31.2)
High level	4283 (6.2)	23 252 (6.7)	1436 (7.0)	7433 (7.2)	2126 (6.0)	11 311 (6.4)
Cumulative exposure (tertiles of exposure†)						
0 unit-years‡	41 632 (60.4)	205 054 (59.5)	12 654 (61.4)	62 874 (61.0)	22 397 (63.1)	110 680 (62.4)
1–20 unit-years	10 384 (15.1)	52 127 (15.1)	2490 (12.1)	12 601 (12.2)	4380 (12.3)	21 672 (12.2)
21–30 unit-years	4091 (5.9)	21 160 (6.1)	1091 (5.3)	5328 (5.2)	1674 (4.7)	8605 (4.9)
31–164 unit-years	12 871 (18.7)	66 549 (19.3)	4380 (21.2)	22 272 (21.6)	7016 (19.8)	36 378 (20.5)
Electric shocks						
Highest level of exposure*						
Background levels	286 201 (69.1)	237 808 (69.0)	14 249 (69.1)	69 896 (67.8)	25 098 (70.8)	124 835 (70.4)
Low levels	76 595 (18.5)	64 195 (18.6)	3731 (18.1)	19 418 (18.8)	6291 (17.7)	31 478 (17.8)
High levels	51 072 (12.3)	42 887 (12.4)	2635 (12.8)	13 761 (13.4)	4078 (11.5)	21 022 (11.9)
Cumulative exposure (tertiles of exposure)						
0 unit-years‡	48 393 (70.2)	237 808 (69.4)	14 249 (69.1)	69 896 (67.8)	25 098 (70.8)	124 835 (70.4)
1–20 unit-years	5795 (8.4)	29 544 (8.6)	1428 (6.9)	7571 (7.3)	2498 (7.0)	12 219 (6.9)
21–35 unit-years	8094 (11.7)	42 515 (12.4)	2644 (12.8)	13 873 (13.5)	4422 (12.5)	22 363 (12.6)
36–164 unit-years	6696 (9.7)	35 023 (10.2)	2294 (11.1)	11 735 (11.4)	3449 (9.7)	17 918 (10.1)

*The cut-off points were 0.15 µT and 0.30 µT; taking the highest exposure levels for each participant.
†Tertiles of exposure distribution among exposed controls used as cut-off points.
‡Job duration multiplied by weights based on the distribution of the intensity of extremely low frequency magnetic field exposure over the occupations to exposure rating (ie, background 0, low 1, high 4).

providing a robust evaluation of the potential association between ELF-MF, electric shocks exposure and lymphomas.

Our results are in accordance with several previous studies. A longitudinal, national study in Switzerland showed no association of occupational ELF-MF exposure with risk of total haematolymphopoietic cancer as well as 12 individual cancers including NHL, CLL and MM. Additionally, no indication of exposure-response relationships was observed with increasing intensity or duration of exposure.[18] A nested case-control study, carried out within a cohort of 170 000 electric utility workers in France between 1978 and 1989, showed no increased risk of MM.[37] A cohort study among electricity generation and transmission workers (1973–2015) in the UK demonstrated no increased risk for CLL, NHL or MM.[21] A Dutch study reported a relative risk of 1.19 (CI 0.86 to 1.64) for NHL among workers ever highly exposed (0.30 µT) to electrical equipment and electronics. Additionally, analyses of cumulative exposure and duration of exposure showed no indication of significant findings for NHL. The only significant finding was a HR of 2.78 (CI 1.20 to 6.44) for follicular lymphoma (subtype of NHL) among seven ever highly exposed workers.[12] Roosli *et al* investigated mortality from some lymphopoietic malignancies among electrical railway workers, with an annual average exposure up to 21 µT, but found no association with NHL.[38] A retrospective cohort study found that occupational exposure to medium (0.084–0.115 µT) or high (≥0.116 µT) level of ELF-MF was not associated with MM.[16]

Table 3 ORs and 95% CIs of occupational exposure to low frequency magnetic fields and three lymphomas

	Non-Hodgkin's lymphoma		Chronic lymphocytic leukaemia		Multiple myeloma	
Agent	Unadjusted OR (CI)	Adjusted OR (CI)*	Unadjusted OR (CI)	Adjusted OR (CI)*	Unadjusted OR (CI)	Adjusted OR (CI)*
Highest level of exposure†						
Background levels	1.00		1.00		1.00	
Low levels	0.97 (0.95 to 0.99)	0.99 (0.97 to 1.01)	0.99 (0.96 to 1.02)	0.99 (0.95 to 1.03)	0.98 (0.95 to 1.00)	1.00 (0.97 to 1.03)
High levels	0.90 (0.87 to 0.93)	0.93 (0.90 to 0.97)	0.96 (0.90 to 1.02)	0.98 (0.92 to 1.05)	0.92 (0.88 to 0.97)	0.96 (0.90 to 1.01)
Duration of exposure above background (per 10 years)‡	0.99 (0.98 to (0.99)	0.99 (0.99 to 1.00)	1.00 (0.99 to 1.01)	1.00 (0.99 to 1.01)	0.99 (0.98 to 1.00)	1.00 (0.99 to 1.01)
Duration of exposure to high levels (per 10 years)‡	0.97 (0.96 to 0.99)	0.98 (0.97 to 1.00)	0.99 (0.97 to 1.01)	1.00 (0.98 to 1.02)	0.98 (0.96 to 1.00)	0.99 (0.97 to 1.01)
Cumulative exposure (tertiles of exposure)						
0 unit-years§	1.00		1.00		1.00	
1–20 unit-years	0.98 (0.96 to 1.00)	0.99 (0.96 to 1.02)	0.98 (0.93 to 1.03)	0.98 (0.93 to 1.04)	1.00 (0.96 to 1.04)	1.02 (0.98 to 1.06)
21–30 unit-years	0.95 (0.91 to 0.98)	0.96 (0.93 to 1.00)	1.02 (0.95 to 1.09)	1.02 (0.95 to 1.10)	0.96 (0.91 to 1.02)	0.98 (0.93 to 1.04)
31–164 unit-years	0.95 (0.93 to 0.97)	0.97 (0.95 to 1.00)	0.98 (0.94 to 1.04)	0.99 (0.94 to 1.03)	0.95 (0.92 to 0.98)	0.98 (0.95 to 1.02)

*Adjusted for social class and aromatic solvents, chlorinated solvents and other solvents on a continuous scale.
†The cut-off points were 0.15 µT and 0.30 µT; taking the highest exposure levels for each participant.
‡The risk per 10-year increase in duration of exposure; duration of exposure above background level was calculated by summing up the time that a person was exposed to both low or high levels.
§Job duration multiplied by weights based on the distribution of the intensity of extremely low frequency magnetic field exposure over the occupations to exposure rating (ie, background 0, low 1, high 4).

Table 4 ORs and 95% CIs of occupational exposure to electric shocks and three lymphomas

Agent	Non-Hodgkin's lymphoma Unadjusted OR (95% CI)	Non-Hodgkin's lymphoma Adjusted OR (95% CI)*	Chronic lymphocytic leukaemia Unadjusted OR (95% CI)	Chronic lymphocytic leukaemia Adjusted OR (95% CI)*	Multiple myeloma Unadjusted OR (95% CI)	Multiple myeloma Adjusted OR (95% CI)*
Highest level of exposure†						
Background levels	1.00		1.00		1.00	
Low levels	0.94 (0.92 to 0.97)	0.96 (0.94 to 0.98)	0.94 (0.90 to 0.98)	0.95 (0.91 to 0.99)	0.99 (0.95 to 1.02)	1.01 (0.98 to 1.05)
High levels	0.93 (0.90 to 0.95)	0.94 (0.91 to 0.97)	0.93 (0.88 to 0.98)	0.93 (0.87 to 0.99)	0.96 (0.92 to 1.00)	0.97 (0.93 to 1.02)
Duration of exposure above background (per 10 years)‡	0.99 (0.98 to 0.99)	0.99 (0.98 to 0.99)	0.98 (0.97 to 0.99)	0.99 (0.98 to 1.00)	0.99 (0.98 to 1.00)	1.00 (0.99 to 1.01)
Duration of exposure to high levels (per 10 years)‡	0.97 (0.96 to 0.99)	1.00 (0.99 to 1.01)	0.98 (0.97 to 1.00)	0.99 (0.97 to 1.01)	0.99 (0.98 to 1.00)	0.99 (0.98 to 1.01)
Cumulative exposure (tertiles of exposure)						
0 unit-years	1.00		1.00		1.00	
1–20 unit-years§	0.96 (0.93 to 0.99)	0.97 (0.94 to 1.00)	0.92 (0.87 to 0.98)	0.93 (0.87 to 0.98)	1.02 (0.97 to 1.06)	1.03 (0.98 to 1.08)
21–35 unit-years	0.93 (0.90 to 0.95)	0.94 (0.92 to 0.97)	0.93 (0.89 to 0.97)	0.95 (0.90 to 1.00)	0.98 (0.95 to 1.02)	1.00 (0.96 to 1.04)
36–164 unit-years	0.93 (0.90 to 0.96)	0.95 (0.91 to 0.98)	0.95 (0.90 to 1.00)	0.97 (0.91 to 1.04)	0.95 (0.91 to 0.99)	0.97 (0.91 to 1.02)

*Adjusted for social class and aromatic solvents, chlorinated solvents and other solvents on a continuous scale.
†Taking the highest exposure levels for each participant.
‡The risk associated with 10-year increase in duration of exposure; duration of exposure above background level was calculated by summing up the time that a person was exposed to both low or high levels.
§Multiplying job duration with weights based on the distribution of the intensity of extremely low frequency magnetic field exposure over the occupations to exposure rating (ie, background 0, low 1, high 4).

Hakansson *et al* reported no significant increased risk for MM, lymphocytic leukaemia and CLL in relation to occupational ELF-MF exposure to medium (0.164–0.25 μT), high (0.25–0.53 μT) and very high (>0.53 μT) levels.[19]

Nonetheless, there is some limited evidence indicating an association between exposure to ELF-MF and lymphomas.[15 16] Schroeder and Savitz found a small positive association between NHL and duration of employment in any MF-exposed job, but only up to 20 years. However, cumulative MF exposure was associated with a rising, then falling, risk of NHL, thus weakening the probability of a causal relationship. The risk of Hodgkin's disease and MM did not appear to be associated with exposure.[14] A case-control study based on individual work histories and personal monitoring observed an association between exposure to medium (0.20–0.28 μT), high (≥0.29 μT) and very high (≥0.41 μT) levels of ELF-MF and risk of CLL.[15]

A large body of evidence suggested no association between exposure to high level of ELF-MF and lymphomas that is in line with the current study findings on CLL, MM and NHL. Additionally, the literature indicated that working in electric power infrastructures or near ELF-MF sources is not a risk factor for lymphoma. These findings could confirm that exposure to occupational level of magnetic fields might be safe as far as lymphoma is concerned.

Almost all the above studies were based on less than 150 cases, and the number of cases among highly exposed workers was small. A recent investigation concluded that if there is any relationship between occupational exposure to ELF-MF and haematolymphopoietic cancers, the risk is small and appears to be restricted to myeloid malignancies.[18] The body of evidence and the current findings support this suggestion. Of note, the current study is the first report estimating risk of lymphomas based on a large number of ELF-MF exposed cases. Additionally, accurate case ascertainment and nearly complete follow-up of NOCCA participants were two important strengths of this study.

In the current study, the data on occupation were extracted from national censuses. Correct classification of individual exposure status and exposure level is highly dependent on the validity of the occupational coding in the censuses . The current population register systems allow tabulation of the entire population by several demographic variables and have therefore diminished the incentive to undertake traditional censuses. Unfortunately, it is difficult to obtain detailed individual information on occupation from registers with similar precision as they were collected from census questionnaires. In general, validity studies[22 39] indicate that the classification by occupation in the Nordic censuses has been reasonably accurate, but that economic activity has been somewhat underestimated, especially among women.

Our study has some limitations. Generally, exposure misclassification cannot be ruled out in this research because of (1) Using JEMs to assign exposure and (2) Our imputations/assumptions in reconstructing the individual work histories from the census data. However, NOCCA cohort studies have previously retrieved known associations indicating that work history limitations are not hampering studies on occupational risk factors. Additionally, the used JEMs have proven to be a reliable source to show the association of exposure and outcomes in previous studies. We therefore conjecture that these limitations are not a likely explanation for our null findings.

CONCLUSION

The current study does not support that occupational exposure to ELF-MFs and electric shocks increases the risk of lymphopoietic malignancies.

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