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Breast Cancer, Occupation, and Exposure to Electromagnetic Fields Among Swedish Men

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Background *Investigations of breast cancer among men may provide clues for environmental and occupational risk factors that may be difficult to study in women, because of confounding or effect modification from reproductive female characteristics. The objective was to estimate occupation-specific risks of male breast cancer and to assess the effect of occupational exposure to extremely low-frequency magnetic fields (ELFMF).*

Methods *Standardized incidence ratios were computed for the period 1971–1989 among Swedish men who were 25–59 years of age at start of follow-up and gainfully employed in 1970. Log-linear Poisson models were fitted to adjust for geographical area. A job exposure matrix was used to classify occupational ELFMF exposure.*

Results *A marked and consistent excess risk was found for machinery repairers. Increased relative risks based on few cases were also noted for librarians/archivists/curators, bank employees, non-specified clerical workers, metal processing workers, tanners/fur dressers, policemen, and custom surveillance officials. The relative risk among subjects with an estimated ELFMF exposure above the first quartile (0.12 μT) was 1.31 (95% confidence interval = 0.94–1.81), without a clear exposure–response pattern. Indications of an exposure–response relationship were found in workers with intermittent ELFMF exposure.*

Conclusion *The findings give no clear evidence for an etiological role of ELFMF in the development of breast cancer in men, but suggest that large variations in exposure over the work-day may be associated with an increased risk.* Am. J. Ind. Med. 39:276–285, 2001. *© 2001 Wiley-Liss, Inc.*

KEY WORDS: ***male breast cancer; occupational risk; magnetic fields; cohort studies; Poisson regression***

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INTRODUCTION

Breast cancer seems to be the same disease entity among women and men, although the incidence among women is about 100 times higher [Parkin et al., 1997]. The two sexes do share some risk factors such as age, a family history of breast cancer [Lenfant-Pejovic et al., 1990; Sasco et al., 1993; Newman et al., 1997], exposure to ionizing radiation [John and Kelsey, 1993; Thomas et al., 1994], a history of benign breast disease [Mabuchi et al., 1985; Thomas et al., 1992; Kelsey, 1993; Sasco et al., 1993], and obesity [Kelsey, 1993; Casagrande et al., 1998; Hsing et al., 1998]. The international and regional variation in incidence is similar in both sexes [Ewertz et al., 1989; Nectoux and Parhin, 1992]. A role for endogenous hormones in the etiology of male breast cancer is suggested by its relationship with gynaecomastia [Sasco et al., 1993], testicular damage associated with Klinefelter's syndrome [Sasco et al., 1993], orchitis [Mabuchi et al., 1985; Thomas et al., 1992], and testicular trauma [Mabuchi et al., 1985; Thomas et al., 1992; Sasco et al., 1993]. Hormonal imbalance can also explain the increased risk linked to obesity, since estrogens in men are derived mainly from adipose tissue by enzymatic transformation of testosterone and androstendione [Bernstein and Ross, 1993]. Studies on breast cancer in men may provide unique clues for environmental and occupational risk factors. Occupational risk factors are generally more prevalent among men and they may be difficult to investigate in women because of confounding or effect modification from reproductive female characteristics like parity, childbearing, breast feeding, age at menarche, etc. [Cocco et al., 1998; Winchester, 1998].

Some studies have reported an association between breast cancer and occupational exposure to extremely low-frequency magnetic fields (ELFMF) in men [Demers et al., 1991; Matanoski et al., 1991; Loomis, 1992; Tynes et al., 1992; Guénel et al., 1993; Floderus et al., 1994] and women [Loomis et al., 1994; Coogan et al., 1996], while others have found no effect [Rosenbaum et al., 1994; Theriault et al., 1994; Cantor et al., 1995; Stenlund and Floderus, 1997; Forssén et al., 2000]. The issue deserves to be further explored because of contradictory epidemiological findings and a proposed biological mechanism for ELFMF exposure and cancer, involving hormones.

The aim of the study was to estimate occupation-specific relative risk of breast cancer from a large cohort of Swedish men, providing a basis for new hypotheses concerning occupational risk factors for the disease. Furthermore, the relationship between ELFMF exposure and male breast cancer was analyzed, using a Swedish job exposure matrix. In two previous studies on ELFMF and cancer based on the same population—a cohort study including 117 male breast cancer cases [Floderus et al., 1999] and a case–control study with 63 of these cases [Stenlund and Floderus, 1997]—the results were inconclusive, partly due to the limited number of cases. In the present study, the numbers are almost doubled by an extension of the follow-up period. We have also refined the analysis of a potential exposure–response relationship, and the results can be evaluated in light of the outcome for specific occupational groups.

MATERIAL AND METHODS

The base population for this historical cohort comprised all Swedish men who: (1) were gainfully employed at the time of the 1970 census; (2) had also been recorded in the 1960 census; (3) and were still alive and over age 24 as of January 1, 1971. This encompassed 1,779,646 men, 25–59 years of age at the beginning of the study in 1971, and subsequently followed-up for 19 years until year-end 1989, rendering a total of 31,668,842 person-years. This age range was chosen to impose the condition that the cohort members would be still working during the first quinquenium of the study.

Information was drawn from two datasets: The first source of data was the Swedish cancer environment register, comprising all cancer cases and including information on occupation, residence, and different demographic variables from the 1960 and 1970 censuses [Barlow and Eklund, 1995; Cancer-Miljöregistret, 1994]. This register was used to compute specific rate numerators, with breast cancer defined as any case with code 170 of the International Classification of Diseases (7th revision). The second data source comprised all individuals in the 1970 census, with information on occupation and residence in 1970, occupation in 1960, and, if applicable, date of death. This register was used to calculate specific rate denominators. During the study period, death was the only event defined as end of follow-up. This implies that cases with breast cancer would still contribute to the denominator, producing a very slight underestimation of rates. It was not possible to censor the follow-up of workers who emigrated during the study period. Nevertheless, the annual emigration rate among Swedish citizens during this period was very low, approximately 1 per 1000 [Statistics Sweden, 1981a,1991].

In the 1970 census, occupations were coded according to the Nordic Classification of Occupations [Cancer-Miljöregistret, 1994]. Similar codes were used in the 1960 census and translations were made to the 1970 code when necessary. Every occupation is represented by a three-digit number. The first digit refers to one of 10 major occupational sectors (0–9), where higher numbers indicate manual occupations, and lower numbers non-manual occupations often requiring longer education associated with a higher socio-economic status.

The overall person-time that each worker contributed to the study was allocated to the corresponding cells of the variables of stratification. These variables were: (1) occupation on a 1- or 3-digit basis; (2) 5-year age group, from 25–29 to 75–79; and, (3) calendar time period, (1971–1975, 1976–1980, 1981–1985 and 1986–1989).

Age-standardized incidence rates per occupational sector were computed using the standard European population as reference. Standardized incidence ratios (SIRs), i.e., the ratio of the observed to the expected number of cases in any given occupation or occupational sector, were computed taking age- and period-specific rates of the study cohort as the reference to obtain the expected number of cases.

TABLE I. Male Breast Cancer by Occupational Sector and by Occupation in 1970 If At Least 2 Cases Observed and a SIR Equal or Greater than 130: Adjusted Rates per 100,000 Man-Years, Number of Observed Cases, Standardized Incidence Ratio per 100 and Relative Risk Adjusted for Age, Period, and Geographical Area

Occupational code	Number of workers	Adjusted[a] rate	Observed cases	SIR[b]	Total cohort RR[c]	Total cohort 95% CI	Younger than 65 RR[c]	Younger than 65 95% CI
Group 0: Professional and technical work	331,862	1.05	46	111	1.11	0.80–1.53	1.10	0.74–1.63
3 Mechanical engineer	67,405		12	135	1.31	0.73–2.34	1.10	0.51–2.34
6 Engineer and technician other	18,113		4	147	1.45	0.54–3.88	1.16	0.29–4.68
31 Physician	6,932		2	218	2.11	0.53–8.49	—	
50 Principal, headmaster	4,031		2	293	2.98	0.74–12.00	4.48	1.11–18.07
51 University, higher educ teacher	6,755		2	326	3.22	0.80–12.94	4.43	1.10–17.86
61 Minister, priest	4,310		2	273	2.92	0.73–11.76	—	
93 Librarian, archivist, curator	1,900		3	994	9.78	3.13–30.57	—	
Group 1: Administrative and managerial	61,969	1.09	12	121	1.18	0.66–2.10	0.95	0.42–2.15
111 Managing director	20,936		6	160	1.55	0.69–3.49	0.86	0.21–3.48
Group 2: Bookkeeping and clerical work	78,611	1.19	15	140	1.39	0.82–2.34	1.03	0.48–2.20
292 Bank employee	5,089		3	722	6.89	2.20–21.57	—	
294 Forwarding and shipping agent	4,293		2	382	3.61	0.90–14.52	—	
299 Non-specif. clerical work	22,280		7	226	2.26	1.07–4.80	2.15	0.80–5.81
Group 3: Sales work	136,916	0.70	16	87	0.84	0.51–1.39	0.79	0.42–1.50
332 Shop manager	13,945		3	145	1.47	0.47–4.58	2.28	0.73–7.14
Group 4: Agricult., Forest. and Fishing	174,902	0.68	24	79	0.80	0.52–1.21	0.64	0.35–1.19
Group 5: Mining and quarrying	10,455	0.40	1	69	—	—	—	
Group 6: Transport and communications	152,944	0.85	22	108	1.08	0.70–1.68	1.04	0.60–1.80
631 Railway engineer	6,265		2	164	1.73	0.43–6.96	2.64	0.66–10.67
643 Railway st. master and dispatch.	7,200		3	220	2.26	0.72–7.04	3.36	1.08–10.60
661 Sorting clerk and postman	10,137		2	151	1.50	0.37–6.04	—	

Group 7: Production I	521,297	0.75	70	97	0.98	0.74–1.29	1.07	0.76–1.51
736 Metal caster and moulder	5,319		2	230	2.21	0.55–8.89	—	
738 Other metal processing worker	2,519		2	496	5.28	1.31–21.27	—	
752 Machinery repairer	55,730		14	202	2.09	1.22–3.59	2.24	1.18–4.25
755 Welder and flame cutter	23,950		4	145	1.48	0.55–3.97	1.56	0.50–4.89
756 Construction smith	6,826		2	225	2.08	0.52–8.37	—	
768 Other electrical and electronic w.	4,459		2	366	3.65	0.92–14.67	—	
774 Frame, circular sawyer and planner	6,461		2	186	2.25	0.56–9.08	—	
782 Industrial spray painter	5,989		2	272	2.70	0.67–10.85	4.11	1.02–16.59
Group 8: Production II	219,488	0.52	21	66	0.63	0.40–0.98	0.83	0.50–1.39
801 Typographer, litographer	16,564		4	205	1.91	0.71–5.13	2.97	1.10–8.03
853 Tanner and fur dresser	837		2	351	11.79	2.92–47.55	21.87	5.39–88.74
881 Packer	4,611		2	269	2.71	0.67–10.88	—	
882 Docker and freight handler	6,131		2	213	2.23	0.55–8.96	—	
Group 9: Services and military work	91,202	1.26	23	177	1.81	1.18–2.78	1.79	1.04–3.11
902 Policeman	12,107		4	293	2.90	1.08–7.80	3.05	0.97–9.55
903 Custom surveillance official	2,197		2	586	5.68	1.41–22.87	8.86	2.19–35.75
908 Other civilian protect. service w.	6,973		2	184	1.80	0.45–7.22	—	
931 Building caretaker	19,076		5	140	1.41	0.58–3.42	1.65	0.53–5.17
932 Cleaner	4,076		2	294	2.82	0.70–11.34	—	
941 Hairdresser, beautician	4,385		2	278	2.72	0.68–10.93	—	
981 Member of the armed forces	14,288		4	234	2.32	0.86–6.23	1.58	0.39–6.36

[a]Age-adjusted rates using the European standard population.
[b]SIR using age-and period-specific rates for the whole cohort as standard.
[c]RR adjusted for age, period and geographical category taking other occupations as reference.

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On the assumption that the observed number of cases in each stratum was distributed as a Poisson variable, log-linear Poisson models were fitted, comparing occupations against others in the cohort, adjusting for geographical risk area. In view of the fact that male breast cancer risk showed a geographical variation, the relative risk (RR) was adjusted for this variable. The 24 counties were grouped into five categories depending on the observed SIR value: lower than 90; 90–95; 95–105; 105–110; and, greater than 110. These five categories were represented by dummy variables in the regression. In these models, the number of expected cases was introduced as an offset [Breslow and Day, 1987]. Given that the expected number was computed on the basis of the age- and period-specific reference rates, the RR for each occupation was likewise age- and period-adjusted. Findings are presented only for occupations with at least two observed cases (57 occupations). The analysis was repeated with a truncation at the age of 65 years, i.e., the common age of retirement and, therefore, the age of exposure cessation for most workers.

To take into account the relationship between social class, life-style, and occupation, RRs were also computed with other occupations of the same occupational sector (i.e., those with the same first digit) as reference. In addition, RRs per occupation were also calculated in a second analysis considering as exposed only those men who reported that occupation in 1970 and in 1960.

The possible role of obesity as a confounder was assessed using data on self-reported body height and weight obtained in a national survey investigation including 6,000 Swedish men [Statistics Sweden, 1981b]. The proportion of persons who were overweight (body mass index (BMI) > 30) in each occupation was available, and all individuals within an occupation were assigned to the same BMI category.

Exposure to ELFMF was assessed by linking occupations to a job-exposure matrix [Floderus et al., 1996]. The matrix covers the 100 most common occupations among Swedish men. For these occupations exposure levels have been estimated, based on at least four full-shift measurements from a total of more than 1,000 measurements. Different metrics of exposure have been computed. In the present study we used the geometric mean of the work-day arithmetic mean values for all individuals in an occupation (hereafter called average mean value). Five exposure groups were formed with cut-off points at the 25th, 50th, 75th and 90th percentile, with the lowest group as reference. In order to quantify the RRs, the models used before were re-fitted replacing occupation by the ELFMF exposure group.

To explore potential differences between intermittent and a more continuous exposure, we also used the estimates of the percentage of time during the work day with field magnitudes exceeding 0.20 μT. We tested the effect of the average mean exposure in those exposed less and those exposed more than or equal to one-third of the workday to magnitudes above 0.20 μT. A high average mean combined with values over 0.20 μT for less than a third of the workday indicates intermittent exposure to high field levels.

The analysis was restricted to persons in any of the 100 occupations included in the matrix. In addition, 10 comparatively rare occupations with estimates based on less than four measurements, but with definitely high exposures were added (occupations according to Table 10 of Floderus et al., 1996). The individuals that were classified with respect to ELFMF exposure produced in total 26,654,664 person-years.

The analyses were also carried out separately for two subgroups, the occupational sectors 0–3 (professionals, managerial, administrative and clerical workers) and 6 to 9 (transport and communication, production and service-workers).

RESULTS

During the follow-up, a total of 250 breast tumors were reported in the study cohort, 156 of them occurring in men younger than 65 years of age. The overall adjusted incidence rate (25–74 years) was 0.81 cases per 100,000 person-years.

Table I shows the adjusted incidence rates, SIRs, and RRs with 95% confidence intervals for major occupational sectors and for specific occupations with at least two observed cases and a SIR greater than 130. Two or more breast cancer cases were diagnosed in 57 out of the 278 occupations reported in 1970 and 34 of these occupations, displayed in Table I, presented a SIR greater than 130.

The occupational sector of services and military work presented an increase in RR of about 80% compared with other professional categories. Among the occupational sectors 0, 1, and 2, only three occupations showed an increased RR: librarians/archivists/curators, bank employees, and non-specified clerical work. In those younger than 65 years, the RR was increased among principals/headmasters, and university and higher educational teachers. None of the occupations related to agriculture, forestry and fishing, or mining and quarrying presented an elevated incidence of breast cancer. Railway station masters/train dispatchers evinced an elevated risk, particularly among workers younger than 65. Relative risks were also increased for other metal processing workers, machinery repairers, and for tanners/fur dressers. For workers younger than 65, increased RRs were found for machinery repairers, industrial spray painters, typographers/litographers, tanners/fur dressers, policemen, and custom surveillance officials. All RRs were based on small numbers, given the rarity of breast cancer in men. Machinery repairers was the only occupation with an increased RR based on more than 10 cases.

Overweight was not related to the incidence of breast cancer in this cohort. For this reason we disregarded this variable in subsequent analyses. Also, intra-group comparisons, taking as reference only workers in the same major occupational sector, produced similar results (data not shown), except for occupations in the "service and military sector." Because of higher incidence in general in this sector, none of the occupation-specific results were statistically significant in this analysis, but the RR was still increased for policemen (RR = 1.82), custom surveillance officials (RR = 3.14), cleaners (RR = 1.68), hairdressers and beauticians (RR = 1.52) and for members of the armed forces (RR = 1.42).

Table II sets out the RRs for men reporting the same occupation in 1970 and 1960, for occupations shown in Table I and with at least two cases in this subcohort. Numbers are very small, but the increased incidence among machinery repairers, policemen, and custom surveillance officials is confirmed in this analysis. Furthermore, managing directors, other electrical and electronic workers, and building caretakers younger than 65 years had an elevated risk.

Table III shows RRs across the ELFMF exposure groups referring to the average mean exposure. RR estimates tended to be elevated in the second, third, and fourth categories, but not in the fifth group (exposures above the 90th percentile), and this was the case among workers younger than 65. The RR seemed to increase with average mean exposure among those exposed to levels above 0.20 μT during less than one-third of the workday. The lowest average mean value among those exposed to levels above 0.20 μT during more than one-third of the workday was 0.18 μT and there was no tendency of an exposure–response pattern. The associations observed were mainly attributable to occupational sectors 6–9, i.e., manual occupations. No effect was observed for sectors 0–3—professionals, managerial, administrative, and clerical work—(results not shown).

DISCUSSION

The entire cohort of Swedish men, gainfully employed in 1970 and followed up for 19 years, has allowed us to estimate the risk of male breast cancer in relation to occupational title and to analyze the relation to ELFMF exposure using a Swedish job-exposure matrix. After adjusting for age, period of diagnosis, and geographical area, eight occupations were identified with a statistically significant increase in the RR, all based on small numbers: librarians/archivists/curators, bank employees, non-specified clerical workers, other metal processing workers, machinery repairers, tanners/fur dressers, policemen, and custom surveillance officials.

The occupational sectors 0, 1 and 2 are all associated with a higher socio-economic level than sectors 4–9. In our study, sectors 0–2 had notably higher risks than sectors 4–8. The only exception from a general association between higher socio-economic level and increased breast cancer risk was sector 9—services and military work—based on 23 cases. Previous studies also found an increased risk among men with a high socio-economic status [Cocco et al., 1998; Hsing et al., 1998]. Among women, there is a well-documented association between an increased risk of breast

TABLE II. Relative Risk of Breast Cancer for Selected Occupations[a] for Workers Reporting that Occupation in 1960 and 1970: Number of Cases, Number of Workers Exposed, Relative Risk, and 95% Confidence Interval

		Total cohort				Workers younger than 65 years			
		Obs	Exp	RR[b]	95% CI	Obs	Exp	RR[b]	95% CI
3	Mechanical engineer	7	4.3	1.57	0.74–3.34	5	2.7	1.76	0.72–4.30
6	Engineer and technician other	2	0.9	2.21	0.55–8.89	1	0.5	2.13	0.30–15.25
61	Minister, priest	2	0.6	3.48	0.86–13.99	0	0.0		
111	Managing director	6	1.6	3.64	1.62–8.18	2	0.8	2.48	0.61–10.02
631	Railway engineer	2	1.1	1.99	0.50–8.02	2	0.7	3.05	0.76–12.32
752	Machinery repairer	7	3.4	2.14	1.01–4.54	5	2.2	2.31	0.95–5.64
768	Other electrical and electronic w.	2	0.1	18.69	4.64–75.28	1	0.1	14.47	2.02–100.0
801	Typographer, litographer	2	1.5	1.26	0.31–5.06	2	1.0	1.98	0.49–8.01
902	Policeman	4	1.2	3.30	1.23–8.87	3	0.8	3.60	1.15–11.30
903	Custom surveyance official	2	0.3	6.59	1.64–26.51	2	0.2	10.43	2.58–42.12
931	Building caretaker	2	1.0	2.05	0.51–8.25	2	0.4	4.68	1.16–18.89
941	Hairdresser, beautician	2	0.7	2.87	0.71–11.54	0	0.0		
981	Member of the armed forces	3	1.4	2.13	0.68–6.64	2	1.0	1.93	0.48–7.81

[a]Occupations of Table I with at least 2 observed cases among workers reporting that occupation in both censuses.
[b]Relative risks adjusted for age, period and geographical category. Reference = other occupations.

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TABLE III. Relative Risks of Male Breast Cancer by ELFMF Exposure Based on Occupations Included in a Job-Exposure Matrix

Type of measure	Total cohort (203 cases)		Younger than 65 years (124 cases)		Occupational sectors 6–9[a] (103 cases)	
	RR[b]	95% CI	RR[b]	95% CI	RR[b]	95% CI
Geometric mean of average work day mean value (quartiles and P90)						
≤0.12 μT	1		1		1	
0.12–0.16 μT	1.37	0.95–1.98	1.56	0.97–2.52	1.49	0.88–2.53
0.16–0.22 μT	1.25	0.82–1.91	1.02	0.56–1.85	1.68	0.87–3.22
0.22–0.30 μT	1.64	1.03–2.61	1.99	1.11–3.56	2.17	1.21–3.88
>0.30 μT	0.92	0.53–1.60	1.00	0.49–2.02	1.01	0.51–2.02
P-value for trend	0.625		0.626		0.310	
≤0.12 μT	1		1		1	
>0.12 μT	1.31	0.94–1.81	1.39	0.90–2.15	1.54	0.98–2.42
Exposed less than 33% of the work day to levels >0.20 μT						
Geometric mean of average work day mean value						
≤0.12 μT	1		1		1	
0.12–0.16 μT	1.38	0.96–2.00	1.56	0.97–2.52	1.49	0.88–2.52
0.16–0.22 μT	1.43	0.89–2.30	1.26	0.66–2.42	1.87	0.94–3.73
>0.22 μT	1.72	1.01–2.93	1.81	0.91–3.58	2.56	1.38–4.74
P-value for trend	0.029		0.126		0.002	
Exposed more than 33% of the work day to levels >0.20 μT						
Geometric mean of average work day mean values (P50 and P75)						
≤0.26 μT	1		1		1	
0.26–0.31 μT	0.71	0.25–2.07	1.20	0.39–3.73	0.81	0.20–3.25
>0.31 μT	1.13	0.56–2.28	1.32	0.54–3.23	0.98	0.35–2.76
P-value for trend	0.816		0.540		0.994	

[a]Transport and communication, production and services.
[b]Relative risks adjusted for age, period and geographical category.

cancer and high socio-economic status. This is probably related to hormonal factors associated with, e.g., later pregnancy, and possibly also with an increased awareness of breast problems [Rubin et al., 1993]. None of these explanations seems to be applicable to men, and the reason for this trend among men is unexplained.

The incidence of breast cancer in working men varied across Swedish counties with higher incidence in Halland, Södermanland and Malmöhus, and lower in Jämtland, Norbotten and Gävleborg. The county of residence was taken into account under the assumption that certain jobs with the potential for exposure to other relevant factors are not randomly located, something already suggested [Rosenbaum et al., 1994]. In this sense, the geographical area is a marker of possible confounders associated with this tumor.

Obesity is one of the risk factors most consistently associated with breast cancer incidence in men [Casagrande et al., 1998; Hsing et al., 1998], probably related to the bioavailability of estrogens [Hsing et al., 1998]. We investigated this factor based on aggregated data, adjusting for the percentage of people in each occupation with a body mass index over 30. However, this variable was not related to an increased incidence in our study, possibly because it has to be assessed on the individual level. The available information may have been too imprecise to reveal an impact.

An elevated breast cancer risk has been observed among workers who hold sedentary jobs [Dosemeci et al., 1993; Hsing et al., 1998], a factor which may trigger a biological pathway involving obesity. For example, lack of physical activity could possibly explain the results for librarian/archivists/curators, teachers, managing directors, bank employees, and clerical workers.

An association with breast cancer was observed for machinery repairers, and the risk estimate was based on a large number of cases (14). Related occupations, such as welders and flame cutters and construction smiths, also presented elevated RRs, but the statistical precision was lower. Also, "other metal processing workers" had an increased RR. An increased risk has been reported for workers in blast furnaces, steel work and rolling mills

[Mabuchi et al., 1985; Lenfant-Pejovic et al., 1990; Cocco et al., 1998], interpreted as possibly related to testicular damage from high temperatures in the workplace. This would imply an impaired testicular function and possibly an imbalance between testosterone/estrogens levels [Thomas et al., 1992]. Although an association has been found between high temperature and male breast cancer using a job-exposure matrix [Rosenbaum et al., 1994], it was not confirmed in another study [Cocco et al., 1998]. Besides increased temperatures, workers in these occupations may have experienced a large variety of potential carcinogens, including PAHs, nitrosamines, and metal fumes [Cocco et al., 1998]. Also, high levels of ELFMF are prevalent among these workers [Floderus et al., 1996]. Some of these occupations, like metal casters/moulders and construction smiths, could not be incorporated in the ELFMF analyses, because these occupations are rare and, therefore, not included in the JEM.

The excess risk found for railway station masters/dispatchers was in agreement with a previous Swedish study on railway engine drivers and conductors [Floderus et al., 1994]. Neither the station masters/dispatchers were included in the JEM due to the same reason, but the level of exposure is clearly elevated (arithmetic mean of mean values = 0.31 μT, based on 12 measurements).

Policemen and custom surveillance officials had an elevated RR of breast cancer. Policemen are highly selected with regard to health status at the time of hiring, as physical fitness is generally required [Forastiere et al., 1994]. They are at risk of physical injuries during employment, but hazardous exposures are few; these include the potential for lead exposure at shooting ranges and exposure to bloodborne biohazards [Finkelstein, 1998]. An excess of male breast cancer among policemen (two cases) [Forastiere et al., 1994], and also of testicular cancer has been reported [Forastiere et al., 1994]. Radiotransmission and/or radar have been suggested as a possible cause [Forastiere et al., 1994]. This exposure is also prevalent among air traffic controllers and among military workers. There were no cases among air traffic controllers in our study, but military workers presented a high, although not statistically significant, relative risk. Other occupations with an increased risk for breast cancer in this study, like bank employees and librarians, are also exposed to electromagnetic fields of frequencies above the ELF-range from electronic security systems. Some animal studies suggest that radiofrequency fields can act as a cancer promoter [Repacholi, 1997].

Increased risks were noted for industrial spray painters, typographers/lithographer, as well as for tanners/fur dressers. Exposure to organic solvents is common to all three groups; industrial spray painting may be associated with heavy exposure, printing workers engaged in rotogravure printing have been exposed to high levels of organic solvents [Svensson et al., 1990], and tanners have used solvents for degreasing of leather, although they are also exposed to a large number of other chemicals, including dyes, arsenic, and chromium [Mikoczy et al., 1994]. Organic solvents were pointed out as a possible etiological factor in a review of occupational exposures and breast cancer among women [Goldberg and Labreche, 1996]. A cohort study of Swedish tanners (482 women and 1,549 men) showed a non-significantly increased risk of breast cancer (19 observed cases vs. 12.9 expected, all among women), in addition to an increased incidence of soft-tissue sarcomas [Mikoczy et al., 1994]. A Swedish study of female laboratory technicians, exposed to organic solvents in addition to other chemicals, showed an increased incidence of breast cancer [Gustavsson et al., 1999]. It has been hypothesized that organic solvents may have carcinogenic action on the female breast related to their lipophilic properties, with a high uptake and biotransformation in fat tissue in the breast [Labreche and Goldberg, 1997]. It is questionable, though, if this mechanism is relevant for breast cancer among men, due to the lower fat content of the male breast.

Despite the extensive study base, most of the occupations characterized by high ELFMF exposures yielded an expected number of subjects that were far below one case. A job exposure matrix offers the advantage of greater statistical power resulting from joining subjects from various occupations. However, ELFMF exposure is extremely variable within occupational groups [Floderus et al., 1996], and the exposure classification, even if it is based on extensive measurements, is a rough proxy measure for the individual's current as well as previous exposure. The misclassification of exposure would be expected to be non-differential with regard to the outcome, leading to a bias of the effect measures toward the null. The exposure from occupational sources contributes only a part of the total ELFMF exposure, which will also lead to an attenuation of risk, in case of a causal association [Loomis et al., 1994]. Given that the ELFMF exposure groups are rather heterogeneous with respect to other conceivable risk factors, it seems less likely that confounding explains the suggested associations.

Using the job-exposure matrix, a slightly higher risk was found among those with an average ELFMF exposure over 0.12 μT, but the risk did not increase with the magnitude of exposure. An indication of an exposure–response relationship was only found among those exposed to levels over 0.20 μT less than one-third of the working day, that is the group more intermittently exposed. The relative risks associated with ELFMF exposure were slightly higher among workers younger than 65, consistent with previous observations [Loomis, 1992; Stenlund and Floderus, 1997]. A positive relationship was only suggested for sectors 6–9, (transport and communication, production and services). If anything, ELFMF is thought to act as a promoter, which should require the presence of inductor substances to develop cancer. There are no well-established carcinogens

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related to breast cancer in men [Sasco et al., 1993], but suspected compounds are probably more prevalent in occupational sectors 6–9.

Stevens put forward the hypothesis that an association between ELFMF exposure and breast cancer could be caused by a negative effect on the production of melatonin by the pineal gland, leading to increased levels of circulating estrogens and an increased risk of breast cancer [Stevens, 1987; Molis et al., 1995]. Inhibited production of melatonin by the pineal gland and/or depressed levels of melatonin in blood, have been observed in rats exposed to ELFMF [Kato et al., 1993; Löscher et al., 1994]. Moreover, melatonin has been shown to inhibit breast cancer cell proliferation in mammary cancer cells [Hill and Blask, 1988].

In summary, our results point out an increased incidence of male breast cancer among higher socioeconomic groups. In spite of the small number of cases involved for specific occupations, machinary repairers, policemen, and custom surveillance officials presented a significant excess risk. The application of the job-exposure matrix of ELFMF did not yield clear evidence of an association, although an exposure–response relationship was found for workers with indications of an intermittent exposure, suggesting that short but high exposures, or large fluctuations in exposure, may be associated with an increased risk. The results do not speak against an association, since several of the occupations showing an increased incidence are characterized by a high exposure to ELFMF.

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