Exposure to electromagnetic fields and suicide among electric utility workers: a nested case-control study

Edwin van Wijngaarden
David A Savitz
Robert C Kleckner
Jianwen Cai
Dana Loomis

Department of Epidemiology
University of North Carolina
School of Public Health
CB 7400
Chapel Hill, NC
27599-7400

Correspondence to:
Dr Savitz
david_savitz@unc.edu

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ABSTRACT **Objective** To examine mortality from suicide in relation to estimated exposure to extremely low–frequency electromagnetic fields in a cohort of 138,905 male electric utility workers. **Methods** Case-control sampling, which included 536 deaths from suicide and 5,348 eligible controls. Exposure was classified based on work in the most common jobs with increased exposure to magnetic fields and indices of cumulative exposure to magnetic fields based on a measurement survey. **Results** Suicide mortality was increased relative to work in exposed jobs and with indices of exposure to magnetic fields. Increased odds ratios (ORs) were found for years of employment as an electrician (OR, 2.18; 95% confidence interval [CI], 1.25-3.80) or line worker (OR, 1.59; 95% CI, 1.18-2.14), whereas a decreased OR was found for power plant operators (OR, 0.67; 95% CI, 0.33-1.40). A dose-response gradient with exposure to magnetic fields was found for exposure in the previous year, with a mortality OR of 1.70 (95% CI, 1.00-2.90) in the highest exposure category. Stronger associations, with ORs in the range of 2.12 to 3.62, were found for men younger than 50 years. **Conclusions** These data provide evidence for an association between occupational electromagnetic fields and suicide that warrants further evaluation. A plausible mechanism related to melatonin and depression provides a direction for additional laboratory research and epidemiologic evaluation.

In the United States, suicide is currently the 8th leading cause of death[1] and is, with homicide, the third leading cause of years of potential life lost.[2] Although suicide rates showed a steady increase from the mid-1950s to the late 1970s, they have changed relatively little during the past 15 years. Mental and addictive disorders are the key risk factors for suicide and suicidal behavior.[3] Analyses of patterns and trends of suicide in the United States show increased risks among people who are male, white, divorced or widowed, elderly, and those living in western states.[3,4]

The potential for an association between extremely low–frequency electromagnetic fields (EMFs) and suicide is biologically plausible. Wilson has postulated a link between exposure to EMFs and depression, based on observations that these exposures alter the daily rhythm of pineal melatonin production and excretion in rats.[5] A pathway involving the effect of EMFs on the production of melatonin, the role of melatonin in depression, and depression as an important risk factor for suicidal behavior points to suicide as a possible consequence of exposure to EMFs. Although data concerning the effects of exposure to EMFs on human pineal function are limited, inhibition of melatonin production has been reported.[6-8] Furthermore, in several reports, lower levels of melatonin formation are associated with depression.[9-12] Moreover, exposure to EMFs has been linked with depression and depressive tendencies.[13-18] Finally, there is strong evidence that depressive illness is an important risk factor for suicide.[3,4]

We conducted a case-control study to consider the risk of suicide for electric utility workers for whom individual estimates of exposure to magnetic fields were obtained based on job titles. The study population of 5,884 subjects was obtained from a cohort of 138,905 men in the original mortality study.[19] Knowledge about the relation between exposure to magnetic fields and suicide is extended through the analysis by time windows, distinguishing possible acute and chronic effects of exposure. Also, analyses were performed for separate age categories. People in different age categories may be more or less vulnerable to the effects of exposure to EMFs because the nature of depression seems to change with age.[20,21]

METHODS

Design and study population

Details of the cohort identification have been published elsewhere, and the cohort is briefly described here.[19] Eligible workers were employed full-time at any of 5 electric power companies in the United States at any time between January 1, 1950, and December 31, 1986, with a total of at least 6 months of continuous employment. Women were excluded because they rarely worked in jobs with the exposure of interest. After exclusions due to lack of availability of records before September 1, 1954, and January 1, 1955, at 2 of the companies, missing date of birth, unknown starting dates, and other errors in the records, 138,905 workers were included in the cohort.

The case-control sampling from the original cohort included all 536 deaths from suicide (*International Classification of Diseases,* 8th and 9th revisions, codes E950-E959) and 5,348 eligible controls. Controls were selected with the use of risk-set sampling.[22] For each suicide case, workers in the cohort who were alive on the date of death of the case-person and who had the same birth year and ethnicity were matched. If fewer than 10 eligible controls were available for the case, then all eligible controls were selected; otherwise, 10 were randomly chosen. This selection procedure generated for each case a set of controls that provided an estimate of the population distribution of exposure at the time of the case-person's death.[23]

Assignment of exposure to magnetic fields

Workers in the electric utility industry have complicated patterns of exposure to EMFs, with several possible measurements, including transient measures of magnetic and electric fields.[24,25] Exposure to EMFs was estimated by an assessment of exposure to magnetic fields, focusing on the time-weighted average, as described in detail elsewhere and briefly summarized here.[19,26-28]

Complete work histories were abstracted and computerized. To consolidate thousands of job titles at the 5 participating companies, 28 occupational categories were constructed based on work activities, responsibilities, and exposure potential[26] to define the rows of a job exposure matrix. Within the occupational categories, 1,060 distinct job titles were monitored. Randomly selected workers wore a personal average magnetic exposure meter (AMEX; Enertech Consultants, Campbell, CA) that recorded the time-integrated mean exposure to magnetic fields over the work shift. A total of 2,842 usable measurements was obtained and used to compute time-weighted average exposures and arithmetic means for each occupational category in the job exposure matrix.[27,28] Cells for exposure to magnetic fields were rank ordered and collapsed into 5 groups to increase statistical precision. Grouping was based on the distribution of the arithmetic mean exposure of each occupational category measured successfully in each company. The 25, 50, 75, and 87.5 percentiles were chosen as arbitrary cutoff points to arrive at 5 groups (5-level job exposure matrix), with time-weighted average exposures of 0.12, 0.21, 0.39, 0.62, and 1.27 μT. Each of the combinations of company and occupational category was placed in 1 of the 5 levels of the job exposure matrix according to the estimated level of exposure to magnetic fields.[28] The average group exposures were assigned for each occupational category and summed over employment intervals for each worker. The mean exposures in each calendar year were summed and multiplied by the proportion of all hours spent at work (0.23) to yield workday exposure in microtesla-days and divided by 365 to yield microtesla-years of occupational exposure.[19]

Confounding factors

Established risk factors for suicide are a history of mental and addictive disorders, abnormalities and alterations in the serotonin system, and disrupted family environment.[3] However, information on these confounding factors was not available from personnel records at the companies. Socioeconomic status,[29,30] solvent exposure,[31] decreased exposure to sunlight,[32-34] and living in the western United States[3,4] are possible risk factors for suicide and were taken into account in this study.

Workers were classified into 4 categories of social class: upper white collar, lower white collar, skilled blue collar, and unskilled blue collar workers. Possible exposure to solvents was assessed by expert panels at each of the 5 participating companies. Solvents were used as thinners, degreasers, cleaners, and lubricants and included 1,1,1-trichloroethane, acetone, carbon tetrachloride, and Varsol. Workers were classified as unexposed to an agent up to the time when they entered a job with exposure potential, and they remained classified as exposed thereafter.[19,35] For exposure to sunlight, workers were classified in a similar manner. Panels classified each job as involving primarily indoor or primarily outdoor work. Information on occupational exposure to sunlight was collected only at the 3 largest companies; therefore, exposures at the 2 smaller ones were estimated.[35] The 5 participating electric utility companies were divided into 2 groups, depending on their location in the United States. One company was located in the western United States, and the other companies were in the eastern United States.

Data analysis

First, the association with exposure to magnetic fields was investigated using occupational categories. Suicide risks were considered for electricians, line workers, and power plant operators, the 3 most common jobs with increased exposure to magnetic fields among the 5 utility companies.[19] Risk estimates were calculated for men in those occupations during the calendar year of death who were ever employed as such in the 1- to 5-year period before death and for men with the specific occupations as the longest held job throughout their career. The reference group consisted of those not employed in the category of interest in the specific time intervals.

As well as the analyses with occupational categories, risk estimates were assessed based on time-integrated exposure. Cumulative exposure (microtesla-year) in the calendar year before the year of death (past 1-2 years) was considered recent exposure. Total exposure was assessed as career exposure for cases and cumulative exposure up to the date of death of the matching case-person for controls. Furthermore, cumulative exposure was examined in 4 time intervals: past 1 to 5 years before death, past 5 to 10 years before death, past 10 to 20 years before death, and 20 years or more before death. The time windows were chosen to consider possible latency of the effect of exposure to magnetic fields on suicide.

For recent and total exposure and for each of the 4 time windows, exposure categories were created based on percentiles of exposure of cases, ensuring an equitable dis-

Table 1 *Crude conditional logistic regression odds ratios (ORs) (95% confidence intervals [CIs] for suicide relative to potential risk factors*

Risk factor	Controls No. (%)	Case-persons No. (%)	OR (95% CI)
Work			
In work	2,865 (93.0)	215 (7.0)	1.00
Out of work	2,483 (88.6)	321 (11.5)	2.15 (1.75-2.66)
Social class			
Upper white	728 (91.9)	64 (8.1)	1.00
Lower white	771 (90.0)	86 (10.0)	1.27 (0.91-1.78)
Skilled blue	2,069 (90.5)	217 (9.5)	1.19 (0.89-1.59)
Unskilled blue	1,780 (91.3)	169 (8.7)	1.07 (0.79-1.46)
Exposure to solvents			
No	1,483 (91.0)	146 (9.0)	1.00
Yes	3,865 (90.8)	390 (9.2)	1.03 (0.84-1.25)
Exposure to sunlight			
No	2,824 (91.8)	254 (8.3)	1.00
Yes	2,524 (90.0)	282 (10.1)	1.25 (1.04-1.50)
Location in United States			
East	3,251 (60.8)	272 (50.7)	1.00
West	2,097 (39.2)	264 (49.3)	1.56 (1.30-1.89)

tribution of deaths across categories. For acute exposure and the 4 windows, 0 exposure was chosen as the referent category (men who were not employed in the relevant time window) and compared with men in quartiles of that distribution. For chronic exposure, men below the 25th percentile formed the referent category, with the other percentiles defined as 25 to 49, 50 to 74, 75 to 89, and 90 or greater. Suicide risk was also evaluated among men in 3 different age categories (≤34 years, 35-49 years, and ≥50 years). Here also, 0 dose was chosen as the referent category and compared with men in percentiles of 0 to 49 and 50 or greater, based on the distribution of exposure of cases.

Adjusted odds ratios (ORs) (estimated rate ratios) and 95% confidence intervals (95% CIs) were derived from conditional logistic regression models with a proportional hazards regression procedure of commercial statistical software (SAS system, version 6.12; SAS Institute, Cary, NC). These analyses were conditioned on the matching factors birth year and ethnicity. Work status, reflecting whether a worker was or was not employed in a given year of death, was included in the model to control for the healthy worker effect,[36] which was important for the outcome of suicide. For consistency, social class, location of company, exposure to solvents, and exposure to sunlight were also included in the model, although little confounding by these variables was found.

RESULTS

Mortality from suicide was similar to overall mortality in the original cohort with respect to race and calendar year.[19] Nearly 87% of the men who committed suicide were white, and most deaths occurred in 1980 to 1988. The average duration of work was 16.2 years (SD 9.8 years). Nevertheless, compared with the overall mortality in the original cohort, the age distribution of suicide deaths was different. The average age of the case-persons was low: 49 years, ranging from 19 to 93 years. Fifty-three percent of all suicide deaths occurred before age 50. Of the 3,502 deaths in this age group in the original cohort, 286 (8.2%) were due to suicide.

Table 1 presents ORs for potential risk factors for suicide available in this study. Being out of work, exposure to sunlight, and location in the western United States were all associated with suicide. Men who were out of work had about a 2-fold increased risk of committing suicide compared with active workers. Exposure to sunlight at the workplace seemed related to a modestly increased risk for suicide (OR, 1.25; 95% CI, 1.04-1.50). Workers living in the western United States had an OR of 1.56 (95% CI, 1.30-1.89). Social class and exposure to solvents were not related to suicide.

Table 2 shows the risk for suicide among men working as an electrician, line worker, or power plant operator at 3 different periods: during the calendar year of death, during 1 to 5 years previously, and throughout a career. Increased risks were found for employment as an electrician in all 3 periods, strongest for the most recent periods. Employment as a line worker also increased the risk, but not in the past year. Employment as power plant operator was weakly inversely associated with suicide.

Table 3 shows the risk estimates for suicide relative to cumulative exposure to magnetic fields in several timeframes. A monotonic dose-response gradient was found, with recent exposure as a categoric measure and an OR of 1.70 (95% CI, 1.00-2.90) in the highest interval. For cumulative exposure in the past 1 to 5 years before death, the categoric analysis yielded ORs of 1.12 to 1.53. Although the dose-response gradient was inconsistent, the highest risk was in the group with the highest exposure. For the other windows of exposure, the ORs were close to or below the null, providing no indication of increased risks. A weak inverse gradient in risk occurred with increasing exposure for a cumulative exposure of 20 years or more before death. For total exposure, increased ORs were found for all levels above the referent, but there was no dose-response pattern.

Men younger than 50 years with recent exposure above the median had notably higher ORs: 2.39 (95% CI, 1.00-5.69) for men younger than 35 years and 3.62 (95% CI, 1.41-9.29) for men aged 35 to 49 years (table 4). Men aged 50 years and older had ORs of less than 1.00, but this group included retired workers without recent exposure. However, restricting the analysis to men aged 50 to 66 years provided similar results. The ORs were lower for cumulative exposure in the period 1 to 5 years before

Table 2 *Adjusted* conditional regression odds ratios (ORs) (95% confidence intervals [CIs]) for suicide relative to type or duration of work in selected occupations*

Time of employment†	Electrician, No. Cases	Electrician, No. Controls	Electrician, OR (95% CI)	Line worker, No. Cases	Line worker, No. Controls	Line worker, OR (95% CI)	Power plant operator, No. Cases	Power plant operator, No. Controls	Power plant operator, OR (95% CI)
Past year†									
No	520	5,235	1.00	509	5,051	1.00	528	5,176	1.00
Yes	16	113	2.18 (1.25-3.80)	27	297	0.98 (0.63–1.54)	8	172	0.67 (0.33-1.40)
Part 1-5 yr									
No	514	5,186	1.00	485	4,955	1.00	522	5,102	1.00
Yes	22	162	1.84 (1.15-2.94)	51	393	1.43 (1.01-2.05)	14	246	0.71 (0.41-1.25)
Career									
No	509	5,148	1.00	441	4,731	1.00	516	5,022	1.00
Yes	27	200	1.59 (1.04-2.45)	95	617	1.59 (1.18-2.14)	20	326	0.69 (0.43-1.11)

*Adjusted for the effects of work (in work or out of work), social class, location in the United States (East or West), and exposure to solvents and sunlight.
†Past year = employment at calendar year of death; past 1-5 yr = ever employed 1-5 years before death; career = longest held job throughout career.

death, with an increased risk for men aged 35 to 49 years (OR, 2.19; 95% CI, 1.12-4.28). Analyses for other exposure windows generally yielded ORs close to or less than 1.00 (data not shown).

DISCUSSION

The results of this study provide support for the hypothesis that occupational exposure to EMFs is associated with an increased risk of suicide. Men employed as electricians, and to a lesser extent as line workers, seemed to be at increased risk, broadly consistent with indications of increased incidences of diagnosed depression and several depressive symptoms in electricians.[37] Power plant operators, however, did not show increased risks. This discrepancy in results could be partially explained by a variation in exposure to levels or patterns of EMFs between those groups. Assessment of exposure to magnetic fields by Kromhout and colleagues showed highest exposures for electricians (1.11 μT) compared with line workers (0.65 μT) and power plant operators (0.79 μT).[28] Also, the inconsistent findings across these jobs could be explained by varying exposure levels of other components of EMFs, which were not captured by our technique of assessing exposure. For example, Armstrong and associates reported high potential exposure to pulsed EMFs for line workers, moderate exposure to pulsed EMFs for electricians, and low exposure to pulsed EMFs for power plant operators.[38]

As expected, men currently working had a substantially decreased risk of suicide, which reflected the healthy worker effect.[36] The increased OR for being out of work indicates that active workers are more physically and mentally fit than those who left the industry and, therefore, tend to be at lower risk of committing suicide. Exposure to sunlight at the workplace seemed to have a small positive association with the risk of suicide, inconsistent with previously reported findings of an association of suicide with decreased exposure to sunlight.[32-34] Nevertheless, a

Table 3 *Adjusted* conditional logistic regression odds ratios (ORs) (95% confidence intervals [CIs]) for suicide relative to cumulative exposure to magnetic fields*

Exposure level, μT-yr	Cases, No.	Controls, No.	OR (95% CI)
Recent exposure			
0	294	2,353	1.00
>0-0.029	58	796	1.19 (0.75-1.89)
0.03-0.049	62	811	1.41 (0.85-2.34)
0.05-0.11	62	719	1.63 (0.97-2.71)
>0.12	60	669	1.70 (1.00-2.90)
Past 1-5 yr			
0	222	1,857	1.00
>0-0.10	75	624	1.25 (0.90-1.75)
0.11-0.19	95	1,338	1.12 (0.76-1.64)
0.20-0.35	73	792	1.45 (0.97-2.17)
>0.36	71	737	1.53 (1.01-2.31)
Past 5-10 yr			
0	202	1,688	1.00
>0-0.13	101	1,254	0.71 (0.53-0.95)
0.14-0.24	89	861	1.01 (0.74-1.39)
0.25-0.43	42	450	0.91 (0.62-1.33)
>0.44	102	1,095	1.00 (0.73-1.38)
Past 10-20 yr			
0	157	1,683	1.00
>0-0.13	93	772	1.09 (0.78-1.53)
0.14-0.32	98	909	1.14 (0.82-1.61)
0.33-0.69	94	943	1.09 (0.77-1.55)
>0.70	94	1,041	1.05 (0.73-1.53)
Past >20 yr			
0	314	3,044	1.00
>0-0.18	57	522	0.91 (0.59-1.41)
0.19-0.43	54	460	0.96 (0.60-1.53)
0.44-1.04	55	588	0.81 (0.50-1.30)
>1.05	56	734	0.72 (0.42-1.21)
Total exposure			
<0.25	133	1,181	1.00
0.25-0.64	135	1,212	1.26 (0.96-1.67)
0.65-1.54	134	1,474	1.13 (0.83-1.53)
1.55-3.00	79	888	1.20 (0.83-1.71)
>3.01	55	593	1.33 (0.89-2.01)

*Adjusted for the effects of work (in work or out of work), social class, location in the United States (East or West), and exposure to solvents and sunlight.

Table 4 *Adjusted* conditional logistic regression odds ratios (ORs) (95% confidence intervals [CIs]) for suicide relative to workers' cumulative exposure to magnetic fields, by age groups*

Exposure level, percentile	Age <35 yr Cases	Age <35 yr Controls No.	Age <35 yr OR (95% CI)	Age 35-49 yr Cases	Age 35-49 yr Controls No.	Age 35-49 yr OR (95% CI)	Age ≥50 yr Cases	Age ≥50 yr Controls No.	Age ≥50 yr OR (95% CI)
Recent exposure†									
0	38	341	1.00	86	527	1.00	170	1,485	1.00
>0-49	39	431	2.12 (0.98-4.59)	41	651	2.40 (1.04-5.55)	46	574	0.67 (0.32-1.42)
≥50	39	398	2.39 (1.00-5.69)	43	517	3.62 (1.41-9.29)	34	424	0.27 (0.32-1.62)
Past 1-5 yr‡									
0	24	210	1.00	73	457	1.00	125	1,190	1.00
>0-49	49	544	1.20 (0.63-2.27)	48	674	1.48 (0.84-2.62)	75	764	1.35 (0.86-2.11)
≥50	43	416	1.50 (0.72-3.10)	49	564	2.19 (1.12-4.28)	50	529	1.48 (0.88-2.49)

*Adjusted for the effects of work (in work or out of work), social class, location in the United States (East or West), and exposure to solvents and sunlight.
†50 Percentile 0.07, 0.08, and 0.05 μT-years for age <35, 35-49, and ≥50 years, respectively.
‡50 Percentile 0.20, 0.21, and 0.22 μT-years for age <35, 35-49, and ≥50 years, respectively.

mechanism of action of light on suicide could involve inhibition of melatonin synthesis because light has an acute suppressing effect of melatonin synthesis in humans.[39] The higher risk of suicide for workers living in the western United States is consistent with historical trends.[3,4]

An association of suicide with exposure to EMFs was first suggested by Reichmanis and co-workers.[40] Results indicated that the calculated strengths of EMFs at the residences of suicide victims differed from those at the residences of controls. Perry and associates measured magnetic fields and found that the strength of magnetic fields was greater at addresses of those who committed suicide than at addresses of controls.[41] However, other studies did not confirm the findings of these 2 initial reports. In a study of mortality of people residing in the vicinity of electricity transmission facilities, McDowall observed 8,000 people and found a standardized mortality ratio of 75 for 8 cases.[42] Baris and Armstrong found no increased rate of suicide in men with occupations likely to have resulted in exposure to electric and magnetic fields.[43] In another study, Baris and colleagues[44] found some evidence of an association with cumulative exposure to the geometric mean of electric fields among electric utility workers but considered the evidence for a causal association to be weak. Kelsh and Sahl found a consistent association of suicide with nonoffice occupations in the electric utility workforce.[45] Johansen and Olsen found, on the basis of 133 observed cases, no indication of excess mortality from suicide as a result of exposure to 50-Hz magnetic fields.[46] Nonetheless, all studies on suicide and EMFs have been limited in the quality of assessment of exposure, sample size, or information on confounding factors.

Wilson postulated that long-term exposure to EMFs may affect pineal function by interfering with tonic aspects of neuronal input to the pineal gland from the central nervous system and that this disruption of normal circadian rhythmicity, particularly in the synthesis of melatonin, may in turn contribute to depressive symptoms.[5] In the present study, an association was found with cumulative exposure in the calendar year before the year of death, which can be considered to be long-term exposure rather than recent exposure in the context of Wilson's hypothesized mechanism.[5] High exposure to EMFs may cause depression, which, as an intermediate variable, may lead to problems at work—for example, calling in sick more often or changing jobs—or even stopping work (and thereby stopping exposure) before suicide occurs. Consequently, lower exposure levels in the intervals shortly before death may not reflect any causal effect of exposure.

Exposure to EMFs may alter melatonin secretion within days or weeks, supported by studies of users of electric blankets[6] and railway and electric utility workers.[7,8] Consequently, depressive symptoms and related problems may develop in the months between recent exposure and suicide. Although recent exposure showed notable increases in risk, if it had been possible to ascertain exposures closer to time of death, such exposures may have shown a stronger association. Studies capable of resolving exposure and its effects over weeks or months would be informative.

An association between recent exposure to EMFs and suicide was found in younger but not older workers, suggesting that younger people may be more vulnerable to the effects of exposure to EMFs. A difference in the nature of depression and suicide between age groups may account for this increased vulnerability. Depression can be subdivided into 2 categories: minor and major depression. The most important risk factor for minor depression, which is common and important in later life, seems to be medical illness. Major depression was found not to be associated with physical health[47] and is more common among younger age groups.[21] The change in the nature of depression with age suggests that people at a younger age may be more vulnerable to the effects of exposure to EMFs, resulting in depressive disorders and suicide.

The results of this study must be interpreted with recognition of the limitations of the use of job titles to estimate exposure to EMFs over decades of work experience. Job titles explain only a small proportion of variability in exposure, as diversity across multiple work environments, electric utility companies, job tasks, and responsibilities contribute to the total variation in exposure to EMFs.[48] Also, the component of EMFs that may be relevant to biologic effects remains uncertain,[49,50] and the current techniques for assessing exposure to EMFs, which focus on time-weighted average magnetic fields, can be considered to be only crude measures. Nevertheless, the assessment of exposure to EMFs used in our study is more thorough than in most previous epidemiologic studies on this topic.

An advantage over previous studies is the relatively large sample size, which made it possible to examine individual jobs and stratify by age. Furthermore, our ability to reproduce well-known associations with work status and location in the United States was encouraging. Finally, it is unlikely that misclassification of cases has occurred. Moyer and co-workers examined the agreement between death certificates for causes of death related to injury and an independent medical review of medical and legal records for deaths occurring among US Army Vietnam war veterans.[51] Sensitivity for broad and specific suicide categories was more than 90%, whereas specificity was 100%. This indicates that the use of death certificates is a valid method of classifying suicides. On the other hand, we were unable to isolate suicide deaths mediated by depression from other suicides, including those related to chronic disease, for which the exposure under study would not be relevant.

An important limitation was the inability to fully examine and control for confounding. Information on several important risk factors for suicide was not available, such as history of mental and addictive disorders and disrupted family environment. Nevertheless, some evidence exists that electrical workers and nonelectrical workers are generally similar in sociodemographic and related attributes and tend to drink less alcohol than other workers.[37] Also, a study by Baris and colleagues showed similar exposure among alcohol users compared with nonusers.[44] The same study, however, showed higher exposure among single workers and workers with mental disorders, so that the lack of adjustment for confounding by marital status and mental disorders could have led to the overestimation of an association. Whether these results are applicable to the present study population is unclear. Nevertheless, it seems unlikely that confounding by unmeasured factors or imprecise measurement on the others has occurred in a sufficient degree to create or mask sizable associations.

CONCLUSIONS

The results of this study provide evidence for an association between cumulative exposure of extremely low–frequency EMFs and suicide, especially among younger workers. We hypothesize that an increased vulnerability at younger ages may be based on a change in the nature of depression with age, with suicide more closely linked to depression among younger workers and physical impairments among older workers. Future research on the effects of exposure to EMFs on suicide and depression is warranted to examine more closely the temporal pattern of exposure, depression, and suicide.

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