

## Exposure to Electromagnetic Fields from Use of Electric Blankets and Other In-Home Electrical Appliances and Breast Cancer Risk

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Exposure to electromagnetic fields (EMFs) from use of electric blankets and other in-home electrical appliances has been hypothesized to increase breast cancer risk. To test the hypothesis, the authors analyzed data from a case-control study of female breast cancer conducted in Connecticut in 1994–1997. A total of 608 incident breast cancer patients and 609 age frequency-matched controls, 31–85 years old, were interviewed by trained study interviewers using a standardized, structured questionnaire to obtain information on lifetime use of various in-home electrical appliances. A total of 40% of the cases and 43% of the controls reported regular use of electric blankets in their lifetime, which gave an adjusted odds ratio of 0.9 (95% confidence interval (CI): 0.7, 1.1). For those who reported using electric blankets continuously throughout the night, the adjusted odds ratio was 0.9 (95% CI: 0.7, 1.2) when compared with never users. The risk did not vary according to age at first use, duration of use, or menopausal and estrogen receptor status. The authors also did not find an association between use of other major in-home electrical appliances and breast cancer risk. In conclusion, exposure to EMFs from in-home electrical appliance use was not found to increase breast cancer risk in this study. *Am J Epidemiol* 2000;151:1103–11.

breast neoplasms; case-control studies; electromagnetic fields

Chronic exposure to electromagnetic fields (EMFs) in the range of 50–60 Hz has been hypothesized to increase female breast cancer risk (1–3). In-home electrical appliances often provide the highest magnetic field levels experienced in the residence, with electric blankets being among the largest sources. Some studies have reported that pineal gland exposure to EMFs from electric blanket use could be 10–40 times greater than exposure to EMFs associated with electrical wiring in or around the home (4–6). Several mechanisms have been suggested to explain the potential relation between EMF exposure and breast cancer risk, including the following: 1) EMFs reduce the pineal gland's production of melatonin, a hormone that inhibits mammary carcinogenesis (1, 2, 7–9); 2) EMFs have a direct effect on circulating prolactin and estrogen (1, 10, 11); or 3) EMFs cause alteration of mitotic

processes (12) and dysfunction of cell membranes (13). It has also been suggested that EMFs might reverse the oncostatic effect of melatonin at the site of action in breast tissue (14).

Limited epidemiologic studies investigating electric blanket use and breast cancer risk have produced inconclusive results (15–19). A case-control study from upstate New York found a borderline significantly increased risk of breast cancer for postmenopausal women (odds ratio (OR) = 1.5, 95 percent confidence interval (CI): 1.0, 2.2) and for premenopausal women (OR = 1.4, 95 percent CI: 0.9, 2.2) among those who reported using electric blankets continuously throughout the night compared with never users (15, 16). When pre- and postmenopausal women were combined (17), the odds ratio was 1.5 (95 percent CI: 1.1, 1.9). Two more recent studies, however, found no increased risk associated with electric blanket use (18, 19). The study by Gammon et al. (18) found an odds ratio of 1.0 (95 percent CI: 0.9, 1.2) for women under age 45 years and an odds ratio of 1.1 (95 percent CI: 0.9, 1.4) for those 45 years and over among women who reported using electric blankets, mattress pads, or heated water beds when compared with never users. Another study by Coogan and Aschengrau (19) reported an odds ratio of 1.0 (95 percent CI: 0.7, 1.4) among women who reported using an electric blanket compared with women who did not.

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Abbreviations: CI, confidence interval; EMF, electromagnetic field; OR, odds ratio.

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Besides electric blankets, there are other in-home electrical appliances that could be significant sources for domestic exposure to EMFs (20). These include electric hair dryers, curling irons, vacuum cleaners, and electric irons. A potential relation between exposure to these in-home electrical appliances and breast cancer risk has been suggested, but no study has been conducted to actually assess the relation. Because of the inconclusive nature of the association and the widespread use of the aforementioned appliances, we examined the relation between in-home use of electrical appliances and the risk of breast cancer in a case-control study conducted in Connecticut between 1994 and 1997.

## MATERIALS AND METHODS

### Study population

Cases were histologically confirmed, incident breast cancer patients (*International Classification of Diseases for Oncology* codes 174.0–174.9) who either had breast-related surgery at the Yale-New Haven Hospital, New Haven County, or who were residents of Tolland County, Connecticut, between January 1, 1994, and December 31, 1997. Subjects were restricted to 31- to 85-year-old women who had no previous diagnosis of cancer, with the exception of nonmelanoma skin cancer, and who were alive at the time of interview.

Potentially eligible cases from the Yale-New Haven Hospital were identified using computerized patient information from the Yale-New Haven Hospital Surgical Pathology Department, where records of all newly performed breast-related surgeries are kept. We consecutively selected all breast cancer patients who met the study eligibility requirements as described above. A total of 561 incident breast cancer cases were identified from Yale-New Haven Hospital, with 432 of them (77 percent) completing in-person interviews. From the computerized files, we also randomly selected 569 potential control patients who had had breast-related surgery and who were histologically diagnosed with normal tissue or benign breast diseases (excluding atypical hyperplasia). Of these, 404 (71 percent) participated in the study. Efforts were made to frequency match the cases and controls by age (within 5-year intervals) using a 1:1 ratio by adjusting the number of controls randomly selected in each age stratum every few months.

In addition to the cases and controls recruited from the Yale-New Haven Hospital, we also recruited cases and controls from Tolland County, Connecticut. Tolland and New Haven counties have similar breast cancer incidence rates, and in recent years they have

had similar breast cancer mortality rates as well. Newly diagnosed cases with Tolland County addresses were identified from area hospital records by the Rapid Case Ascertainment Shared Resource of the Yale Comprehensive Cancer Center, where the staff are assigned geographically to survey all of the state's non-pediatric hospitals in order to identify newly diagnosed cases. Cases identified in the field are sent regularly to the Rapid Case Ascertainment Shared Resource data entry staff where the case's demographic information is entered, verified, and screened against the Connecticut Tumor Registry database. Connecticut also has reciprocal reporting of cancer cases with adjacent states, facilitating complete ascertainment.

A total of 238 such cases were identified for this study with 176 of them (74 percent) completing in-person interviews. Population-based controls with Tolland County addresses were recruited using either random digit dialing methods for those below age 65 as described by Hartge et al. (21) or Health Care Finance Administration files for those aged 65 years and over. The participation rate from random digit dialing-selected controls was 64 percent including the initial telephone screening and from Health Care Finance Administration controls, 54 percent. A total of 152 random digit dialing-selected controls and 53 Health Care Finance Administration controls participated in the study. Efforts were made to frequency match the cases and controls by age (within 5-year intervals) using a 1:1 ratio by adjusting the number of controls randomly selected in each age stratum every few months.

The study pathologist (D. C.) reviewed all the pathologic information for the breast cancer cases and for the benign breast disease controls recruited from Yale-New Haven Hospital. He also reviewed the pathologic information for the cases recruited from Tolland County. Carcinomas were classified as in situ, invasive ductal, or invasive lobular and were staged according to the tumor-nodes-metastasis system (22).

### Interviews

All procedures were performed in accordance with a protocol approved by the Yale Human Investigations Committee. After approval by the hospitals and by each subject's physician, or following selection through random sampling, potential participants were approached by letter and then by phone. Those who agreed were interviewed by trained study interviewers, either at the subject's home or at a convenient location. A standardized, structured questionnaire was used to obtain information on electric blanket usage. The respondents were asked whether they had used an electric blanket regularly at any time in their life. If their response was affirmative, the respondents were then

asked to provide information related to each period when they had used an electric blanket. Specifically, they were asked to give their age at first/each use, age when they stopped use, the number of years of use, and finally, the number of months per year and days per week during months of reported use. Respondents were also questioned about their most typical pattern (or mode) of use, that is, whether their electric blanket was left on for most of the entire night, if it was only used to warm the bed, or if it was left on for up to 1 hour or 1–3 hours after getting into bed. Most of the participants in this study reported the same mode of use over the different periods of use reported. Only eight controls and one case reported different modes of use over different periods of use. The results were essentially the same even when the reported mode of use spanned a lifetime as opposed to being only the current mode of use. Therefore, in tables 2 and 3, we reported only the lifetime mode of use. The nine subjects who reported different modes of use over different periods were grouped into the other use pattern category in tables 2 and 3.

Information on the use of other in-home electrical appliances (such as electric hair dryers, electrically heated waterbeds, and electric heating pads) was also collected. Briefly, respondents were questioned about their age at first use, the number of years of use, and the number of days per month during those months of reported use.

Information on other potential confounding factors, including menstrual and reproductive history, family cancer history, occupation, diet, and demographic factors, was also collected during the interview. Dietary information was collected using a scannable semi-quantitative food frequency questionnaire developed by the Fred Hutchinson Cancer Research Center and specifically designed to optimize estimation of fat intake. Each subject was asked to characterize her usual diet in the year prior to being interviewed.

### Data analysis

The primary analyses involved comparisons of usage of various in-home electrical appliances between cases and controls. Since it has been suggested that EMF exposure may differentially affect premenopausal and postmenopausal breast cancer risk (16, 23), we stratified data by menopausal status. In addition, since it has been suggested that breast cancer risk related to EMF exposure may vary based on hormone receptor status (24), we examined the association by stratifying on estrogen receptor status. About 92 percent (399/432) of the breast cancer patients recruited from the Yale-New Haven Hospital have information on estrogen receptor levels. These levels

were measured immunohistochemically at the pathology department of Yale-New Haven Hospital and were considered to be positive with an H-score larger than 75 as described by McCarty et al. (25) (an "H-score" is calculated as the percentage of stains  $\times$  the intensity of the stain). Detailed information also allowed us to examine breast cancer risk by cumulative exposure (lifetime duration in months of use), by duration of exposure (number of years of use), and by intensity of exposure (such as the average number of months of use per year and the average number of days of use per year).

Unconditional logistic regression was used to estimate the association between exposure and disease and to control for potential confounders. Potential confounding variables included in the final model were age ( $<50$ ,  $\geq 50$  years), body mass index ( $<22$ ,  $22\text{--}24.9$ ,  $25\text{--}29.9$ ,  $\geq 30$  kg/m<sup>2</sup>), age at menarche ( $<13$ ,  $13\text{--}15$ ,  $\geq 16$  years, or unknown), lifetime months of lactation (0,  $1\text{--}6$ ,  $7\text{--}12$ ,  $\geq 13$ ), age at first full-term pregnancy (nulliparous,  $<20$ ,  $20\text{--}25$ ,  $\geq 26$  years), dietary fat intake in grams per day ( $<46$ ,  $47\text{--}71$ ,  $\geq 72$ , or unknown), income 10 years before disease diagnosis or interview ( $\$<20,000$ ,  $\$20,000\text{--}24,999$ ,  $\geq \$25,000$ , or unknown), race (Whites, Blacks, and others), family breast cancer history in a first degree relative, and study site (Yale-New Haven Hospital or Tolland County, included in all models excluding those in table 3, which stratified by study site). Odds ratios and 95 percent confidence intervals were calculated using SAS statistical software (26). Tests for trend were conducted by using a likelihood ratio statistic in a logistic regression model.

### RESULTS

As shown in table 1, cases were slightly older than controls despite the attempt at matching. Women with a later age at first full-term pregnancy showed a significantly increased risk. In comparison with those less than age 20 at first full-term pregnancy, the odds ratio was 1.6 (95 percent CI: 1.1, 2.4) for those having first full-term pregnancy at ages 20–25. The odds ratio was 1.8 (95 percent CI: 1.1, 2.7) for those having a first full-term pregnancy at ages 26 and over. Those having a lifetime lactation history of more than 12 months experienced a reduced risk (OR = 0.8, 95 percent CI: 0.5, 1.1) compared with those who never lactated. A history of having a first-degree relative with breast cancer was associated with a nonsignificantly increased risk of breast cancer (OR = 1.2, 95 percent CI: 0.9, 1.6). Dietary fat intake at the second tertile showed a slightly increased risk. These observations are generally in line with what is known about breast cancer etiology.

Data relating electric blanket use and breast cancer risk are presented in table 2. A total of 40 percent of the

TABLE 1. Selected characteristics of breast cancer cases and controls, Connecticut, 1994–1997

Characteristics	No. of cases (n = 608)	No. of controls (n = 609)	OR*,†	95% CI*
Age (years)				
<50	186	234	1.0	
≥50	422	375	1.3	1.0, 1.7
Race				
Whites	551	557	1.0	
Blacks	38	35	1.2	0.7, 2.1
Others	19	17	1.2	0.6, 2.4
Annual income (\$)				
<20,000	354	343	1.0	
20,000–24,999	46	60	0.7	0.4, 1.0
≥25,000	102	119	0.8	0.6, 1.1
Unknown	106	87	1.1	0.8, 1.5
Body mass index (kg/m <sup>2</sup> )				
<21.0	80	105	1.0	
21.0–24.9	238	234	1.3	0.9, 1.9
≥25.0	290	270	1.3	0.9, 1.8
Fat intake (g/day)				
<46	173	207	1.0	
46–71	230	199	1.4	1.1, 1.9
≥72	186	183	1.2	0.9, 1.7
Unknown	19	20	1.2	0.6, 2.4
Age at menarche (years)				
≥15	67	66	1.0	
13–14	245	259	1.0	0.7, 1.2
<13	290	283	1.1	0.8, 1.6
Unknown	6	1	6.1	0.7, 53.6
Age at first full pregnancy (years)				
<20	54	73	1.0	
20–25	260	240	1.6	1.1, 2.4
≥26	209	198	1.8	1.1, 2.7
Nulliparous	85	98	1.4	0.8, 2.3
Lifetime lactation (months)				
0	390	366	1.0	
1–6	96	101	0.8	0.6, 1.2
7–12	46	50	0.9	0.5, 1.3
≥13	76	92	0.8	0.5, 1.1
Family breast cancer history				
No	463	485	1.0	
Yes	145	124	1.2	0.9, 1.6

\* OR, odds ratio; CI, confidence interval.

† Odds ratios for each selected characteristic were adjusted for all other selected characteristics listed in table 1.

cases and 43 percent of the controls reported regular use of an electric blanket, yielding an adjusted odds ratio of 0.9 (95 percent CI: 0.7, 1.1). There was no clear pattern to the association between age of first use and breast cancer risk. Breast cancer risk did not vary by the typical pattern of use. The adjusted odds ratio was 0.9 (95 percent CI: 0.7, 1.1) for those who reported using

electric blankets continuously throughout the night when compared with nonusers. There was also no excess risk associated with increasing the duration of electric blanket use. An adjusted odds ratio of 0.8 (95 percent CI: 0.6, 1.1) was observed for those using an electric blanket for 37 or more months when compared with nonusers (table 2). The risk of breast cancer also

TABLE 2. Electric blanket use and risk of breast cancer, Connecticut, 1994–1997

Blanket use	No. of cases	No. of controls	OR*,†	95% CI*
Never	367	346	1.0	
Ever	241	263	0.9	0.7, 1.1
Age (years) at first use				
<25	49	51	1.0	0.7, 1.6
25–34	55	81	0.7	0.5, 1.0
35–44	79	69	1.1	0.8, 1.6
≥45	58	62	0.8	0.5, 1.1
<i>p</i> for trend			0.34	
Months of lifetime use				
1–12	90	81	1.1	0.8, 1.6
13–24	30	42	0.7	0.4, 1.2
25–36	25	32	0.7	0.4, 1.3
≥37	96	108	0.8	0.6, 1.1
<i>p</i> for trend			0.17	
Mode of use				
To warm bed only	56	64	0.8	0.6, 1.2
Throughout night	147	159	0.9	0.7, 1.2
Other use patterns	37	39	1.2	0.7, 2.0
Missing information	1	1		

\* OR, odds ratio; CI, confidence interval.

† Adjusted for age, body mass index (kg/m<sup>2</sup>), lifetime months of lactation, age at menarche, age at first full-term pregnancy, family breast cancer history, fat intake, race, income 10 years before disease diagnosis or interview, and study site. Never use is the referent category for all odds ratios.

was not associated with the number of years of use, with the average number of months of use per year, or with the average number of days of use per year (data not shown). The results stratified by study site did not show an increased risk of breast cancer associated with electric blanket use among subjects from either Yale-New Haven Hospital or Tolland County (table 3).

We also explored the possibility that the risk might be apparent only among current users as has been shown for other breast cancer risk factors (27). We compared both the cases and controls among current or former users with never users, by age at first use, duration of use, and mode of use. We did not find an increased risk of breast cancer associated with these variables among either current users or former users. Among the 115 cases and 147 controls comprising the current user group, we found an odds ratio of 0.5 (95 percent CI: 0.2, 1.1) for those whose mode of use was "throughout night," an odds ratio of 1.2 (95 percent CI: 0.6, 2.4) for those with mixed use patterns, and an odds ratio of 0.7 (95 percent CI: 0.3, 1.5) for those whose mode of use was to warm the bed only.

Stratification by menopausal status also showed no increased risk of breast cancer associated with electric blanket use among either premenopausal ( $n = 342$ ) or postmenopausal ( $n = 875$ ) women. For example, for those who reported leaving an electric blanket on all

night, the adjusted odds ratio was 0.8 (95 percent CI: 0.5, 1.5) for premenopausal women and 0.8 (95 percent CI: 0.6, 1.2) for postmenopausal women when compared with never users. Stratification of cases by estrogen receptor status ( $n = 220$  for estrogen receptor positive and  $n = 179$  for estrogen receptor negative) also showed no increased risk associated with age at first use, duration of use, and typical pattern of electric blanket use. For example, for those who reported leaving an electric blanket on all night, the adjusted odds ratio was 1.1 (95 percent CI: 0.7, 1.7) for estrogen receptor-positive patients and 0.9 (95 percent CI: 0.6, 1.5) for estrogen receptor-negative patients.

Table 4 presents the odds ratios for breast cancer risk and use of other major in-home electrical appliances. None of the odds ratios was statistically significant, except for the estimate for using an electric razor for 1–35 months (OR = 1.7, 95 percent CI: 1.1, 2.8). Among those who reported using an electric razor for more than 36 months, however, the risk was borderline significantly reduced (OR = 0.6, 95 percent CI: 0.3, 1.0).

## DISCUSSION

This study does not support an association between risk of female breast cancer and exposure to EMFs in

TABLE 3. Electric blanket use and risk of breast cancer by study site, Connecticut, 1994–1997

Blanket use	YNHH* subjects				Tolland County			
	No. of cases	No. of controls	OR*,†	95% CI*	No. of cases	No. of controls	OR†	95% CI
Never	260	237	1.0		107	109	1.0	
Ever	172	167	1.0	0.7, 1.3	69	96	0.7	0.5, 1.1
Age (years) at first use								
<25	35	31	1.2	0.7, 2.1	14	20	0.8	0.4, 1.8
25–34	39	57	0.7	0.5, 1.1	16	24	0.5	0.3, 1.2
35–44	60	42	1.3	0.9, 2.1	19	27	0.8	0.4, 1.5
≥45	38	37	0.8	0.5, 1.3	20	25	0.7	0.4, 1.5
<i>p</i> for trend								
Months of lifetime use								
1–12	64	55	1.2	0.8, 1.8	26	26	1.0	0.5, 1.9
13–24	20	19	1.1	0.6, 2.2	10	23	0.4	0.2, 1.0
25–36	19	20	0.9	0.4, 1.7	6	12	0.5	0.2, 1.5
≥37	69	73	0.8	0.6, 1.2	27	35	0.7	0.4, 1.4
<i>p</i> for trend								
Mode of use								
To warm bed only	37	38	0.9	0.6, 1.5	19	26	0.7	0.3, 1.3
Throughout night	110	98	1.0	0.7, 1.5	37	61	0.6	0.4, 1.0
Other use patterns	25	30	1.0	0.6, 1.9	12	9	1.7	0.6, 4.9
Missing information	0	1			1	0		

\* YNHH, Yale-New Haven Hospital; OR, odds ratio; CI, confidence interval.

† Adjusted for age, body mass index (kg/m<sup>2</sup>), lifetime months of lactation, age at menarche, age at first full-term pregnancy, family breast cancer history, fat intake, race, and income 10 years before disease diagnosis or interview. Never use is the referent category for all odds ratios.

the range of 50–60 Hz from in-home electrical appliance use, including but not limited to electric blankets. The risk did not vary by menopausal status or by hormone receptor status. These results are in contrast to the results by Vena et al. (15–17), yet consistent with two recent case-control studies (18, 19), which also did not find an association between electric blanket use and breast cancer risk.

Experimental studies have suggested a potential relation between exposure to EMFs and breast cancer risk. A study by Liburdy et al. (14) found that a 12-mG, 60-Hz magnetic field can reverse melatonin's oncostatic action on a human MCF7 breast cancer cell line in culture. Blask (28) suggested that melatonin may be directly oncostatic, and this has led Stevens (24) to speculate that lower melatonin production due to EMF exposure might increase risk by releasing previously quiescent transformed cells from growth inhibition.

It may be difficult, however, to directly compare the results from epidemiologic studies with those from laboratory studies. The exposure characteristics, such as time of exposure and the levels of exposure, could be very different between the two types of studies. For example, the exposure conditions in the experimental studies are generally well defined, while the exposures

from use of in-home appliances are quite the opposite. Furthermore, the exposure levels are usually much lower and vary between in-home appliances. A recent study by Hatch et al. (29) reported an average level of magnetic fields of 2.2  $\mu$ T from electric blankets that is lower than what was reported by others (4, 30). Water bed heaters produce lower magnetic fields than do electric blankets; however, they are used throughout the year, with the strength of magnetic fields depending upon the position of the heater (29). Magnetic fields from hair dryers can range between 0.100 and 70.0  $\mu$ T within 6 inches (15.24 cm) of the electric motor (30). Since curling irons contain only a heating element but no motor, curling irons produce magnetic fields considerably lower than those of hair dryers (29). Considering the significant differences in exposure characteristics, caution should be taken when comparing the results of epidemiologic and experimental studies.

One potential reason that recent epidemiologic studies have not found an association between exposure to domestic EMFs and breast cancer risk could be due to a lack of detail in collected information related to domestic EMF exposure. Regarding the use of electric blankets, for example, a number of factors may affect

**TABLE 4. Lifetime duration (in months) of in-home electric appliance use and risk of female breast cancer, Connecticut, 1994–1997**

Appliance use	No. of cases	No. of controls	OR*,†	95% CI*
Heated waterbed (months)				
Never	548	524	1.0	
<72	26	46	0.6	0.4, 1.0
≥73	34	38	1.0	0.6, 1.7
Missing information	0	1		
Hair dryer (months)				
Never	181	162	1.0	
1–59	129	146	0.9	0.6, 1.2
60–236	167	146	1.3	0.9, 1.8
>236	131	155	1.0	0.7, 1.4
Curling iron (months)				
Never	378	352	1.0	
1–58	104	128	0.8	0.6, 1.1
≥59	126	129	1.0	0.8, 1.4
Heating pad (months)				
Never	550	556	1.0	
1–13	30	26	1.2	0.7, 2.1
≥14	28	27	1.2	0.7, 2.1
Electric razor (months)				
Never	532	541	1.0	
1–35	52	33	1.7	1.1, 2.8
≥36	24	34	0.6	0.3, 1.0
Missing information	0	1		
Electric toothbrush (months)				
Never	513	510	1.0	
1–32	38	48	0.8	0.5, 1.2
≥33	57	51	1.0	0.7, 1.6
Vacuum cleaner (months)				
Never	58	52	1.0	
1–46	135	136	1.1	0.7, 1.8
47–70	127	141	0.9	0.5, 1.5
71–109	147	136	1.0	0.6, 1.6
≥110	141	144	0.9	0.5, 1.4
Popcorn maker (months)				
Never	503	509	1.0	
1–9	51	50	1.2	0.8, 1.8
≥10	54	50	1.2	0.8, 1.9
Computer (months)				
Never	312	261	1.0	
1–38	92	115	0.7	0.5, 1.0
39–90	115	118	0.9	0.6, 1.2
≥91	89	115	0.7	0.5, 0.9
Iron (months)				
Never	72	63	1.0	
1–53	170	181	0.9	0.6, 1.4
54–100	188	182	0.9	0.6, 1.4
≥101	178	183	0.9	0.6, 1.4

\* OR, odds ratio; CI, confidence interval.

† Adjusted for age, body mass index (kg/m<sup>2</sup>), lifetime months of lactation, age at menarche, age at first full-term pregnancy, family breast cancer history, fat intake, race, income 10 years before disease diagnosis or interview, and study site.

the actual level of exposure to EMFs, including the following: the type and routing of the heating element; the controller design; the means of overheat protection; and human use factors such as heat tolerance, frequency, and pattern of use (31). Lack of detailed information about these factors would cause a misclassification of exposure. While the misclassification is unlikely to be differential, nondifferential misclassification can still cause underestimation of the association between in-home electrical appliance use and breast cancer risk. This argument, however, does not seem to coincide well with the fact that there was no apparent increased risk for women who started using electric blankets at a very early age, used them for a long time, and kept them on continuously throughout the night.

Another potential explanation for the lack of association observed in our study concerns the use of benign breast disease patients as part of the control group. If benign breast diseases were associated with EMF exposure, a weak association between use of electrical appliances and breast cancer risk could be obscured. However, this explanation does not seem to be highly likely because population-based controls were used for subjects recruited from Tolland County. As described earlier, when these two study sites were analyzed separately, we reached essentially the same conclusions as in the combined analyses.

Another potential limitation of our study is that we did not collect information on occupational and residential electric wiring exposure to EMFs. However, the proportion of the female work force employed in electrical occupations associated with exposure to EMFs is small, and most of the studies relating such occupational exposures to breast cancer risk have produced largely negative results (32, 33). Studies have also suggested that EMF exposure associated with electrical wiring in or around the home was substantially smaller than that from electric blanket use or from the use of other in-home electrical appliances (4, 5, 20). Finally, residential exposure to EMFs also has not been consistently associated with breast cancer risk (33–36). Therefore, it is unlikely that the observed lack of association between in-home electrical appliance use and breast cancer risk can be entirely explained by confounding from occupational and residential EMF exposures.

One of the advantages of our study is that we have collected detailed information on major in-home electrical appliances and not limited our investigation to electric blanket use. Examination of the relation between breast cancer risk and use of electrical appliances other than electric blankets is important since studies have shown that these other in-home electrical

appliances could also significantly contribute to human EMF exposure (20).

Our study assessed the effect of lifetime use of major in-home electrical appliances and was not limited to exposures at just one time. It is currently unknown which exposure (past or current) is more important if a relation indeed exists between EMFs and breast cancer risk. It has been suggested (8) that EMF exposure many years in the past should be assessed if stem cell turnover has been affected. On the other hand, if cancer cell growth is the underlying mechanism for an association between EMFs and breast cancer risk, then very recent exposures could be crucial. Savitz et al. (37) pointed out that, if prolonged exposure is the basis for purported adverse health effects, the duration of exposure from different sources would be of paramount importance. These suggestions emphasize the importance of examining the relation by age at first regular use and duration of use of various electric appliances.

In summary, there has been increasing concern that exposure to EMFs resulting from in-home electrical appliance use and residential and occupational exposures may increase breast cancer risk, as well as cause other adverse health effects (1–3). This possibility has provoked considerable controversy, as summarized by others (7–9, 33, 38–40), and is far from resolved. While recent epidemiologic studies, including this one, do not support an association between exposure to EMFs from in-home electrical appliances and breast cancer risk, several possible limitations may have hampered these findings. One of the potential limitations discussed earlier is a lack of detail in information collected through in-person interviews related to domestic EMF exposure. The resultant misclassification of exposure may cause an underestimation of the association between in-home electrical appliance use and breast cancer risk. Future epidemiologic studies would be needed to improve the measurement tools so that a better estimate of EMF exposure from various sources over many years could be achieved, but thus far the evidence for such an association is not strong.

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