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VIDEO DISPLAY TERMINALS AND THE RISK OF SPONTANEOUS ABORTION

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Abstract *Background.* The relation between spontaneous abortion and the use of video display terminals (VDTs) is of great public health concern. Previous investigators of this issue have reported inconsistent findings.

Methods. To determine whether electromagnetic fields emitted by VDTs are associated with an increased risk of spontaneous abortion, a cohort of female telephone operators who used VDTs at work was compared with a cohort of operators who did not use VDTs. To obtain reliable estimates of exposure, we determined the number of hours of VDT use per week from company records and measured electromagnetic fields at VDT workstations and, for purposes of comparison, at workstations without VDTs. Operators who used VDTs had higher abdominal exposure to very-low-frequency (15 kHz) electromagnetic fields (workstations without VDTs did not emit very-low-frequency energy). Abdominal exposure to extremely-low-frequency fields (45 to 60 Hz) was similar for both operators who used VDTs and those who did not. Among 2430 women interviewed, there were 882 pregnancies that met our criteria for inclusion in the study.

Results. We found no excess risk of spontaneous abortion among women who used VDTs during the first trimester of pregnancy (odds ratio = 0.93; 95 percent confidence interval, 0.63 to 1.38), and no dose–response relation was apparent when we examined the women's hours of VDT use per week (odds ratio for 1 to 25 hours per week = 1.04; 95 percent confidence interval, 0.61 to 1.79; odds ratio for >25 hours per week = 1.00; 95 percent confidence interval, 0.61 to 1.64). There continued to be no risk associated with the use of VDTs when we accounted for multiple pregnancies, conducted separate analyses of early abortion, late abortion, and all fetal losses, or limited our analyses to spontaneous abortions for which a physician was consulted.

Conclusions. The use of VDTs and exposure to the accompanying electromagnetic fields were not associated with an increased risk of spontaneous abortion in this study. (N Engl J Med 1991; 324:727-33.)

CONCERN about the potential reproductive effects of using video display terminals (VDTs) was first raised in 1980, when adverse pregnancy outcomes among several clusters of women who used VDTs were reported.[1-5] Most subsequent epidemiologic analyses of the use of VDTs and pregnancy outcome had equivocal results or found no effect.[6-14] Two studies found a significantly increased risk of spontaneous abortion among women who used VDTs more than 15 hours[15] or more than 20 hours[16] per week. Only a few studies were initially designed to investigate the effects of VDTs on reproduction.[11-13] All the studies estimated the extent of VDT use on the basis of responses to interview questions[11-16] or data on job titles.[6-10,14,15] None measured the electromagnetic fields produced by the VDTs.

A VDT containing a cathode-ray tube to generate a visual display emits both extremely-low-frequency (approximately 45 to 60 Hz) and very-low-frequency (approximately 15 kHz) electromagnetic fields. Extremely-low-frequency fields have been found to be associated with spontaneous abortion in two studies that showed a seasonal pattern of abortions in families with electrically heated beds[17] or ceiling-cable electric heat.[18] Studies of the relation of very-low-frequency electromagnetic fields and spontaneous abortion in humans have been limited primarily to studies of the effects of VDTs.[6-16]

In this study we examined the hypothesis that electromagnetic energy produced by VDTs might cause spontaneous abortions. By selecting two groups of full-time female telephone operators with similar work situations, we intended to minimize any potential ef-

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fect of physical and psychological stress. We obtained data on VDT use from the employers' personnel records and measured electromagnetic fields at a sample of the operators' workstations.

Methods

Study Population

The study population consisted of women employed as directory-assistance operators and general telephone operators (reached by dialing zero) at two companies in eight southeastern states. The directory-assistance operators used VDTs to provide telephone numbers to customers, whereas the comparison group of general operators primarily assisted customers in placing long-distance calls. The general operators used units containing a light-emitting diode or neon glow tube to display the numbers, rather than a VDT. Typically, both directory-assistance and general operators worked an 8½-hour day, which included 1 hour for lunch and two 15-minute breaks. Both groups of operators sat in front of their equipment for the entire workday. A computer automatically routed incoming calls to the next available operator, so the time between calls was usually less than a second. Both groups of operators were monitored by a supervisor and by a computer that recorded the number and length of calls. During the study period, 50 directory-assistance offices and approximately 36 general-operator offices were in operation at the two companies. Education and salary levels were similar for both directory-assistance–operator and general-operator positions. Although there may have been some differences in work practices between the two groups, we did not observe any. The primary difference was the presence or absence of the VDT.

Recruitment and Interviews of Study Subjects

To maximize the number of pregnancies in the study population, we set the following criteria: a woman was eligible for participation in the study if she was 18 to 33 years of age (born after June 30, 1953) and married at any time during the study period. In addition, a woman had to be employed full time at any time between January 1, 1983, and August 1, 1986, as a directory-assistance or general operator. We used employers' personnel records to identify women who met the eligibility criteria for age and employment. These women were then telephoned at home and asked to participate in the study. Because the personnel records did not include marital status, we screened out unmarried women during the interviews. A valid phone number was obtained by visiting the home if it could not be obtained from the telephone company or directory-assistance services.[19] The study was described to both the interviewers and the potential participants as a study of the outcomes of pregnancy among office workers. The 25-minute telephone interviews, conducted between July 1987 and August 1988, were used to obtain lifetime reproductive histories. For each pregnancy during the study period, information on the consumption of alcohol and cigarettes, use of medications and other treatments, and medical conditions was recorded.

Definition of a Study Pregnancy

Only pregnancies that met the following criteria were included in the study: the pregnancy resulted in a live birth, stillbirth (fetal loss after 28 weeks' gestation), or spontaneous abortion (fetal loss at 28 weeks' gestation or earlier); the operator was employed for at least one day as a directory-assistance operator or general operator during the first 28 weeks of pregnancy; the pregnancy ended between January 1, 1983, and December 31, 1986, for spontaneous abortions, or between May 1, 1983, and December 31, 1986, for live births and stillbirths. The latest date for live births and stillbirths eligible for inclusion in the study had originally been set at April 30, 1987. After December 1986, however, VDTs began to be introduced into the general operators' workstations. Since after this date general operators would have been exposed to VDTs, only pregnancies that ended on or before December 31, 1986, were included in our analyses.

The date of the last menstrual period, obtained during the interview, was considered the beginning date of each pregnancy. The pregnancies of two women who reported using an intrauterine device at the time of conception were excluded from analyses because of the high rate of spontaneous abortion among women who become pregnant while using this method of contraception.

Validation of Data on Spontaneous Abortions

To identify possible recall differences in subject-reported data on outcome, we collected state vital records on each live birth reported during the study period. We then compared the number of previous terminations reported on the birth certificate with the number reported in the interview. In addition, we asked each woman if she had consulted a physician regarding the spontaneous abortion and conducted a separate analysis including only data on spontaneous abortions reported to a physician.

Definition of VDT Use

Directory-assistance operators used VDTs exclusively and had no other duties, whereas general operators used units containing a light-emitting diode or neon glow tube exclusively and had no other duties. Thus, company records on dates of employment as a directory-assistance or general operator could be used to ascertain the women's use of VDTs. We used personnel records and interview data on dates of pregnancy to determine whether the women had used a VDT during each pregnancy (exposure status).

We defined VDT use in two ways. First, we defined VDT use as a dichotomous variable (yes or no). If the woman had worked as a directory-assistance operator at any time during the first trimester (defined as the first 13 weeks of pregnancy), a pregnancy was classified as exposed. If the woman had worked only as a general operator during the first trimester, a pregnancy was classified as unexposed. Second, to examine the possibility of a dose–response relation, we used weekly payroll records to calculate the hours of VDT use during each study pregnancy. From payroll records, we calculated each woman's actual hours of work with a VDT during her pregnancy. Information on actual hours worked was crucial, because the total number of hours a woman worked with a VDT depended on the stage of her pregnancy when she was hired, the timing of vacations, the amount of sick leave used, and the number of hours worked in a given day. For pregnancies during which the woman worked as a directory-assistance operator, we constructed two indexes of continuous exposure. For the first index, we calculated the woman's hours of VDT use per week in the first trimester, the period of greatest risk for spontaneous abortion, as follows:

$$\text{hours of VDT use per week} = \frac{\text{hours of VDT use during first trimester}}{\text{hours of pregnancy during first trimester}} \times 168 \text{ hours per week.}$$

For the second index, we calculated each woman's hours of VDT use per week during the first 28 weeks of gestation (the entire period of risk for a spontaneous abortion in our study). For both indexes, a pregnancy that terminated early had fewer hours of VDT use (numerator), as well as a smaller denominator. Pregnancies during which the mother worked only as a general operator during the first trimester or the first 28 weeks were assigned zero hours per week of VDT use.

Statistical Analysis

We defined the rate of spontaneous abortion as the number of reported spontaneous abortions divided by the total number of reported spontaneous abortions plus reported live births. Multiple logistic-regression analysis[20] was used to assess the effect of VDT use on the incidence of spontaneous abortion while controlling for the effects of other variables.[19] All potential confounders were examined for interaction with exposure to a VDT. We performed separate analyses for early spontaneous abortion (≤8 weeks' gestation) and late spontaneous abortion (9 to 28 weeks). In addition, analyses were performed that included stillbirths and excluded spontaneous abortions not reported to a physician.

A problem with the analysis of studies of pregnancy outcome is that the outcomes of several pregnancies in the same woman are not independent events. To address the problem of correlated out-

comes, we performed additional analyses for each measure of VDT exposure, as proposed by Zeger and Liang.[21] In these analyses, a class of generalized estimating equations is used that takes into account the correlation of pregnancy outcomes for the same woman and adjusts odds ratios and their corresponding standard errors.

Measurements of Electromagnetic Fields

Only two models of VDT were used by the directory-assistance operators during the study period: International Business Machines (IBM) model 4978 and Computer Controls, Inc. (CCI), model 4500. In 1990, we visited 8 of the 50 directory-assistance offices and measured electromagnetic fields at 6 randomly selected VDTs at each site, for a total of 48 VDTs (24 IBM and 24 CCI).

Only a single model of light-emitting diode and a single model of neon glow tube, both made by Western Electric, were used by the comparison population of general operators. After December 1986, the end of the study period, VDTs were introduced into the general-operator offices. Therefore, in 1990, when we measured the fields emitted by the light-emitting diodes and neon glow tubes, we disabled all VDTs in the offices, so that only emissions from the light-emitting diodes and neon glow tubes were measured. Twenty-four light-emitting-diode and 24 neon-glow-tube units were randomly selected for measurement at two sites.[19]

A VDT containing a cathode-ray tube can produce several types of electromagnetic energy, including x-rays and electric and magnetic fields at both extremely low and very low frequencies. To detect x-ray emissions, an x-ray monitor (Stoms meter) was slowly passed over every accessible surface of VDT and non-VDT units. Several background measurements were made at each office. The electric fields and magnetic fields in the very-low-frequency and extremely-low-frequency bands were measured with two field-strength meters (Holaday Industries models HI 3600-01 and HI 3600-02). With the operator absent, the very-low-frequency and extremely-low-frequency emissions were measured at a distance of 30 cm from each side of the unit. While the operator was seated at her terminal, exposure measurements were taken at her face, chest, and abdomen. Detailed measurements of very-low-frequency and extremely-low-frequency emissions were made at one of the six units at each site. These measurements included the spatial variation of the strength of the electric and magnetic fields between 10 cm and 100 cm from the screen and the rate of change in the very-low-frequency magnetic-flux density per unit of time (dB/dt).[22] Geometric means and geometric standard deviations were calculated for data on emissions and exposure for all VDTs, light-emitting diodes, and neon-glow-tube units.

Results

Of 5544 subjects identified from company records, we could not contact 19.3 percent (Table 1). Of the 4475 women contacted, 4246 (94.9 percent) agreed to participate (76.6 percent of the women initially identified). Both groups of operators had similar rates of participation. Of the 4246 women who agreed to participate, 2430 were married during the study period and were interviewed in detail.

Of the women we interviewed, 730 had one or more pregnancies that met our criteria for inclusion ("eligible pregnancies"). The two groups of operators were similar in mean age, mean lifetime number of pregnancies, race, education, percentage currently employed at a company included in the study, and mean years employed by a company included in the study (Table 2). The proportion of Hispanic women was higher among general operators. The 730 women in the study had 882 eligible pregnancies, which included 16 pregnancies with twins. The proportions of live births, spontaneous abortions, and stillbirths were similar for directory-assistance and general operators

Table 1. Response Rate of Potential Study Participants, According to Job Category.*

Category	Directory-Assistance Operators	General Operators	All Operators
		number (percent)	
Agreed to participate	2118 (78.3)	2128 (75.0)	4246 (76.6)
Unable to contact	483 (17.9)	586 (20.6)	1069 (19.3)
Ineligible	21 (0.8)	24 (0.8)	45 (0.8)
Declined	83 (3.1)	101 (3.6)	184 (3.3)
Total	2705	2839	5544

*Directory-assistance operators used VDTs in their work, whereas general operators did not. Because of rounding, percentages may not total 100.

(Table 3). The overall crude rates of spontaneous abortion for all reported pregnancies were 14.8 percent for VDT-exposed pregnancies and 15.9 percent for unexposed pregnancies. In both groups, the rate of reported spontaneous abortion was highest during the second and third months of gestation (Fig. 1).

The rate of spontaneous abortion for pregnancies during which the mother had 1 to 25 hours of VDT use per week in the first trimester was slightly but not significantly higher than that for women with no hours of use per week (17.2 vs. 15.6 percent) (Table 4). The rate of spontaneous abortion for women with more than 25 hours of VDT use per week was similar to that for women with no hours of use per week (15.4 vs. 15.6 percent). A similar pattern was observed when we analyzed hours of VDT use during the first 28 weeks of gestation.

The final multiple logistic-regression model included the dichotomous VDT-exposure variable, spontaneous abortion before the study period, cigarette smoking, thyroid disorder, and alcohol consumption (Table 4). The analysis showed no association between VDT use in the first trimester and spontaneous abortion (odds ratio = 0.93; 95 percent confidence interval, 0.63 to 1.38). When we substituted the other two VDT-exposure variables (hours of VDT use per week in the first trimester and in the first 28 weeks) in the model, we continued to find no increased risk with VDT use (Table 4). These results did not change

Table 2. Characteristics of Study Participants, According to Job Category.*

Characteristic	Directory-Assistance Operators (N = 323)	General Operators (N = 407)
Mean age†	29.6	29.6
Mean lifetime no. of pregnancies	2.6	2.6
Mean duration of work at study company (yr)	8.2	7.7
Currently employed at study company (%)†	50.8	57.0
White (%)	71.5	68.3
Hispanic (%)	2.8	8.6
More than a high-school education (%)	28.9	35.3

*Directory-assistance operators used VDTs in their work, whereas general operators did not. For eligibility criteria, see Methods.

†As of July 1, 1987.

when the hours of VDT use per week were modeled as a continuous variable.

Only 17.1 percent of the women (n = 125) had more than one pregnancy during the study. The maximal number of pregnancies during the study was four (for six women). Adjustment for multiple pregnancies with the correlated-outcome method of Zeger and Liang[21] did not significantly affect the coefficients in our final models (odds ratio for VDT exposure as a dichotomous variable = 0.94; 95 percent confidence interval, 0.61 to 1.44).

Logistic-regression analyses of data for early and late spontaneous abortion showed no effect of VDT use. The odds ratios were 0.84 (95 percent confidence interval, 0.51 to 1.38) for early spontaneous abortion and 1.05 (95 percent confidence interval, 0.58 to 1.88) for late spontaneous abortion. When all fetal losses, including the nine stillbirths that occurred after 28 weeks' gestation, were included in the model, there was a negligible change in the odds ratio for VDT use (odds ratio = 0.99; 95 percent confidence interval, 0.68 to 1.44). When we eliminated the 10 spontaneous abortions that were not reported to a physician, we found only a minimal change in the odds ratio (odds ratio = 0.90; 95 percent confidence interval, 0.61 to 1.35).

Although our analyses demonstrated no significant association between the use of VDTs and spontaneous abortion, we found that several other factors were associated with an altered risk of spontaneous abortion, notably a history of spontaneous abortion, consumption of more than eight alcoholic drinks per month, smoking more than 20 cigarettes a day, and the presence of a thyroid disorder (Table 4). The coefficients for these factors did not vary substantially when we substituted different VDT-use variables in the model. The exclusion of these factors individually or in combination did not change the relation between VDT use and spontaneous abortion.

None of the measurements of x-ray emissions from the VDT and non-VDT units differed from background levels. The VDTs in this study emitted extremely-low-frequency electromagnetic energy at 45 Hz (the CCI units) and 60 Hz (the IBM units) and very-low-frequency energy in the range of 15 kHz. Geometric means for very-low-frequency emissions from the front of the VDTs and for abdominal exposure were statistically higher for the VDTs than for the non-VDT units ($P<0.05$) (Table 5). The neon-glow-tube and light-emitting-diode displays do not produce very-low-frequency fields above background levels. The rate of change in the magnetic-flux density of the very-low-frequency fields for the VDT units ranged between 9.0 and 38.0 mT per second. Although the mean extremely-low-frequency emissions were significantly higher for VDT units than for non-VDT units, there was substantial overlap in individual measurements of operator exposure. The measurements of spatial variation in the extremely-low-frequency range showed that the electrical environment in the room contributed to the operators' exposure.[22] Because mean values for very-low-frequency and extremely-low-frequency emissions at the CCI terminals were, in some cases, higher than the values at the IBM terminals, we conducted an additional analysis that included separate exposure variables for pregnancies during which the women used CCI or IBM terminals. This analysis showed no difference in the risk of spontaneous abortion between women using a CCI unit (odds ratio = 0.92; 95 percent confidence interval, 0.58 to 1.47) and those using an IBM unit (odds ratio = 0.98; 95 percent confidence interval, 0.58 to 1.64).

Table 3. Outcome of Eligible Pregnancies, According to Job Category.*

Outcome	Directory-Assistance Operators	General Operators	All Operators
	number (percent)		
Live birth	307 (83.9)	430 (83.3)	737 (83.6)
Stillbirth	5 (1.4)	4 (0.8)	9 (1.0)
Spontaneous abortion	54 (14.8)	82 (15.9)	136 (15.4)
Total	366	516	882

*Directory-assistance operators used VDTs in their work, whereas general operators did not. For a definition of pregnancies included in the study, see Methods. Because of rounding, percentages may not total 100.

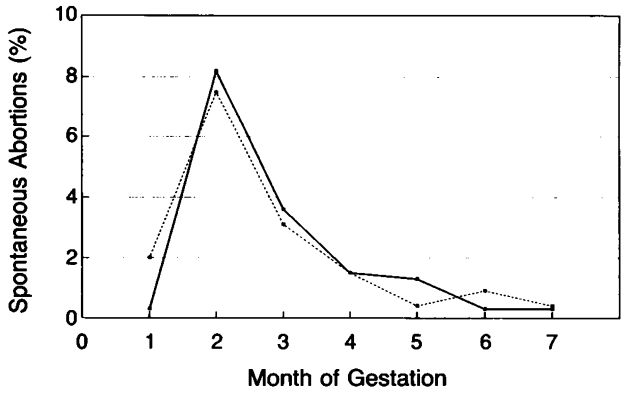

Figure 1. Rate of Spontaneous Abortion According to Month of Gestation and VDT Use.

The denominator for each month of gestation was obtained by subtracting the number of spontaneous abortions in the previous period from the previous denominator. The solid line represents pregnancies during which the woman used a VDT (exposed pregnancies), and the dotted line pregnancies during which the woman did not use a VDT (unexposed pregnancies).

Discussion

In this study we found no increase in the risk of spontaneous abortion associated with the occupational use of VDTs. We did not observe an increased risk associated with three different measures of VDT use or with the VDT model used, after adjusting for confounders, or after accounting for more than one pregnancy in the same woman. Separate analyses of early spontaneous abortion, late spontaneous abortion, all fetal loss, and spontaneous abortions reported to a physician also failed to identify an increased risk of spontaneous abortion associated with VDT use. Al-

Table 4. Unadjusted Rates of Spontaneous Abortion and Adjusted Odds Ratios for Occupational VDT Use and Other Variables in the Final Logistic Model.*

Variable	No. of Pregnancies	Spontaneous Abortion Rate (95% CI)	Odds Ratio (95% CI)	P Value
		%		
Spontaneous abortion before study period				
No	709	12.8 (10.3–15.3)	1.0	
Yes	167	25.7 (19.1–32.3)	1.64 (0.98–2.77)	0.06
No. of alcoholic drinks/mo				
None	716	16.6 (13.9–19.3)	1.0	
1–8	143	4.9 (1.4–8.4)	0.22 (0.10–0.49)	<0.01
>8	17	47.1 (23.4–70.8)	2.81 (0.99–8.04)	0.05
Cigarettes smoked/day				
None	671	14.2 (11.6–16.8)	1.0	
1–19	144	14.6 (8.8–20.4)	1.09 (0.64–1.84)	0.76
≥20	61	29.5 (18.1–40.9)	2.89 (1.50–5.56)	<0.01
Thyroid disorder (diagnosed during or before first trimester)				
No	853	14.8 (12.4–17.2)	1.0	
Yes	23	34.8 (15.3–54.3)	2.75 (1.09–6.94)	0.03
VDT use in first trimester				
No	510	15.7 (12.5–18.9)	1.0	
Yes	366	14.8 (11.2–18.4)	0.93 (0.63–1.38)	0.73
Other VDT-exposure variables†				
VDT use in first trimester (hr/wk)				
None	499	15.6 (12.4–18.8)	1.0	
1–25	128	17.2 (10.7–23.7)	1.04 (0.61–1.79)	0.88
>25	169	15.4 (10.0–20.8)	1.00 (0.61–1.64)	0.99
VDT use in first 28 wk (hr/wk)				
None	494	15.8 (12.6–19.0)	1.0	
1–25	119	18.5 (11.5–25.5)	1.18 (0.69–2.04)	0.54
>25	179	14.5 (9.3–19.7)	0.90 (0.55–1.47)	0.67

*Odds ratios compare the odds of spontaneous abortion for a pregnancy with the specified risk factor with the odds for a pregnancy without that risk factor. Each odds ratio is adjusted for all the other risk factors in the model. CI denotes confidence interval. P values are for the comparison between pregnancies in each category and the reference group (odds ratio = 1.00).

†When these VDT-exposure variables were substituted in the model, confounder coefficients did not vary substantially and the relation between VDT use and spontaneous abortion remained unchanged. Because of missing data, the total number of pregnancies varied in each analysis.

though the upper confidence limit on the odds ratio (1.39) cannot exclude a moderate positive association, there were no other indications of a causal association, such as a trend toward increased risk with increasing hours of VDT use. The overall rates of spontaneous abortion among the VDT users (14.8 percent) and among those who did not use VDTs (15.9 percent) were within the range in published data (11 to 20 percent).[23] Although we found no association between VDT use and spontaneous abortion, we did find significant associations with spontaneous abortion for three previously reported risk factors: heavy alcohol consumption, cigarette smoking, and the presence of a thyroid disorder.[23-26]

Because information on the outcomes of pregnancy was reported by the women themselves, there was a possibility of differences in recall between the two groups. The 2430 women we interviewed reported a total of 203 spontaneous abortions between 1983 and 1986. The women who reported 77 (38 percent) of these spontaneous abortions had subsequent live births, which provided us with the opportunity to confirm previous spontaneous abortions from information recorded on birth certificates. We found that 89 percent (49 of 55) of the spontaneous abortions reported by general operators and 86 percent (19 of 22) of the spontaneous abortions reported by directory-assistance operators were recorded in subsequent vital records. We discovered only one spontaneous abortion that had not been reported in the interview. Although we were able to review only spontaneous abortions that were followed by live births (38 percent of all spontaneous abortions), the consistent findings in both the exposed group and the comparison group argue against differences in the recall of spontaneous abortions as a logical explanation for our negative findings.

Differences in the rate or timing of induced abortions between the exposed and the comparison group are unlikely explanations for our negative findings. We identified all reported induced abortions among directory-assistance or general operators during the study period. The rates of induced abortion in VDT-exposed pregnancies (4.8 percent) and unexposed pregnancies (5.3 percent) were similar, as was the gestational age at the time of the induced abortion (mean number of weeks at abortion, 9.6 and 7.9, respectively).

Since the ascertainment period for live births and stillbirths (May 1, 1983, through December 31, 1986) differed slightly from that for spontaneous abortions (January 1, 1983, through December 1, 1986), our study contained proportionally fewer full-term pregnancies during the later months of 1986. If the

Table 5. Geometric Mean (GM) and Standard Deviation (GSD) of Measurements of Electromagnetic Fields.*

Type of Unit	Very Low Frequency		Extremely Low Frequency	
	E field (V/m)	H field (mA/m)	E field (V/m)	H field (mA/m)
	GM (GSD)			
Frontal emissions (operator absent)				
VDT				
CCI	4.2 (1.54)†	98.9 (2.61)†	1.9 (1.63)†	313.6 (1.22)†
IBM	3.3 (2.07)†	22.1 (4.68)†	1.8 (1.93)†	236.1 (2.14)†
Non-VDT				
LED	0.1 (1.16)	1.6 (1.01)	0.4 (1.10)	72.3 (1.68)
NGT	0.1 (2.05)	1.4 (1.04)	0.5 (1.40)	30.3 (1.72)
Abdominal exposure (operator present)				
VDT				
CCI	0.5 (1.68)†	17.4 (1.74)†	0.8 (3.61)†	62.3 (1.59)
IBM	0.1 (1.71)†	4.0 (1.85)†	0.4 (1.70)†	57.7 (2.12)
Non-VDT				
LED	0.1 (1.35)	2.0 (1.15)	0.4 (1.18)	62.4 (2.79)
NGT	0.2 (1.64)	1.6 (1.00)	0.4 (1.92)	32.4 (2.01)

*E denotes electric, H magnetic, CCI Computer Controls, Inc., and IBM International Business Machines. For details, see Methods. Non-VDT units were units with light-emitting diodes (LED) or neon glow tubes (NGT).

†$P<0.05$ for the comparison of VDT units (IBM and CCI units combined) with non-VDT units (LED and NGT units combined).

two groups of operators had a different number of pregnancies during the later months of 1986, the number of spontaneous abortions in one group could have been artificially increased. To examine this possibility, we reanalyzed the data after eliminating the 11 spontaneous abortions that occurred after April 30, 1986, and found no increased risk (odds ratio = 0.86; 95 percent confidence interval, 0.57 to 1.30).

Differences in VDT use outside the workplace are not a likely explanation for our findings. We examined data from the interviews on home VDT use and found that only 1.9 percent of the VDT-exposed pregnancies and 2.2 percent of the unexposed pregnancies involved VDT exposure at home.

When we compared payroll records with data on VDT use from the interviews, we found that approximately 52 percent of general operators who did not use a VDT while pregnant reported such use in the interview. Only 4 percent of directory-assistance operators who used a VDT while pregnant reported no use. A likely reason for this overreporting by the general operators is that they may have mistakenly referred to the light-emitting-diode or neon-glow-tube equipment as a VDT in the interview. If this is the reason for the overreporting, studies of different populations might have fewer errors in reported VDT use than documented here. However, the discrepancy between reported and record-based VDT use indicates that the accuracy of self-reported data may vary. When we analyzed the data according to women's reports of VDT use, we still observed no effect on the rate of spontaneous abortion (odds ratio = 0.85; 95 percent confidence interval, 0.56 to 1.29).

Elements of the study design did not allow us to address certain other questions directly. First, we could not assess whether early (subclinical) fetal loss might be affected by VDT use. The data shown in Figure 1, however, suggest that the incidence of the earliest recognized losses was similar for the exposed and unexposed pregnancies. Second, we could not assess effects of VDT use on older or unmarried women, since our study was limited to married women from 18 to 33 years of age. Such women make up the majority of pregnant women in the United States. Third, we studied a population that used only two models of VDT; the electromagnetic fields produced by the VDTs in our study were similar to those reported for other VDTs, however.[27-29] Finally, we selected the directory-assistance and general operators because of the similar levels of physical and psychological stress in their jobs. Therefore, this study could not address the association between spontaneous abortion and physical or psychological stress — two factors that may accompany the use of VDTs.

Although concern has been expressed that VDTs may produce harmful levels of electromagnetic energy, our research found that VDT operators had abdominal exposure to extremely-low-frequency fields (45 to 60 Hz) in the same range as exposures in the home. Studies of exposure to extremely-low-frequency electromagnetic fields have found average exposures to magnetic fields in the home between 40 and 200 mA per meter,[30-32] and average electric-field exposures of 2.5 V per meter.[32] Although VDT operators were exposed to very-low-frequency fields (in the range of 15 kHz), light-emitting-diode or neon-glow-tube units used by the general operators produced no measurable emissions in this range.

The strengths of this study include the similarity of the VDT-user group and the comparison group, the use of record-based data on the extent of VDT use during each pregnancy, and the direct measurement of electromagnetic fields. When we examined our data for potential biases, we found none that were likely to have substantively influenced the results. We conclude that in this study, the use of VDTs and exposure to the electromagnetic fields they produce were not associated with an increased risk of spontaneous abortion.

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RACIAL DIFFERENCES IN THE RELATION BETWEEN BLOOD PRESSURE AND INSULIN RESISTANCE

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Abstract *Background.* Insulin resistance and the concomitant compensatory hyperinsulinemia have been implicated in the pathogenesis of hypertension. However, reports on the relation between insulin and blood pressure are inconsistent. This study was designed to investigate the possibility of racial differences in this relation.

Methods. We studied 116 Pima Indians, 53 whites, and 42 blacks who were normotensive and did not have diabetes; the groups were comparable with respect to mean age (29, 30, and 31 years, respectively) and blood pressure (113/70, 111/68, and 113/68 mm Hg, respectively). Insulin resistance was determined by the euglycemic–hyperinsulinemic clamp technique during low-dose (40 mU per square meter of body-surface area per minute) and high-dose (400 mU per square meter per minute) insulin infusions.

Results. The Pima Indians had higher fasting plasma insulin concentrations than the whites or blacks (176, 138, and 122 pmol per liter, respectively; $P = 0.002$) and lower rates of whole-body glucose disposal during both the low-dose (12.7, 17.1, and 19.5 mmol per minute; $P<0.001$) and the high-dose (38.0, 43.1, and 45.7 mmol per minute; $P<0.001$) insulin infusions. After adjustment for age, sex, body weight, and percentage of body fat, mean blood pressure (calculated as ⅓ systolic pressure + ⅔ diastolic pressure) was significantly correlated with the fasting plasma insulin concentration ($r = 0.42$) and the rate of glucose disposal during the low-dose ($r = -0.41$) and high-dose ($r = -0.49$) insulin infusions ($P<0.01$ for each) in whites, but not in Pima Indians ($r = -0.06$, -0.02, and -0.04, respectively) or blacks ($r = -0.10$, -0.04, and 0.02, respectively).

Conclusions. The relations between insulinemia, insulin resistance, and blood pressure differ among racial groups and may be mediated by mechanisms active in whites, but not in Pima Indians or blacks. (N Engl J Med 1991; 324:733-9.)

SEVERAL studies have demonstrated insulin resistance in patients with essential hypertension[1-4] and an inverse relation between blood pressure and insulin-mediated glucose disposal.[1,2] Thus, it has been postulated that the compensatory hyperinsulinemia that results from insulin resistance may contribute to the pathogenesis of hypertension.[5] Indeed, hyperinsulinemia has been reported in patients with hypertension,[6-9] and a strong positive relation between plasma insulin concentration and blood pressure has been documented in some studies.[10-13] Insulin may elevate blood pressure by stimulating the sympathetic nervous system,[14] increasing renal sodium retention,[15] modulating cation transport,[16] or inducing hypertrophy of vascular smooth muscle.[17] Several studies, however, found no relation between insulin concentrations and blood pressure, or only a weak one.[18-26]

Pima Indians commonly have insulin resistance

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