Video display terminal use during pregnancy and reproductive outcome—a meta-analysis

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Abstract
Study objective—The aim was to obtain quantitative information from published data on the potential association between video display terminal (VDT) use during pregnancy and the outcome.
Design—Results of nine published case-control studies (or cohort studies analysed as case-control) on the relation between VDT exposure during pregnancy and the outcome were sought by reviewing reference lists in relevant reports and by conducting manual and computer searches of the reports published in English.
Measurements and main results—The nine reviewed reports included information on about 9000 cases of spontaneous miscarriages, 1500 of low birth weight, 2000 of congenital malformation, and 50 000 controls. The results of these studies on each outcome of pregnancy examined were reduced to a single 2×2 table (cases/controls—exposed/unexposed). Pooled odds ratio (OR) estimates were computed separately for miscarriage, low birth weight, and congenital malformation. Seven studies analysed the relation between VDT exposure in pregnancy and the risk of miscarriage: the estimates’ crude OR of spontaneous abortion ranged from 0·9–1·2 and the pooled OR was 1·0 (95% confidence interval (CI) 0·9–1·0). No consistent evidence of increasing risk with duration of exposure to VDT was found. Two studies analysed the relation between VDT use and risk of having a low birth weight infant: the OR estimates in the individual studies were 1·0 and 1·1. Likewise, no relation emerged from the five studies providing information on congenital malformations and VDT use: the pooled OR was 1·0 (95% CI 0·9–1·2). No specific malformation pattern emerged.
Conclusions—This meta-analysis provides reassuring evidence on the absence of any major risk of adverse pregnancy outcome as a result of exposure to a VDT. With the number of cases reviewed, it was possible to exclude excess risk of 20% for spontaneous abortion, low birth weight, and congenital malformations.

J Epidemiol Community Health 1993; 47: 265–268

The potential adverse consequences of exposure to electromagnetic fields during pregnancy have been a topic of scientific and public health interest since the middle 1970s, when clusters of spontaneous abortions and birth defects in pregnant women using visual display terminals (VDT) received widespread attention in the scientific and lay press, particularly in the United States and Canada. Animal data partially supported these suggestions. Damage to chick embryos or fetal malformations in mice were reported after exposure to pulsed electromagnetic and magnetic fields.

Because of the large number of women exposed to VDT or other common electrical equipment such as televisions, electric typewriters and domestic appliances which are sources of electromagnetic fields, even a limited risk of adverse outcome of pregnancy may constitute a considerable public health issue.

Several formal analytical epidemiological studies have been published on this subject. The present report aimed to review their results to obtain quantitative pooled estimates of the potential association between VDT use and various outcomes of pregnancy.

Methods
The results of published case-control studies (or cohort studies analysed as case-control studies) on the relation between VDT exposure and pregnancy outcome were sought by reviewing reference lists in relevant reports and by conducting manual and computer (MEDLINE) searches of the papers published in English. A total of nine articles were retrieved (two of which were based on the same study) (MEDLINE). The results of these studies on each outcome of pregnancy examined were reduced to a single 2×2 table (cases/controls—exposed/unexposed). Pooled odds ratio (OR) estimates were computed separately for miscarriage, low birth weight, and congenital malformation.

STATISTICAL TECHNIQUES
Standard methods for the combination of information from 2×2 tables were used. The expected number of cases exposed to VDT (E) and the variance (V) of the difference between the observed (O) and expected number of cases were computed using the usual procedure described by Mantel and Haenszel. The trend in risk was assessed using the test given by Mantel. If exposure was completely without effect on the risk of the disease, the quantity (O-E) with variance V (and hence with standard error √V) would differ only randomly from zero. If it were associated with the disease, however, the quantity (O-E) would tend to be positive, and although in any particular study this tendency might be obscured or even reversed by the effect of chance, it should stand
out clearly when the grand total (GT) of the (O-E) values from several independent studies was examined. If the factor were unrelated to the disease, this grand total would itself differ only randomly from zero, with variance equal to the sum of individual variances (SIV), and hence standard error \( \sqrt{SIV} \). If, in addition, it is assumed that any real effect of VDT exposure is not heterogeneous in different studies, then the odds ratio (OR) in exposed compared with unexposed subjects is estimated by exponential (exp) (GT/SIV), with an approximate 95% confidence interval (CI=\( \exp\) (GT/SIV)±1.96 SIV).

Examination of these statistics is based on the assumption that data from all studies have been included without any material bias caused by unavailability of negative results or biased selection of cases and controls. However, it does not assume implicitly that subjects in one study can be compared directly with subjects in another, but it is based entirely on comparison of the cases in each study with their own controls.

**Results**

The main characteristics of the studies considered are shown in table I. Most were initially designed in the early 80s as cohort investigations of pregnant women to evaluate the effect of several occupational exposures on reproductive outcomes. Nested case-control analyses for the relation between VDT exposure and pregnancy outcome were subsequently performed following suggestions from the published reports. The definition of exposure was generally based on self-reporting. In one study the interview data were checked according to the information retrieved from company personnel records. The level of exposure was defined in term of the average number of hours per week.

**SPONTANEOUS ABORTIONS**

Seven studies analysed the relation between VDT exposure in pregnancy and the risk of miscarriage, including more than 4000 cases of spontaneous abortions and about 30 000 controls. The prevalence of exposure in controls varied widely from less than 20% in the largest study conducted on working women in Canada to more than 50% in a case-control analysis nested in a cohort study conducted in Sweden. The estimated OR for spontaneous abortion ranged from 1:0 to 1:2 and the pooled OR was 1:0 (95% CI, 0:9-1:0, table II). A significantly increased risk (OR 1:5) of miscarriage in the first trimester in women exposed to VDT was reported in one study. No other study

<table>
<thead>
<tr>
<th>Author, country, study period</th>
<th>Type of study</th>
<th>Outcomes considered</th>
<th>Selection of Cases</th>
<th>Controls</th>
<th>Definition of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryant and Love; Canada, 1984-1985</td>
<td>Case-control</td>
<td>SA (&lt;20 weeks' gestation) admitted in a network of collaborating hospitals</td>
<td>Two control groups: (a) prenatal: women &lt;25 weeks gestation identified from prenatal clinic list (interviewed at home or in the office) (b) post partum: women delivering healthy infants in the same hospitals as cases.</td>
<td>Self-reported (interview)</td>
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<tr>
<td>Brandt and Nielsen; Nielsen and Brandt; Denmark, 1983-1985</td>
<td>Case-control</td>
<td>SA, CM</td>
<td>SA or CM in women members of the Danish Union of Commercial and Clerical Employees. SA, CM, LBW reported in three cohorts of women at professional high, medium, and low probability of using VDT.</td>
<td>Self-reported (postal questionnaire, response rate 76% for cases and 75% for controls).</td>
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<tr>
<td>Ericson and Källen; Sweden, 1980-1981</td>
<td>Case-control nested in a cohort</td>
<td>SA, CM, LBW (&lt;1500g)</td>
<td>Sample of women with favourable reproductive outcome in the same cohorts as cases.</td>
<td>Self-reported (postal questionnaire, response rate 99%).</td>
<td></td>
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<tr>
<td>Goldhaber et al; USA, 1981-1982</td>
<td>Case-control nested in a cohort</td>
<td>SA and CM</td>
<td>SA and CM reported in a cohort of women self-referring for pregnancy testing at three Kaiser Permanente Medical Care Programs.</td>
<td>Random sample (20%) of normal deliveries in the cohort.</td>
<td>Self-reported (postal questionnaire and for non-responders interview by phone) overall response rate 83% for SA, 88% for CM and controls.</td>
</tr>
<tr>
<td>Kurppa et al; Finland, 1976-1982</td>
<td>Population based case-control</td>
<td>CM</td>
<td>Sample of cases reported to the National Register of Congenital Malformations. SA, LBW, CM in women with professional high probability of using VDT.</td>
<td>Women who delivered immediately before the cases in the same maternity health care district Normal delivery in women at professional high probability of using VDT.</td>
<td>Self-reported (interview in hospital)</td>
</tr>
<tr>
<td>McDonald et al; Canada, 1982-1984</td>
<td>Case-control</td>
<td>SA, LBW (&lt;2500g) CM</td>
<td>Women who reported normal pregnancy</td>
<td>Personal records and interview data</td>
<td></td>
</tr>
<tr>
<td>Schnorr et al; USA, 1983-1986</td>
<td>Case-control</td>
<td>SA</td>
<td>Married women aged 18-33 employed as directory assistants or general telephone operators who reported SA</td>
<td>Women who had a SA by 20 weeks' gestation, for which a pathology specimen was submitted to a network of hospitals.</td>
<td>Self-reported (telephone interview, response rates 73% and 81% respectively cases and controls).</td>
</tr>
<tr>
<td>Windham et al, USA, 1986-1987</td>
<td>Case-control</td>
<td>SA, LBW (&lt;2500g)</td>
<td>Women who had a live birth matched with cases by last menstrual period and hospital. LBW were compared with normal controls.</td>
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</table>

SA=spontaneous abortions; CM=contenital malformations; LBW=low birth weight
analysed separately the risk of spontaneous abortion according to gestational age. Potential covariates were taken into account in most analyses: no appreciable differences were observed between crude and adjusted estimates. An increasing risk with duration of exposure to VDT was found in one study.10 In another,12 there was a direct trend in risk with duration of VDT exposure for the current, but not for previous pregnancies. No significant association was observed in the remaining five studies and the pooled trend in risk was not statistically significant ($\chi^2$ trend 0.05, table III).

LOW BIRTH WEIGHT
Two studies analysed the relation between VDT use and the risk of giving birth to an infant of low birth weight (defined as $\leq$5000g) for a total of over 1500 cases and 21 000 controls (table IV). The OR estimates in the individual studies ranged from 0.5 to 1.1, with a pooled OR of 1.0 (95% CI 0.9, 1.2). In one study, an increasing risk of low birth weight with hours/week of VDT use was observed, but this finding was not statistically significant.14

Table III  Odds ratios of spontaneous abortions according to level of video display terminal (VDT) exposure (defined as h/week). (Figures in parenthesis are number of case:controls.)

<table>
<thead>
<tr>
<th>Authors</th>
<th>No VDT use</th>
<th>Low (≤20h/ wk)</th>
<th>High (≥20h/ wk)</th>
<th>$\chi^2$ trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryant and Love*</td>
<td>1++ (191:175)*</td>
<td>0.8 (102:121)</td>
<td>1.0</td>
<td>0.72 (p&lt;0.05)</td>
</tr>
<tr>
<td>Ericson and Kallen*</td>
<td>1++ (119:354)</td>
<td>1.2 (125:360)</td>
<td>1.2</td>
<td>1.19 (p&lt;0.05)</td>
</tr>
<tr>
<td>Goldhaber et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>1++ (240:510)</td>
<td>0.8 (63:148)</td>
<td>1.0</td>
<td>3.82 (p&lt;0.05)</td>
</tr>
<tr>
<td>McDonald et al&lt;sup&gt;12&lt;/sup&gt;</td>
<td>1++ (140:2:18 501)</td>
<td>1.0 (177:2243)</td>
<td>1.2</td>
<td>2.96 (p&lt;0.05)</td>
</tr>
<tr>
<td>Nielsen and Brandt†</td>
<td>1++ (447:25 885)</td>
<td>1.0 (249:859)</td>
<td>1.0</td>
<td>1.67 (p&lt;0.0001)</td>
</tr>
<tr>
<td>Schnorr et al&lt;sup&gt;13&lt;/sup&gt;</td>
<td>1++ (316:356)</td>
<td>1.0 (237:319)</td>
<td>1.0</td>
<td>0.07 (p&lt;0.05)</td>
</tr>
<tr>
<td>Windham et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>1++ (78:421)*</td>
<td>1.0 (22:106)</td>
<td>1.2</td>
<td>0.00 (p&lt;0.05)</td>
</tr>
<tr>
<td>Total</td>
<td>1++ (200:448)</td>
<td>1.0 (109:207)</td>
<td>1.0</td>
<td>0.55 (p&lt;0.05)</td>
</tr>
</tbody>
</table>

*Prenatal controls, included in the pooled analysis; †postnatal controls, not included in the pooled analysis; ‡current pregnancies; §previous pregnancies; £estimated from percentages.

CONGENITAL MALFORMATIONS
No relation emerged from five studies that provided information on congenital malformation and VDT use: the pooled OR based on about 2000 cases and 50 000 controls was 1.0 (95% CI 0.9, 1.2, table V). An increased risk of cardiac malformation, renal malformation, or hydrocephalus was reported from some studies, but these findings were not confirmed. Likewise, an increased risk of specific malformation with increasing exposure to VDT was seen in one study9 but not in others.11

PRETERM BIRTH AND PERINATAL MORTALITY
The relation between preterm births, perinatal mortality, and VDT exposure in pregnancy was analysed in three studies,9 12 14 No association emerged.

Discussion
The results of this meta-analysis of published epidemiological studies are largely reassuring and indicate that VDT use during pregnancy is not associated with any material risk of miscarriage, low birth weight, or congenital malformation. No consistent trend in risk was observed with duration of exposure to VDT and no specific pattern of malformation emerged in women exposed to electromagnetic fields from a VDT. Fewer data are available on the extent of VDT on perinatal mortality, but the scanty figures showed no convincing relationship.

We considered only unadjusted estimates in the computation of the pooled OR. In the individual studies, however, multivariate estimates, including terms for major potential covariates (such as smoking habits or socioeconomic indicators), were in general consistent with crude ones.

Although the studies reviewed differ in terms of study population, type of exposure, and methods of data collection, the OR estimates in individual studies were generally comparable, and, in any case, not statistically heterogeneous, giving strong evidence of the consistency of the pooled results.

In the interpretation of the results of meta-analysis, publication bias is one of the major issues. In this case, however, it is unlikely that such a bias plays a major role. Epidemiological studies in this field are generally large and expensive, and tend therefore to be published independently from their results. Furthermore, negative results are also of interest for publication, given the public health relevance of the issue.

Most studies considered only exposure at work to minimise the bias related to the potential association of VDT use with pregnancy risk because of psychological stress associated with some occupations.17 19 No difference emerged, however, in OR estimates from hospital based case-control or cohort studies including women who were not working. Whichever study design is considered, moreover, it is likely that any bias in exposure assessment tends to overestimate the true association, since cases may systematically remember better their potential sources of exposure.

It has been suggested that it is difficult to define exposure to VDT, since the extremely low frequency magnetic fields produced do not diminish
appreciably with distance from the displays—that is, the ambient fields in an office are per se a source of exposure to electromagnetic fields.20 21 Similar considerations should hold for domestic exposure. Furthermore, electromagnetic fields due to VDT exposure are minimal and generally not significantly above background levels.22 Other sources of electromagnetic fields may constitute greater risks for reproduction23 and the contribution of VDT may therefore be irrelevant. This overview therefore is largely reassuring with regard to the effect of VDT use and pregnancy outcome, but it is not possible to exclude any potential effects from other sources of electromagnetic fields. Another possible drawback of published studies is the absence of information on subclinical miscarriages, but early concern about the reproductive hazards of VDT was raised after identification of clusters of clinically recognised miscarriages. In general, any definition, and hence risk assessment, of chemical or physical risk factors for subclinical miscarriage is always extremely difficult.

In conclusion, the present overview provides important reassurance on the absence of any major adverse risk during pregnancy from exposure to VDT, since with the number of cases reviewed, it was possible to exclude an excess risk of 20% for spontaneous abortion, low birth weight, and congenital malformation.