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OCCUPATIONAL EXPOSURE TO NON-IONIZING RADIATION
AND AN ASSOCIATION WITH CONGENITAL ANOMALIES:
AN EXPLORATORY CASE-CONTROL STUDY

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ABSTRACT

In an exploratory case-control analysis derived from a survey of male physical therapists, the relationship between paternal occupational exposure to non-ionizing radiation prior to conception and congenital anomalies in their offspring was investigated. The study included 148 fathers of 169 children with anomalies and 169 pair-wise matched control fathers. A significant association between shortwave occupational exposure of fathers prior to conception and an increased rate of anomalies among their offspring was observed. The estimated relative risk was 2.9. Shortwave exposure within 3 months prior to conception and an association with congenital anomalies showed a relative risk of 2.0. For specific groups of anomalies, case fathers reported significantly longer durations of exposure prior to conception than control fathers relative to heart anomalies ($P < 0.025$) and an excess, which yielded borderline significance ($P < 0.10$), relative to single gene dominant anomalies. A significant risk associated with exposure to shortwave energy 3 months prior to conception was noted for clubfoot and single gene dominant case groups (estimated relative risks of 2.8 and 4.5 respectively). For the 3 months prior to conception, the group of heart anomaly cases were only borderline significant ($P < 0.10$). These findings suggest that paternal occupational exposure to shortwave radiation may be associated with an increased risk of congenital anomalies in the offspring of the exposed workers.

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Introduction and Background

The relationship between occupational exposure to radiofrequency/microwave energy and the occurrence of congenital anomalies among the exposed workers' offspring has received little study. Two reports have been published on the association between paternal exposure to microwave radiation and Down's Syndrome.^{1,2} The first report resulted from an incidental finding in an x-ray study which indicated a marginal excess of radar exposure, during military service, among fathers of Down's Syndrome cases. The excess was not confirmed in a follow-up report. An excess of congenital anomalies, particularly clubfoot, was reported in Dale and Coffee counties in Alabama.³ Most of the excess was reported from the hospital at a military aviation training center. Hypotheses were generated that the incidence of congenital anomalies would be higher for offspring of the military population and that the higher rates would be related to some environmental factor, especially paternal exposure to radar. A subsequent investigation did not support these hypotheses.⁴ A study of reproductive hazards among power plant workers, in Sweden, noted a higher rate of congenital anomalies among the offspring of workers occupied with the management of high voltage (<400 Kv) switchyards when compared to workers with lower exposure.⁵ Significant changes in spermatogenesis have been reported among technicians exposed to microwave energy.⁶ In a Swedish study of female physiotherapists, women who gave birth to malformed or perinatally dead offspring had a higher incidence of occupational usage of shortwave diathermy during pregnancy relative to a group of matched controls.⁷

Although several animal studies on the teratogenic effects of micro-

wave radiation have been reported, the evidence is not conclusive.⁸ Most of this research has focused on female experimental animals. Studies of male experimental animals exposed to microwave radiation have demonstrated various deleterious reproductive effects.⁹⁻¹³ A review of epidemiologic studies by Silverman on potential health effects of microwave radiation stressed the need for more intensive study of congenital anomalies among offspring of both fathers and mothers who were exposed.¹⁴

This report describes the results of an exploratory case-control analysis of paternal occupational exposure to non-ionizing radiation in relation to congenital anomalies. The study is based on data collected under contract for a larger retrospective mail survey of potential health effects to male physical therapists, with occupational exposure to RF/microwave energy, and their offspring. An earlier report has described specific findings for the physical therapists.¹⁵

METHODS

The study was planned as a self administered mail survey for assessing health and reproductive outcomes, including birth defects, which might be associated with paternal exposure to low-level, non-ionizing electromagnetic energy. The target population was approximately 5300 male members of the American Physical Therapy Association (APTA).

An occupational history of diathermy utilization by modality, length of employment, and frequency of use was identified on the questionnaire. The four different radiation modalities were: microwave (M), shortwave (S), infrared (I), and ultrasound (U). The study questionnaire in-

cluded a birth defects checklist, which was to be completed by either the respondent or his spouse, of the following congenital anomalies: (1) Down's syndrome, (2) clubfoot, (3) cleft lip/palate, (4) missing/extra fingers or toes, (5) heart defect, (6) digestive defect, (7) spina bifida, (8) condition requiring special education or care, (9) cerebral palsy, (10) hearing disorder. An additional column was provided for conditions not specified on the checklist. Information was collected on the age of the respondent and spouse, the respondent's race, his occupational and marital history, health data for the respondent and his spouse, parental congenital anomalies, therapeutic and diagnostic exposure to ionizing and non-ionizing radiation of the respondent and/or spouse. The pregnancy history for the spouse included contraceptive usage prior to the pregnancy, use of cigarettes, rubella, occupational history, and exposure to x-ray and/or ultrasound.

For the 3004 (58%) respondents to the questionnaire, 4732 live births were identified among 2172 fathers (2.18 live births/father).

There were 2464 males and 2268 females. A computer program provided a list of all respondents who gave one or more positive responses on the birth defects checklist. The questionnaires for these respondents were manually reviewed and a new list was compiled of the birth defects cases using the eighth revision of the International Classification of Diseases.¹⁶ The total number of children with anomalies was 255, and the total number of anomalies was 262. Analyses were limited to those cases with congenital anomalies coded 740 through 759 from the above reference. One hundred and seventy-five cases with 192 anomalies were iden-

tified in this code range. These anomalies represented 67% of all anomalies which were reported. The selection of cases for assessment, in this range, was based on several criteria. Congenital anomalies which could be recognized as present at birth was one criterion. Another was that the defect would generally interfere with normal function. The ability to compare rates found in this study to the National Center for Health Statistics rates was considered.¹⁷ All congenital anomalies identified in other ranges of the ICD were excluded.

One hundred and fifty-four men who had one or more children with congenital anomalies were identified. Twenty-one fathers had 2 children with anomalies. All cases were born between 1942 and 1979 (90% between 1952 and 1977). The number and prevalence rate of anomalies by ICD codes are provided in Table 1. The major anomalies noted in this study include: heart anomalies (N=30), clubfoot (N=37), other anomalies of limbs (N=27), and Down's syndrome (N=13).

Twelve of the 175 cases were children with multiple anomalies; 8 cases had 2 anomalies, 3 cases had 3 anomalies, and one case had 4 anomalies. Again, the total number of anomalies in this study was 192. Table 2 provides the rates of congenital anomalies for eight birth year intervals from 1940 through 1978. Overall, the rate of congenital anomalies (single and multiple), in the ICD code range 740 - 759, among the 175 cases in this study is 3,698 per 100,000 liveborn.

Controls were matched to cases on a pair-wise basis according to the fathers' race, year of birth of the case ($\pm$ 3 years), maternal

age ($\pm$ 5 years), and sex of case. Six cases had missing information for the year of birth of the case and were eliminated from the case-control analysis (5 with single anomalies, ICD 742, 745, 754, and 759.5 and 1 with multiple anomalies, ICD 741, 745, 754, and 755.7). Three cases had missing information for the year of birth of the mother and paternal age was used as a proxy for maternal age. The race for 3 cases was unknown, and it was assumed that these cases were white. The sex for one child was unknown, and it was assumed that the child was male. The matching process yielded 169 pair-wise matched cases and controls.

Two methods of analysis were applied to all cases and controls and to the following separate case groups with matched controls: 1) heart anomalies, 2) clubfoot, 3) Down's syndrome, and 4) anomalies which are known to occur as monogenic dominant traits (single gene dominant). Single gene dominant anomalies, in this study, were eye anomalies including congenital cataract, hypospadias, deformities of upper and lower limbs including polydactyly, anomalies of the face and skull, and skin anomalies.¹⁸ The first analysis assessed the effects of occupational exposure by total length of employment and by the number of treatments administered per typical work week averaged over the total length of employment, prior to conception, for the different radiation modalities. The second analysis assessed the effects of occupational exposure during the 3 month period, prior to conception, for a given radiation modality. In this analysis, exposure was treated both as a qualitative variable (yes/no), and as a quantitative variable (average number of treatments administered per week).

Tests of statistical significance were conducted using the paired t-test¹⁹ for analyses of continuous variables and the McNemar test²⁰ for analyses of dichotomous variables. For selected dichotomous variables, the odds ratio was also calculated as an approximate measure of relative risk of one or more congenital anomalies. The maximum likelihood estimate of the relative risk and 95% confidence limits were derived using the technique described by Miettinen.²¹ The programs developed by Rothman and Boice²² were employed for the estimated relative risk calculation.

RESULTS

Comparability of Cases and Controls

Table 3 compares cases and controls with respect to selected matching and personal characteristics. Both the case and control group were found to be comparable with respect to the matching and other potential confounding factors, with the exceptions of previous adverse pregnancy outcomes and parity (first born). Among the cases, 17% had experienced previous adverse pregnancy outcomes as compared to 2% for the controls. Problems with earlier pregnancies may serve as markers for genetically caused effects not associated with environmental factors. The proportion of first births was higher among controls than cases. However, it has been reported that, for all congenital anomalies combined, rates for first births are higher than for other birth orders regardless of the age of the mother.¹⁷ Thus, any confounding due to parity, in this study, should result in an underestimate of the effect of paternal occupational exposure and subsequent anomalies among offspring.

Occupational History and Exposure for Fathers of Cases and Controls

Table 4 shows the distribution of fathers of cases and controls according to the occupational exposure subgroup prior to conception. Both groups were comparable concerning membership in any of the possible exposure subgroups, including the no exposure subgroup. Fathers of cases were more likely to be exposed to one or more of the four radiation modalities (microwave, shortwave, infrared and ultrasound) than fathers of controls (71% versus 63%). Excluding the no exposure group, the MSIU subgroup was the most common subgroup among fathers of cases (30%) and fathers of controls (27%). One hundred and eighteen fathers of cases (70%) and 99 fathers of controls (59%) were exposed to either microwave or shortwave radiation. Of this number, 64 fathers of cases (38%) and 58 fathers of controls (34%) were exposed to both microwave and shortwave radiation (subgroups MSIU, MSU, and MSI). Sixty-eight fathers of cases (40%) and 65 fathers of controls (38%) were exposed to microwave radiation regardless of other modalities. Of those exposed to microwave, only 4 fathers of cases (2%) and 7 fathers of controls (4%) were exposed to microwave radiation (subgroups MIU and MU) but not to shortwave radiation. One hundred and fourteen fathers of cases (67%) and 92 fathers of controls (54%) were exposed to shortwave radiation regardless of other modalities. Of those exposed to shortwave radiation, 50 fathers of cases (30%) and 34 fathers of controls (20%) were exposed to shortwave radiation (subgroups SIU, SU, and SI) but not to microwave radiation.

An analysis, for each of the radiation modalities, was conducted on the effect of duration of employment and the average number of treat-

ments per typical work week associated with paternal occupational exposure prior to conception. Since most exposure subgroups in the study involved multiple subgroups (Table 4), the 4 modalities considered are not mutually exclusive. No significant differences were found between the case and control groups for microwave and infrared modalities. Effects associated with ultrasound cannot be given a physical explanation since ultrasound diathermy produces biological effects by direct contact which physical therapists would not experience in the therapeutic administration of this modality, and the ultrasound frequencies used in diathermy do not propagate in air.

Table 5 presents the results of the analysis for the shortwave modality. The shortwave modality was assessed both in conjunction with other modalities and exclusive of other modalities. For both assessments, 3 months prior to conception, case fathers occupationally exposed to shortwave shortwave radiation administered significantly more treatments per week than control fathers ($P < 0.03$ and $P < 0.02$ respectively).

Fathers of cases and controls were also classified by high or low exposure to shortwave radiation according to length of employment (high > 26 months, low ≤ 26 months), number of treatments per typical work week (high > 9 treatments, low ≤ 9 treatments), and a combination of the length of employment and number of treatments per week. There was a significant difference between fathers of cases and controls for length of employment (Chi square with 1 degree of freedom, 13.1; $P < 0.001$) and the combination of length of employment

and number of treatments per week (Chi square with 1 degree freedom, 7.2; $P < 0.01$). Among case fathers, the relative risk of a birth anomaly was 2.8 (confidence interval, 1.6 to 4.8) for length of employment and 2.9 (confidence interval, 1.3 to 6.2) for the combination of length of employment and treatments per week.

Analyses of fathers of specific case groups (heart anomalies, clubfoot, Down's syndrome, and single gene dominant anomalies) revealed significantly higher ($P < 0.025$) shortwave exposure for fathers of offspring with heart anomalies compared to matched control fathers. The relative risk was 5.0 (confidence interval, 1.5 to 17.3). Testing approached significance ($P < 0.10$) for fathers of offspring with single gene dominant anomalies compared to matched control fathers. Comparisons were based on total length of occupational exposure to shortwave diathermy prior to conception.

Paternal occupational exposure to shortwave diathermy within the 3 month period prior to conception, for the same specific case groups, was assessed for case and matched control fathers. When the assessment was based simply on the fact of occupational exposure to shortwave energy during the 3 months prior to conception, the relative risk of clubfoot and single gene dominant was 2.8 (confidence interval, 1.1 to 7.4) and 4.5 (confidence interval, 1.1 to 18.1) respectively. The number of shortwave diathermy treatments administered per week was not significantly different for fathers of offspring with clubfoot and single gene dominant anomalies when compared to control fathers. A comparison between fathers of offspring with heart anomalies and matched control fathers suggested a trend

($P < 0.10$) for greater frequency of shortwave diathermy treatments administered per week, among case fathers, 3 months prior to conception.

DISCUSSION

Data in this study suggest an increased risk of congenital anomalies in the offspring of male physical therapists occupationally exposed to shortwave radiation. This association is relative to length of time exposed and frequency of exposures, based on both total exposure prior to conception and exposure 3 months prior to conception. Analyses of specific case subgroups reveal similar, although less obvious, effects for heart anomalies and single gene dominant anomalies. Also, a possible indication of an increased risk for clubfoot is associated with short-term (< 3 months) paternal exposure to shortwave energy.

Although the case-control analysis for the Down's syndrome case group yielded no significant findings, it is curious that the rate is 2 to 3 times higher than other reported rates.^{17,23-26} The excess is not due to maternal age as a review of the 13 cases of Down's syndrome revealed that the maternal age was 30 years or less in all but 1 case. Unlike earlier literature¹⁻⁴ which raised the possibility that an increased risk of congenital anomalies might be associated with paternal exposure to microwave radiation, this study finds that the risk may be associated with paternal shortwave energy exposure. Since ease of recognition at birth and impairment of function are basic criteria for case selection in this study, reporting should be rather complete.

The selection of subgroups for analyses was influenced by reports in the literature of associations of anomalies (Down's syndrome and clubfoot) with exposure to non-ionizing radiation and the finding of an unusually large group with heart anomalies in this data. A separate subgroup was selected as an alternative approach to assess the effects on offspring of paternal exposure to non-ionizing radiation in the occupational environment, where the possible etiology is genetic or mutagenic. The genetic subgroup was constructed of cases anomalies whose genetic origin is classified as single gene dominant and included in the ICD code range of 740.0 to 759.9. Defects resulting from a single gene dominant etiology would be likely to become evident in a relatively short time frame. If the mutagenic effect was associated with paternal exposure to non-ionizing radiation, single gene dominant anomalies would most likely occur in direct proportion to the exposure.

Exposure levels were sampled by Ruggera in conjunction with this study.²⁷ The emission levels of shortwave (27MHz) energy varied. Six shortwave diathermy units were surveyed at actual sites, and the details are provided in the previous report. In another study, Stuchly et al. reported a potential of excess exposure to the operators of shortwave diathermy.²⁸ However, the inability to quantify individual occupational exposures of personnel to low level non-ionizing radiation for a long duration is an intrinsic weakpoint. Exposure to energy sources vary relative to a specific piece of equipment and the therapist's orientation to the field. Accurate dosimetry for a large population, over a protracted period, is not feasible with the current state of the art. For a given modality, length of

employment and frequency of treatments administered are necessary surrogates for physical measurements.

The positive associations found in this study are related to chronic exposure to radiofrequency in the shortwave range. Overall, case fathers had greater exposure to shortwave and microwave radiation when compared to control fathers (Table 4). The overall difference is noteworthy, but it is not statistically significant. Congenital anomalies from chronic exposure to microwave energy were not a finding in this study. This might be because exposure to microwave energy was less than exposure to shortwave energy. To our knowledge, no epidemiologic studies have been associated human congenital anomalies with exposure to infrared radiation, and, in this study, ultrasound effects cannot be given a physical and biological explanation because therapists are not exposed (only their patients). A greater number of control fathers was in the "no exposure" group. However, the selection of controls allowed equal opportunity for a control father to be in the "no exposure" group, so this should not prejudice the analysis.

Analyses of separate exposure modality groups which are not independent of each other impose limitations which must be considered in the interpretation of the results. Since this was an exploratory study, the analyses involved multiple comparisons, and the actual alpha level was, in effect, greater than the 0.05 that was used. Therefore, the significant results must be considered suggestive and not confirmatory. However, an effect associated with exposure to shortwave radiation could be noted when the focus was on respondents exposed to shortwave radiation exclusive of microwave radiation.

Recall bias, relative to identification of anomalies and occupational exposure, must also be considered. While it is possible that the anomalies self-reported by the respondents or their spouses might not be totally accurate, the physical therapist are an unusual population as their educational level is high and medically oriented. We believe the biases due to the method of ascertainment were minimal. It seems unlikely that fathers of offspring with birth anomalies would have systematically over-reported occupational exposures which have not previously been associated with anomalies. Taking these considerations into account, an association of paternal occupational exposure to shortwave radiation with an increase in both overall anomalies and specific anomalies among offspring appears to exist.

References

1. Sigler AT, Lilienfeld AM, Cohen BH, et al. Radiation exposure in parents of children with mongolism (Down's syndrome). Bull Johns Hopkins Hosp. 1965; 117:374-399.
2. Cohen BH, Lilienfeld AM, Kramer S, et al. Parental factors in Down's syndrome - results of the second Baltimore case-control study. In Hook EB, Porter IH, eds. Population cytogenetics, studies in humans. New York: Academic, 1977:301-352.
3. Peacock PB, Simpson JW, Alford CA, et al. Congenital anomalies in Alabama. J Med Ass State AL. 1971; 41:42-50.
4. Burdeshaw JA, Schaffer S. Factors associated with the incidence of congenital anomalies: A localized investigation. In: Final Report, contract No. 68-02-0791, March 31, 1976. Research Triangle Park, N.C.: Environmental Protection Agency, 1977.
5. Nordstrom S, Birke E, Gustavson L: Reproductive hazards among workers at high voltage substations, 1982. In press, Bioelectromagnetics.
6. Lancranjan I, Maicanescu M, Rafaila E, et al. Gonadic function in workmen with long term exposure to microwave. Health Phys. 1975; 29: 381-383.
7. Kallen B, Malmquist G, Moritz U. Delivery outcome among physiotherapists in Sweden: is non ionizing radiation a fetal hazard? Arch Environ Health: 1982; 37:81-84.

References (cont'd)

8. Glaser ZR, Cleveland RF, Lielman JK. Mechanisms of interaction and bioeffects of radiofrequency (RF) and microwave radiation. In: Rom WN, Archer VE, eds. Health implications of new energy technologies. Ann Arbor, MI.: Ann Arbor Science, 1980: 705-746.
9. Bereznitskaya AN, Kazbekov IM. Studies on the reproductive testicular microstructure of mice exposed to microwaves. In: Gordon AV, ed, Biological effects of radiofrequency electromagnetic fields. Arlington, VA.: US Joint Publications Research Service No. 63321, 1974:221-229.
10. Varma MM, Traboulay EA Jr. Biological effects of microwave radiation on the testes of Swiss mice. *Experientia*. 1975; 31: 301-302.
11. Manikowska JM, Luciani B, Czerski P, et al. Effects of 9.4 GHz microwave exposure on meiosis in mice. *Experimenta*. 1979; 35: 388-390.
12. Goud SN, Usha Rani MV, Reddy PP, et al. Genetic effects of microwave radiation in mice. *Mutation Res*. 1982; 103: 39-42.
13. Manikowska-Czerska E, Czerski P, Leach WM. K-5 changes in metaphase counts, meiotic translocations and univalency following 2.45 GHz exposure of male CBA mice. Presented at the 4th Annual Scientific Session of the Bioelectromagnetics Society, Los Angeles, June, 1982.
14. Silverman C. Epidemiologic studies of microwave effects, *Proc IEEE*. 1980; 68:78-84

References (cont'd)

15. Hamburger S, Logue JN, Sternthal, P. Occupational exposure to non ionizing radiation and an association with heart disease: an exploratory study. 1982. Submitted for publication.
16. International Classification of Diseases, Eighth Revision, vol 1. Washington, D.C.: DHEW Public Health Service Publication 1693, U.S. Government Printing Office, 1969.
17. National Center for Health Statistics. Congenital anomalies and birth injuries among live births: United States, 1973-74. In: Vital and Health Statistics, series 21, No. 31. Washington, D.C.: Government Printing Office, 1978 (DHEW Publication No. (PHS) 79-1909).
18. Trimble BK, Doughty JH. The amount of heredity in human populations. Ann Hum Genet. 1974; 38:199-223.
19. Snedecor GW, Cochran, WG. Statistical methods. Ames, Iowa: The Iowa State University Press, 1972.
20. McNemar Q. Note on the sampling error of the difference between correlated proportions or percentages. Psychometrika. 1947; 12: 153-157.
21. Miettinen OS. Estimability and estimation in case-referent studies. Am J Epidemiol. 1976; 103:226-235.
22. Rothman KJ, Boice JD. Epidemiologic analysis with a programmable calculator. Washington, D.C.: Government Printing Office, 1979. (DHEW publication no. (NIH) 79-1649).

References (cont'd)

23. Seegmiller RE, Hansen WN. Congenital malformations in Utah. Liberty, 1978.
24. Harris LE, Stayura LA, Ramirez-Talavera PF, et al. Congenital and aquired abnormalities observed in live-born and stillborn neonates. Mayo Clin Proc. 50: 85-90, 1975.
25. Hay S. Incidence of selected congenital malformations in Iowa. Am J Epidemiol 94: 572-584, 1971.
26. Center for Disease Control: Congenital Malformations Surveillance Report July 1977 - June 1978. DHEW Publication No. (CDC) 79-8362. Washington, D.C.: U.S. Gov't Printing Office, 1979.
27. Ruggera PS: Measurements of Emission Levels During Microwave and Shortwave Diathermy Treatments. Rockville, MD.: Bureau of Radiological Health, 1980. (DHHS Publication (FDA) 80-8119)
28. Stuchly M, Repacholi MH, Lecuyer DW, et al. Exposure to the operator and patient during short wave diathermy treatments. Health Phys. 1982; 42: 341-366.

Table 1

Rate of Congenital Anomalies per 100,000 Live Births

ICD	Anomaly	Cases	Rate*
741	Spina bifida	8	169.1
742	Hydrocephalus	3	63.4
743.1	Microcephalus	3	63.4
744	Eye anomaly	4	84.5
745	Hearing anomaly	11	232.5
746	Heart anomaly	30	634.0
748	Anomaly of respiratory system	2	42.3
749	Cleft lip/palate	5	105.7
750.1	Pyloric stenosis	8	169.1
751	Other congenital anomalies of digestive system	13	274.7
751.0	Meckel's diverticulum	2	42.3
751.3	Atresia and stenosis of anal canal	3	63.4
751.9	Unspecified anomalies of digestive system	8	169.1
752	Congenital anomalies of genital organs	7	147.9
752.1	Undescended testicle	3	63.4
752.2	Hypospadias	4	84.5
753	Anomaly of urinary system	2	42.3
754	Clubfoot	37	781.9
755	Other anomalies of limbs	27	570.6
755.0	Polydactyly	4	84.5
755.3	Reduction deformity of lower limb	1	21.1
755.6	Congenital dislocation of hip	8	169.1
755.7	Other anomaly of lower limb	14	295.9
756	Other anomalies of musculoskeletal system	15	317.0
757	Anomalies of skin	2	42.3
759	Congenital syndromes affecting multiple systems	15	317.0
759.3	Down's syndrome	13	274.7
759.4	Trisomy 13	1	21.1
759.5	Turner's syndrome	1	21.1
TOTAL ANOMALIES**		192	
1 or more ICD 740-759 anomalies		175	3698.0

* Based on 4,732 live births

** 8 cases had 2 anomalies, 3 cases had 3 anomalies, and 1 case had 4 anomalies

Table 2

Rate of Congenital Anomalies per 100,000 Live Births
by Birth Year Interval

<u>Birth Year Interval</u>	<u>Cases</u>	<u>Total Live Births</u>	<u>Rate</u>
1940 - 1944	1	33	3030
1945 - 1949	2	141	1418
1950 - 1954	12	388	3093
1955 - 1959	21	731	2873
1960 - 1964	36	783	4598
1965 - 1969	45	797	5646
1970 - 1974	29	896	3237
1975 - 1978	23	819	2808
Unknown	6	144	4167
TOTAL	175	4732	3698

Table 3

Summary of Comparisons of Cases and Controls for
Selected Matching and Personal Characteristics

<u>CHARACTERISTIC</u>	<u>CASES</u>	<u>CONTROLS</u>
Race - white (%)	90	90
Sex of child - male (%)	54	54
Average maternal age (yr)	27	27
Average paternal age (yr)	29	29
Pregnancy events		
Contraceptive use within 12 months prior to this pregnancy - yes (%)	60	60
Cigarette smoking during pregnancy - yes (%)	26	21
Rubella during pregnancy - yes (%)	1	0
Abdominal x-ray/pelvimetry during pregnancy - yes (%)	12	11
Diagnostic ultrasound during pregnancy - yes (%)	4	5
Difficulties in conception - yes (%)	14	9
Previous adverse pregnancy outcomes* - yes (%)	17	2
Parity - 1st born (%)	52	73
Singletons - yes (%)	98	99
Birth defects experienced by either parent - yes (%)	4	2

* Stillbirths, miscarriages, and therapeutic abortions

Table 4

Paternal Occupational History Prior to Conception* of
Cases and Matched Controls, According to Exposure Subgroup

Exposure subgroup†	CASES NO. (%)	CONTROLS NO. (%)
No exposure	49 (29)	60 (36)
MSIU	51 (30)	46 (27)
MSU	12 (7)	11 (7)
MSI	1 (1)	1 (1)
MIU	2 (1)	5 (3)
MU	2 (1)	2 (1)
SIU	26 (15)	19 (11)
SU	20 (12)	11 (7)
S	0 (0)	1 (1)
SI	4 (2)	3 (2)
U	2 (1)	3 (2)
IU	0 (0)	5 (3)
I	0 (0)	2 (1)
Total	169 (100)	169 (100)

* Defined as nine months before date of birth given for children who were not premature and seven months before date of birth given for premature children

† Independent subgroups exposed to one or more of the following four modalities: microwave (M), shortwave (S), infrared (I), ultrasound (U)