Association of semen quality and occupational factors: comparison of case-control analysis and analysis of continuous variables

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Objective: To compare two statistical approaches, case-control and analysis of continuous parameters of semen, in examining the relationship between occupational exposures and male reproductive function.

Design: Case-control study.

Setting: Males providing semen samples at a university infertility clinic.

Patient(s): Nonvasectomized males who provided at least one semen sample at an infertility clinic.

Main Outcome Measure(s): Standard clinical semen analysis.

Result(s): Analyses using a dichotomous dependent variable did not uncover significant associations between any occupational factor and infertility case status. However, linear models incorporating continuous variables identified a number of occupational factors that were associated with specific parameters of semen. A reduction in percentage of progressive sperm and an increase in percentage of coiled tail sperm defects in welders, compared with unexposed subjects, were found. Significant dose-response relationships between level of perceived job stress and percentage of progressive sperm, total motile count, morphology, abnormal heads, and coiled tail defects were found.

Conclusion(s): The findings suggest that subtle changes in semen variables, possibly associated with workplace exposure, may be detected only with parametric analyses of continuous variables of semen. (Fertil Steril 1998;69:11-8. ©1998 by American Society for Reproductive Medicine.)

Key Words: Occupation, sperm, semen quality, male, human

Men who have their semen analyzed at infertility clinics are often studied to investigate the relationship between various exposure factors and semen quality. The approach taken to assess the relationship between the dependent and independent variables may involve either the classification of subjects into cases and controls (1, 2) or the use of continuous dependent variables as they are determined by the laboratory (3, 4). There are advantages and disadvantages of each of these analytical approaches as shown in this investigation of occupational factors and male infertility.

The classification of men into cases and controls based on "cutoff" values for sperm concentration, motility, or morphology is common because of the clinical significance of such cutoffs. In most studies, reference is made to normozoospermic individuals who provide samples at an infertility clinic, rather than preferred controls who are fertile men who do not attend infertility clinics. However, in a review of published studies, Lamb and Bennett (5)
showed that the distribution of sperm concentrations in men requesting a vasectomy was similar to those found for factory and agricultural workers and for infertility clinic patients. Of the three standard parameters of semen quality, sperm motility has been shown to correlate with fertility (6), whereas sperm concentrations below 5, 10, or 20 million/mL have been associated with an increased risk of infertility (6).

Because many semen parameters are continuous variables (e.g., sperm concentration), some analyses of infertility clinic data have been conducted without dichotomization into categories reflecting abnormalities. The statistical methods most often used are correlation, linear regression analysis, and analysis of variance. These methods of statistical inference require that continuous variables follow a normal distribution, when, in fact, seminal parameters are generally far from being normally distributed. Logarithmic, arc-sine, and cube-root transformations have been used to normalize the distribution of various semen parameters (3, 4).

The results obtained from analyses of continuous semen parameters are typically not easily interpreted; in particular, a statistically significant difference may or may not relate to a clinically significant change in semen quality. The need to consider various transformations of dependent variables for parametric analyses and the issues related to interpretation of results from semen analyses have led investigators to rely on case-control methods in the analysis of semen quality data obtained from infertility clinics.

We conducted a study at an infertility clinic in Calgary, Alberta, Canada, to compare the case-control analysis and the parametric analysis of continuous parameters of semen and to investigate the influence of occupational factors on male infertility.

MATERIALS AND METHODS

Population and Study Design

All subjects for the investigation were drawn from the population of patients attending the Diagnostic Semen Laboratory (DSL) at The University of Calgary from May 28, 1990, to December 20, 1991. A total of 1,469 nonvasectomized males who had provided a semen sample as part of a semen function analysis either for an infertility workup, therapeutic donor insemination (TDI), IUI, or IVF were invited to participate. The standard procedures for the collection and examination of semen, as outlined in the World Health Organization Manual for the Examination of Human Semen and Semen-Cervical Mucus Interaction (7), were followed throughout the investigation. The study protocol was approved by the Conjoint Medical Ethics Committee of the Faculty of Medicine, University of Calgary and affiliated teaching institutions.

Each participant, after providing his semen sample at the DSL, was given a self-administered questionnaire, which could be completed on site, mailed, or later delivered to the investigators. To ensure the prompt completion of questionnaires, subjects were contacted by telephone if a completed questionnaire was not returned within the first 7 days. Upon receipt of the completed questionnaire, records from the DSL were searched to determine the individual's most appropriate semen analysis for use in the investigation because many of the subjects had provided more than one semen sample.

A procedure for selecting the most appropriate semen sample, described in detail below, was developed to include as many participants as possible yet avoid sources of error related to the length of time between questionnaire completion and semen sample collection and the collection characteristics of the semen sample (period of abstinence and sample completeness). Ideally, each participant would provide a complete semen sample after 2–4 days of abstinence at the first visit to the DSL and would return his completed questionnaire within 14 days.

The following criteria were used for the selection of semen analysis results among subjects who had completed and returned the questionnaire: [1] date of the semen analysis within 14 days of the questionnaire completion date, [2] abstinence of 2–4 days before the semen sample collection, and [3] the semen sample being complete (no loss of ejaculate). If the first criterion was not met, then the semen analysis records were searched to determine if the subject had provided other semen samples.

If other samples were provided, the sample result that met both criteria [2] and [3] and was produced closest to the date the questionnaire was completed was selected. If criterion [1] was fulfilled, but criteria [2] or [3] were not satisfied, the sample result was checked to determine if any of the following seven parameters was not within the normal range: volume (>2 mL), sperm concentration (>20 × 10⁶/mL), total sperm count (>80 × 10⁹), motile progression (>35%), progressivity (>3), morphology (>30% normal forms), and vitality (>50%). If none of these parameters was abnormal, then the sample result was selected. If any one parameter was abnormal, then the DSL records were searched until a sample result meeting both criteria [2] and [3] and falling closest to the completion date of the questionnaire was selected. Subjects whose questionnaires were not received within 60 days of initial contact were considered nonrespondents.

Items on the questionnaire were divided into six categories: present employment, employment history, avocational activities, lifestyle characteristics, medical history, and sociodemographic characteristics. Questions on present employment emphasized current occupational duties and procedures taken to reduce exposures to hazardous chemicals and physical agents. Current and past occupations were categorized according to the Standard Occupational Classification (SOC) as published by Statistics Canada (8). Work in specific industries was coded in accordance with the
Semen quality variables and transformations needed to satisfy normality.

<table>
<thead>
<tr>
<th>Variable (unit)</th>
<th>Description</th>
<th>Transformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (mL)</td>
<td>Sample volume</td>
<td>Square root</td>
</tr>
<tr>
<td>Concentration (10⁹/mL)</td>
<td>Sperm concentration per mL</td>
<td>Cube root</td>
</tr>
<tr>
<td>Total count (10⁶)</td>
<td>Total sperm count</td>
<td>Cube root</td>
</tr>
<tr>
<td>Percent progressive</td>
<td>Percent progressive*</td>
<td>Cube root</td>
</tr>
<tr>
<td>Motile concentration</td>
<td>Motile sperm (10⁹) per mL*</td>
<td>Square root</td>
</tr>
<tr>
<td>Total motile count (10⁶)</td>
<td>Total motile sperm*</td>
<td>Square root</td>
</tr>
<tr>
<td>Progressivity</td>
<td>Progressivity code (1-4)*</td>
<td>None†</td>
</tr>
<tr>
<td>Morphology (%)</td>
<td>Percent normal forms</td>
<td>Square root</td>
</tr>
<tr>
<td>Abnormal heads (%)</td>
<td>Percent abnormal heads</td>
<td>Cube root</td>
</tr>
<tr>
<td>Midpiece defects (%)</td>
<td>Percent midpiece defects</td>
<td>Square root</td>
</tr>
<tr>
<td>Tail defects (%)</td>
<td>Percent tail defects</td>
<td>Cube root</td>
</tr>
<tr>
<td>Coiled tails (%)</td>
<td>Percent coiled tails</td>
<td>None†</td>
</tr>
<tr>
<td>Tapering heads (%)</td>
<td>Percent tapering heads</td>
<td>None†</td>
</tr>
</tbody>
</table>

* Time is 30 minutes postejaculation.
† No transformation was used, because none of the transformations resulted in $P > 0.05$ on Kolmogorov-Smirnov test for normality.

Standard Industrial Classification 1980 manual (SIC) (9).
With the use of self-reported job titles and job duties, all currently employed respondents were classified to the four-digit level for both SOC and SIC.

Information pertaining to avocational activities and lifestyle characteristics was obtained from questions on hobbies, domestic pesticide use, type of underwear worn, time spent in hot environments (baths, showers, hot tubs, saunas), smoking, caffeine consumption, and drug use. Respondents were asked to estimate the time spent in the pursuit of specific activities during each month of the year.

**Statistical Analysis**

Two distinct analyses were conducted, one in which the semen quality variables were treated as continuous and the other in which seminal parameters were dichotomized in order to classify men as having normal or abnormal semen quality. Thirteen parameters of semen were selected for inclusion in the analyses of continuous variables (Table 1). Semen volume, concentration, total count, percent progressive, motile concentration, total motile count, progressivity, and morphology were included in the analyses because they are clinically meaningful and are commonly reported.

A number of the parameters of semen quality related to morphology, such as percentages of abnormal sperm heads, midpiece defects, tail defects, coiled tails, and tapering heads, were selected because changes in their values may indicate specific effects of exposure. For example, if exposure to an agent truly increases the likelihood of midpiece or tail defects, the detection of this association would be important in that such an effect would not likely be evident in other semen parameters.

The statistical methods used in the analysis of continuous semen parameters required that such variables follow approximately normal distributions. However, frequency distributions of many semen parameters were highly skewed so that transformations were required to achieve normality (Figs. 1 and 2). Numerous transformations were evaluated with the Kolmogorov-Smirnov test for normality (10). Table 1 shows the transformations that were selected for the analyses involving continuous dependent variables. Reported mean values were based on retransforming the arithmetic mean of the transformed data back to the original units.

Those medical conditions and therapeutic agents that are known to adversely affect the quality of human semen were statistically evaluated with analysis of variance; the results showed that men who had reported past or present varicocele, testicular injury, or kidney infection had significantly lower values of sperm concentration, total sperm count, motility, and morphology compared with the rest of the subjects. Those subjects who reported ever having been exposed to antineoplastic agents and those reporting the current use of therapeutic agents for gastrointestinal ailments also had values of sperm concentration and total sperm count that were significantly less than the values for the remainder of the subjects.

Because these conditions and therapeutic drug uses had such a profound negative effect on the semen quality of subjects in the study, data from these individuals were ex-
Frequency distribution of the cube root of sperm concentration. The retransformed mean sperm concentration was 67.5 million/mL.

The respondents ranged in age from 20 to 69 years (mean, 33.9 years) and had a higher level of education than the general population of Calgary, Alberta (37% with university degrees, compared with 26% in the general population) (11).

The duration of infertility, as reported by the respondents who submitted samples for infertility workup, IUI, IVF, and other infertility related tests, ranged from 1 to 264 months (mean, 38.6 months). The self-reported rate of secondary infertility was 33%.

The overall response rate was 72.2% (n = 1,060). The response rate was highest for participants of the IVF program (75.9%; n = 220). Seventy-two percent of individuals who provided semen samples for infertility workup completed and returned their questionnaires (n = 753). Lower response rates were observed for those submitting samples for TDI (63.2%; n = 24) and IUI (65.7%; n = 63).

Most respondents returned their questionnaires within the 1st week. Overall, 944 questionnaires (89.0%) were linked to semen samples that had been provided within 14 days of the completion of the questionnaire, whereas only 42 questionnaires (4.0%) were linked to semen samples that had been provided between 30 and 60 days previously. For 92% of semen samples (n = 976), abstinence was between 1 and 4 days; 12 semen samples had some reported sample loss (not complete) but had normal parameters.

The most frequently reported caffeinated product consumed was coffee; all information on consumption of caffeine was converted to the equivalent number of cups of coffee per day based on mean caffeine contents of foods (12, 13). Most respondents (85.2%) reported that they regularly consumed alcoholic beverages. A much smaller percentage reported regularly using marijuana (9.2%), and only 1.4% reported use of LSD, cocaine, downers, uppers, narcotics, or other recreational drugs.

Slightly over 90% of the study subjects reported that they were employed full-time. A substantial percentage were employed in occupations for which exposure to industrial contaminants was likely to be minimal or infrequent. Sixty percent reported current work in two-digit SOC category codes that were <52, which includes managerial, science and engineering, social science, religion, teaching, medicine,
Descriptive statistics for semen quality variables (n = 845).

<table>
<thead>
<tr>
<th>Variable (unit)</th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
<th>SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (mL)</td>
<td>3.6</td>
<td>3.4</td>
<td>0.20–12.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Concentration (10^6/mL)</td>
<td>108.1</td>
<td>82.5</td>
<td>0.10–761</td>
<td>3.3</td>
</tr>
<tr>
<td>Total count (10^9)</td>
<td>35.1</td>
<td>28.6</td>
<td>0.12–2,477</td>
<td>10.7</td>
</tr>
<tr>
<td>Percent progressive*</td>
<td>47.4</td>
<td>51.0</td>
<td>0.00–78.0</td>
<td>0.430</td>
</tr>
<tr>
<td>Motile concentration*</td>
<td>53.3</td>
<td>40.6</td>
<td>0.00–410</td>
<td>1.68</td>
</tr>
<tr>
<td>Total motile count (10^6)</td>
<td>174.4</td>
<td>139.5</td>
<td>0.00–1072</td>
<td>5.37</td>
</tr>
<tr>
<td>Progressivity*</td>
<td>2.7</td>
<td>3.0</td>
<td>0.00–4.0</td>
<td>0.022</td>
</tr>
<tr>
<td>Morphology (%)</td>
<td>49.8</td>
<td>52.0</td>
<td>0.00–81.0</td>
<td>0.471</td>
</tr>
<tr>
<td>Abnormal heads (%)</td>
<td>37.0</td>
<td>36.0</td>
<td>0.00–88.0</td>
<td>0.455</td>
</tr>
<tr>
<td>Midpiece defects (%)</td>
<td>13.5</td>
<td>12.0</td>
<td>0.00–54.0</td>
<td>0.280</td>
</tr>
<tr>
<td>Tail defects (%)</td>
<td>12.6</td>
<td>11.0</td>
<td>0.00–80.0</td>
<td>0.282</td>
</tr>
<tr>
<td>Coiled tails (%)</td>
<td>3.2</td>
<td>2.0</td>
<td>0.00–36.0</td>
<td>0.136</td>
</tr>
<tr>
<td>Tapering heads (%)</td>
<td>0.4</td>
<td>&lt;0.1</td>
<td>0.00–64.0</td>
<td>0.088</td>
</tr>
</tbody>
</table>

* Time is 30 minutes postejaculation.

**Table 2**

Note: SD = standard deviation.

arts, clerical, and sales occupations. The most prevalent occupational category was science and engineering (20%). Many respondents reported work in the crude petroleum and natural gas industry (20%), with the next most prevalent SIC two-digit category, business service industry, being reported by only 7% of the subjects.

**Analysis Using a Continuous Dependent Variable**

The results from 845 semen samples were used in this analysis (Table 2). Adjustments were made in the linear models for the confounding influence of age, length of abstinence, smoking, consumption of caffeine, and season. Analysis of variance with and without confounding variables revealed no significant correlation between any parameter of semen and work in any occupational category (two-digit SOC), with the exception of farming. The mean sperm concentration of farm workers was 77.5 X 10^6/mL compared with the mean for nonfarm workers of 87.7 X 10^6/mL, although this difference was not statistically significant. Farm workers had a mean value for semen volume that was significantly higher (P < 0.001) than that in the unexposed group (3.3 mL). Sperm concentration and motile concentration were lower, and percentage of tapering head defects was higher in the agricultural workers, but the only difference that was statistically significant was the increase in tapering heads (P < 0.01).

Welders have been the focus of research on the effects of occupational exposures on semen quality. Only 11 men reported current employment as welders or flame cutters. Fourteen respondents worked in these occupations in the 3 months before their semen analyses. Compared with subjects in the nonexposed category, this group of 14 subjects had significantly lower percent progressive sperm (46.9% versus 50.4%; P < 0.05) and significantly higher percent coiled tail defects (5% versus 1.8%; P < 0.01).

Although the mean sperm concentration was less for the 45 respondents who were employed in the transportation industry (80.1 X 10^6/mL) than for the unexposed group (87.7 X 10^6/mL), the difference was not statistically significant. The reported number of hours spent driving each work day also was not significantly associated with any parameter of semen. Respondents who reported more than 6 hours of sitting each work day had lower mean values of sperm concentration, total count, motile concentration, and total motile count than those reporting less than 3 hours of sitting, although the differences were not statistically significant.

Nine different shift schedules were identified, with most subjects reporting regular day shifts (75%); only 8.5% reported true rotating shifts, and smaller percentages of subjects reported permanent evening, afternoon, and other combinations of shifts. Although the mean sperm concentration of men working only day shifts was 6.7% greater than that for shift workers (83.9 and 78.6 X 10^6/mL, respectively), the difference was not statistically significant.

One item on the questionnaire pertained to the respondent's perceived level of emotional stress associated with his job. When the data for currently employed subjects were grouped by perceived level of occupational stress, trends suggesting a deterioration of semen quality with increased levels of stress were observed in five seminal parameters (Table 3). Percent progressive sperm, total motile count, morphology, abnormal heads, and coiled tail defects showed dose-response relationships that were statistically significant in multiple linear regression analyses that adjusted for the effects of potential confounders.
Mean values of seminal parameters by perceived level of occupational stress.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>None (n = 18)</th>
<th>Hardly any (n = 88)</th>
<th>Some (n = 457)</th>
<th>A great deal (n = 218)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume†</td>
<td>2.74</td>
<td>3.93</td>
<td>3.49</td>
<td>3.15</td>
<td>NS</td>
</tr>
<tr>
<td>Concentration†</td>
<td>139.1</td>
<td>78.7</td>
<td>84.4</td>
<td>81.9</td>
<td>NS</td>
</tr>
<tr>
<td>Total count†</td>
<td>370.2</td>
<td>296.7</td>
<td>278.4</td>
<td>251.1</td>
<td>NS</td>
</tr>
<tr>
<td>Percent progressivet†</td>
<td>49.6</td>
<td>53.2</td>
<td>50.2</td>
<td>49.5</td>
<td>0.018</td>
</tr>
<tr>
<td>Motile conc.t†</td>
<td>71.1</td>
<td>42.7</td>
<td>44.1</td>
<td>42.0</td>
<td>NS</td>
</tr>
<tr>
<td>Total motile countt†</td>
<td>188.8</td>
<td>161.6</td>
<td>146.4</td>
<td>130.4</td>
<td>0.039</td>
</tr>
<tr>
<td>Progressivityt†</td>
<td>2.8</td>
<td>2.8</td>
<td>2.7</td>
<td>2.6</td>
<td>NS</td>
</tr>
<tr>
<td>Morphology†</td>
<td>55.2</td>
<td>54.5</td>
<td>51.9</td>
<td>50.8</td>
<td>0.009</td>
</tr>
<tr>
<td>Abnormal heads†</td>
<td>33.4</td>
<td>32.3</td>
<td>35.0</td>
<td>36.4</td>
<td>0.015</td>
</tr>
<tr>
<td>Midpiece defectst†</td>
<td>11.8</td>
<td>12.1</td>
<td>12.2</td>
<td>12.0</td>
<td>NS</td>
</tr>
<tr>
<td>Tail defectst†</td>
<td>10.6</td>
<td>10.2</td>
<td>11.3</td>
<td>11.1</td>
<td>NS</td>
</tr>
<tr>
<td>Coiled tailst</td>
<td>1.8</td>
<td>2.6</td>
<td>3.1</td>
<td>3.4</td>
<td>0.036</td>
</tr>
<tr>
<td>Tapering headst</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>NS</td>
</tr>
</tbody>
</table>

Note: NS = not significant.
* Multiple linear regression analysis with each exposure variable forced into the regression equation and control variables allowed to enter final model if P < 0.20. All estimates based on the final models.
† Means for parameters that required transformations computed by taking the mean of the transformed data and then retransforming back to the original units.
‡ Time 30 minutes postejaculation.

Analysis Using a Dichotomous Dependent Variable

The case and control groups were comparable in terms of age, education, and the duration of infertility. As expected, the proportion of cases who provided their sample for infertility workup was higher than that in the control group, whereas a greater proportion of controls was part of the IVF program.

To investigate the association of specific occupations at risk of an abnormal semen parameter, several logistic regression models were developed to adjust for potential confounders (Table 4). Present or past employment in the group of occupations classified as welding or flame cutting was not associated with case status. The results also showed no association between semen abnormalities and present or past employment as a farmer. Grouping of occupations with industrial exposures also failed to provide evidence to support the hypothesis that occupational exposures to chemical or physical agents are associated with abnormalities of semen. In addition, no statistically significant associations by level of occupational stress, time spent sitting, or shift work were found.

DISCUSSION

In analyses using continuous variables, the finding of a significantly higher semen volume, higher percentage of tapering head defects, and a lower, but not statistically significant, mean sperm concentration in agricultural workers is suggestive of an effect that may increase the risk of infertility. In previous studies, infertile men were found to more likely have higher ejaculate volumes compared with men from fertile marriages, with their infertility most likely related to their lower sperm concentration (14).

When statistical analyses were based on a dichotomous dependent variable, the results did not support the supposition that farming increases the risk of male infertility because ejaculate volume is not a parameter used to classify a semen analysis as abnormal and because the finding of a lower sperm concentration was not statistically significant, the lack of association between farming and infertility in the case-control analysis might be expected.

The relationship between exposure to the common herbicide 2,4-D has been found to be associated with male reproductive dysfunction, causing asthenozoospermia, necrozoospermia, and teratozoospermia (15). The finding of lower sperm concentration and an increase in tapering head defects in the 55 agricultural workers in this study supports the hypothesis that agricultural chemicals may affect male reproductive function in this employment population. However, misclassification may have diluted this association because exposure to pesticides in agricultural workers is highly variable and dependent on geographical area, time period, work practices, and duties (16). In addition, the small proportion of agricultural workers in the study limited the power to detect statistically significant differences in mean values of these parameters.

Although only 11 men reported welding or cutting exposure, the analysis using continuous variables provided evidence of a deleterious effect, whereas the case-control method did not. The significant reduction in sperm motility and the increase in coiled tail defects are consistent with
creased risk of seminal abnormalities. Results from cross-
mark also support the association of welding with
resulted in no significant findings with either method of
be due to a number of reasons. The associations themselves
linking specific occupations and abnormalities of semen may
decrements in various parameters of semen, including sperm
motility and morphology (19).

Sectional and longitudinal investigations conducted in Den-

With the exception of employment in welding and agri-
culture, no significant associations between work in a spe-
cific occupation and semen abnormalities or infertility were
found. Similarly, current employment in specific industries
resulted in no significant findings with either method of
analysis. The paucity of evidence from this investigation
linking specific occupations and abnormalities of semen may
be due to a number of reasons. The associations themselves
may be weak, and the study may have had insufficient
statistical power to detect the subtle differences. This ration-
ale is supported by the results of studies that have not
shown relationships between occupation and semen quality
(2, 20, 21).

Misclassification is a major limitation in all investiga-
tions that use occupation and industry titles for classification
of exposure. Although information on job duties
was obtained and reviewed by an industrial hygienist, it
was used primarily to ensure that occupation and industry
coding were correct. When only a proportion of the group
classified as exposed actually is exposed, such as for
agricultural workers, the association is generally biased
toward the null (22).

Because of the nature of the questions pertaining to
occupation, the possibility of recall bias was unlikely. For
independent variables that were more subjective in nature,
such as stress at work, the recall bias may have been a
factor. However, analysis of the data using only individ-
uals who had submitted samples for infertility workup
(i.e., they had not yet had a diagnosis) yielded essentially
the same results.

A limitation that may affect both the generalizability of
results and the statistical power of the study pertains to the
population of patients attending infertility clinics. There
are economic and social considerations that lead couples
to IVF, IUI, and other infertility therapies (23). Patients at
infertility clinics usually have a higher level of education
than the general population, and there is less diversity in
terms of both socioeconomic status and occupations rep-
resented (24). In this study, highly educated men holding
administrative and professional jobs were probably over-
represented, with fewer individuals reporting work in
occupations for which exposure to reproductive hazards is
more likely.

Classification of continuous variables into categorical
variables typically results in some loss of statistical power in
data analysis (25). The statistically significant findings from
the analyses of continuous variables suggests that there may
be effects of work as a farmer or welder or job stress on
sperm quality. The direction of effects is consistent with
what has been reported previously, and the failure to find
occupations that significantly improve semen parameters
suggests that the findings are not due to the number of
statistical tests conducted. Primarily because of the lower
statistical power in the case-control analyses, no significant
associations were identified, suggesting that, in this popu-
lation, occupational exposures play a relatively minor role in
the etiology of male infertility.

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