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Andrology

No Decline in Semen Quality Among Potential Sperm Donors in Sydney, Australia, Between 1983 and 2001

Michael F. Costello,[1,2,3] Peter Sjoblom,[2] Youala Haddad,[2] Stephen J. Steigrad,[2] and Edward G. Bosch[2]

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***Purpose*:** To determine whether the quality of semen has changed over time in men screened for semen donation.
***Methods*:** All 448 men volunteering for semen donation between 1983 and 2001 at a donor insemination clinic in Sydney, Australia, were included in this longitudinal single centre observational analysis of semen parameters. There was no selection for fertility or marital status but all volunteers had to be aged between 18 and 40 years.
***Results*:** There was no change in the total sperm count during the study period ($r = 0.065$, $P = 0.17$) using a linear regression model. The ejaculate volume did not change ($r = 0.002$, $P = 0.97$), while an increase in sperm motility was seen (Spearman $R = 0.194$, $P < 0.001$).
***Conclusion*:** The semen quality of volunteers for sperm donation presenting to our donor insemination clinic in Sydney between 1983 and 2001 has not declined.

KEY WORDS: Semen donation; semen quality; sperm count; sperm motility.

INTRODUCTION

In 1929, Macomber and Saunders reported the normal sperm density to be 100 million/mL, based on the sperm counts of 294 males with no regard to their fertility potential. Their conclusion was that men with sperm counts less than 60 million/mL were able to initiate pregnancies (1). It is noteworthy that the lower reference value for a "normal" sperm count has changed from 60 million/mL in the 1940s (2,3) to the present value of 20 million/mL (4).

Concern has been raised that there has been a decline in the human sperm count by as much as 50% over the past 50 years, and also a corresponding increase in the incidence of abnormalities of the male reproductive tract such as testicular cancer, undescended testes, and hypospadias (5–7). A postulated cause of a downward trend in male fertility is the exposure to chemicals in the environment called "endocrine disruptors" that act like estrogens (6). For the proposed cause of declining sperm counts to be due to estrogenic global environmental pollution, such effects should be evident in all areas of the globe.

However, the question of whether the sperm count of the human population is declining is controversial. Reports from Europe and America that semen quality has declined (5,8–11) are balanced by others showing no decline (12–15).

Since geographical and ethnic variations may have an impact on the results, we decided to evaluate whether semen quality has declined over time in Sydney, Australia. If a global environmental effect is responsible for declining sperm counts, then one would expect to see a similar decline in semen counts over time in Sydney, Australia. We, therefore, aimed to analyse variations of first ejaculate sperm counts

[1] School of Women's and Children's Health, Division of Obstetrics and Gynaecology, University of New South Wales, Sydney, Australia.
[2] Department of Reproductive Medicine, Royal Hospital for Women, Sydney, Australia.
[3] To whom correspondence should be addressed at School of Women's and Children's Health, Division of Obstetrics and Gynaecology, Level 1 Women's Health Institute, Royal Hospital for Women, Locked Bag 2000, Randwick, Sydney, New South Wales 2031, Australia; e-mail: mfcostello@unsw.edu.au.

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over time in men screened for semen donation at a single centre in Sydney from 1983 to 2001.

MATERIALS AND METHODS

A retrospective analysis was undertaken of the first ejaculates of all males volunteering for sperm donation at the donor insemination clinic at the Royal Hospital for Women, Sydney, over the 18 year period from 1983 to 2001. Potential donors were recruited by advertisements and screened for suitability for sperm donation. There was no selection for fertility or marital status but all volunteers had to be aged between 18 and 40 years. All potential donors were first seen at the donor insemination clinic where a medical history and physical examination was performed to screen for hereditary and infectious diseases. The potential donors were then instructed to observe 3–4 days of abstinence prior to the semen collection by masturbation into sterile wide-mouth plastic containers to assess suitability for semen donation. Specimens were brought to the andrology laboratory within 1 h of collection.

All potential donor semen samples were analysed according to the WHO methodology by the head of the andrology laboratory, who was present during the entire study duration, or a laboratory scientist trained by him. Semen samples were assessed by the standard approved World Health Guidelines of the day (4,16–18). Sperm counts during the entire study period were assessed using a Neubauer hemacytometer.

Regular interobserver variation assessments were performed by quality assurance activities. Quality assurance during the study period consisted of interobserver assessments with internal and external quality control procedures. Internal quality control consisted of monthly assessments of laboratory trainees or new staff by the head of the andrology laboratory. External quality control comprised of 2–3 yearly testing by the National Association of Testing Authorities Australia (NATA), in combination with three monthly testing by the Fertility Society of Australia (FSA) since 1997.

The main outcome measure was the change in total sperm count over time as investigated by regression analysis. Morphology was not evaluated as the morphology assessment criteria had changed during the study period. Only the first semen samples were analysed as some men provided only a single semen sample before inclusion or rejection. Use of multiple semen samples would have introduced bias as men accepted as sperm donors would have had higher sperm counts by design.

Statistical Analysis

The distribution of the total sperm count and ejaculate volume deviated from normal (Shapiro-Wilk $W = 0.86$, $P < 0.001$ and $W = 0.92$, $P < 0.001$, respectively). However, after square root transformation a normal distribution was achieved (Shapiro-Wilk $W = 0.98$, $P = 0.26$ and $W > 0.98$, $P = 0.38$, respectively) for both these variables. Logarithmic transformation did not produce a normal distribution of either variable. For the nonnormally distributed motility data, the distribution was unable to be normalised by using trigonometric functions, square root, logarithmic, or power transformations.

Means, medians, ranges, and quartiles were calculated for total sperm count, ejaculate volume, and motility. Linear regression analysis was used to assess changes in transformed data for total sperm count and ejaculate volume over time. The nonparametric Spearman rank order correlation was used to analyse changes in motility over time. Statistical analysis was carried out using the statistical packages Excel 97, Statistica release 5.0, and Minitab student release 12.

RESULTS

Four hundred and forty-eight males aged between 18 and 40 years had volunteered for semen donation over the period 1983–2001. Figure 1 depicts a histogram of the frequency of all 448 male sperm donor volunteers by year of presentation.

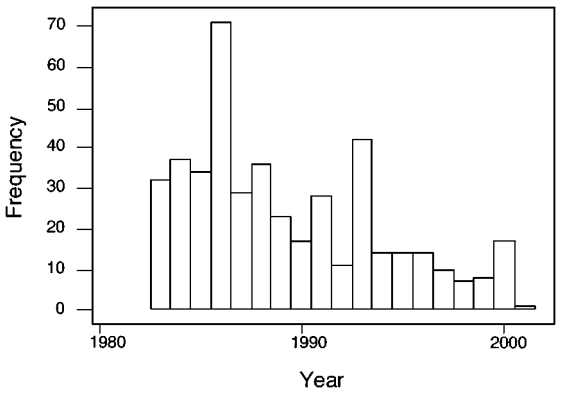

Fig. 1. Frequency of all 448 new male sperm donor volunteers by year 1983–2001.

Table I. Descriptive Statistics of All 448 Male Sperm Donor Volunteers, 1983–2001

	Total sperm count (millions)	Volume of semen (mL)	Motile sperm (%)
Mean ± SD	194.9 ± 105.6	3.7 ± 1.9	52.5 ± 11.3
Median (range)	180 (0–700)	3.5 (0.2–14.0)	55 (5–81)
25th and 75th centiles	120, 252	2.4, 4.8	45, 60

The median total sperm count over the period 1983–2001 was 180 million, ranging from 0 to 700 million (Table I). There were three men with azoospermia, presenting in 1983, 1997, and 2001. Over the same 18-year time period, the median volume of ejaculated sperm was 3.5 mL (range 0.2–14 mL) and the median percent motile sperm was 55% (range 5–81%).

The main outcome measure for this study of 448 males was the change in total sperm count over time from 1993 to 2001. Linear regression analysis showed no significant change in the total sperm count ($r = 0.065$, $P = 0.17$) over the study period (Fig. 2). Linear regression analysis also revealed no significant change in ejaculate volume ($r = 0.002$, $P = 0.97$) over the same 18-year period (Fig. 3). However, the percent motile sperm increased during this period (Spearman $R = 0.194$, $P < 0.001$) (Fig. 4).

DISCUSSION

Over the study period 1983–2001, there has been a general trend towards a reduction in the number of new potential male sperm donor volunteers presenting to our donor insemination clinic in Eastern Sydney, Australia (Fig. 1). The results of our study of 448 men reveals no downward trend in semen quality during this time (Fig. 2). This data provides further evidence that deterioration of semen quality is not geographically uniform.

All the volunteer potential sperm donors in our study were aged between 18 and 40 years with no selection for fertility or marital status. A weakness of our study is that potential confounders such as age and fertility status were not able to be compared over time due to incomplete and missing information on the potential sperm donors. The narrow age range (18–40 years) along with a recent review on the effects of male age on semen quality concluding that increased male age is not associated with a decline in sperm concentration (19) should eliminate age as

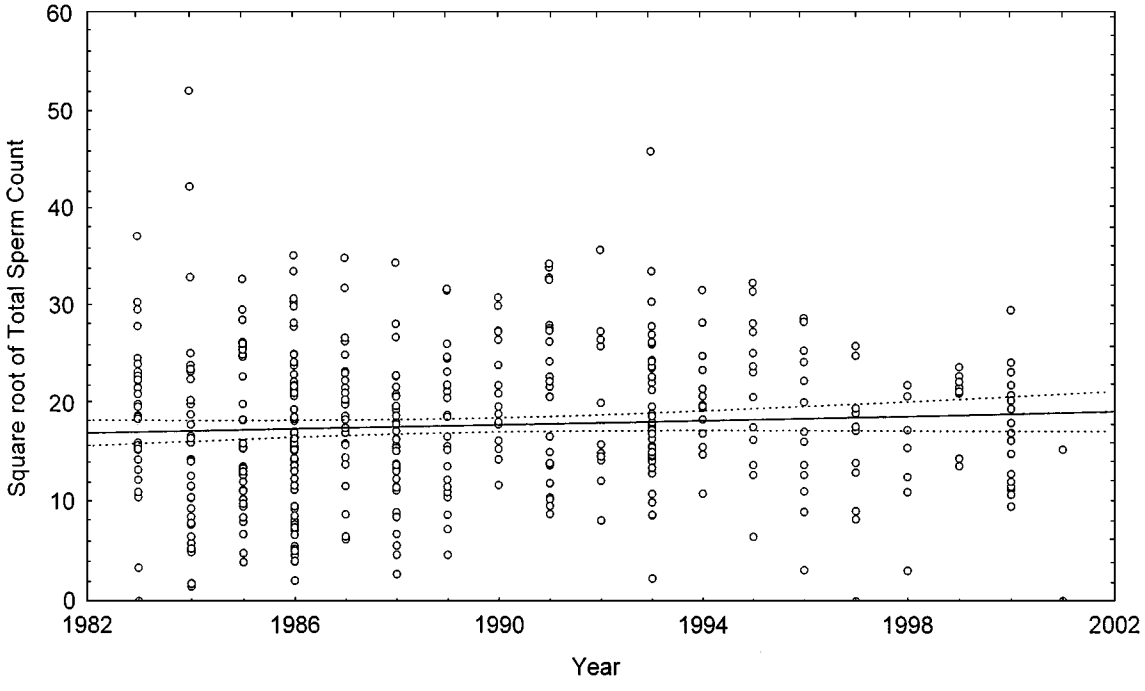

Fig. 2. Regression analysis of the change in total sperm count over time. Data are square root transformed. The equation of the regression line ($y = a + bx$) is square root of total sperm count = $8.40 + 0.105 \cdot$ Year. The 95% confidence limits of the regression coefficient are 0.020–0.230; the correlation coefficient, $r = 0.065$, and $P = 0.17$.

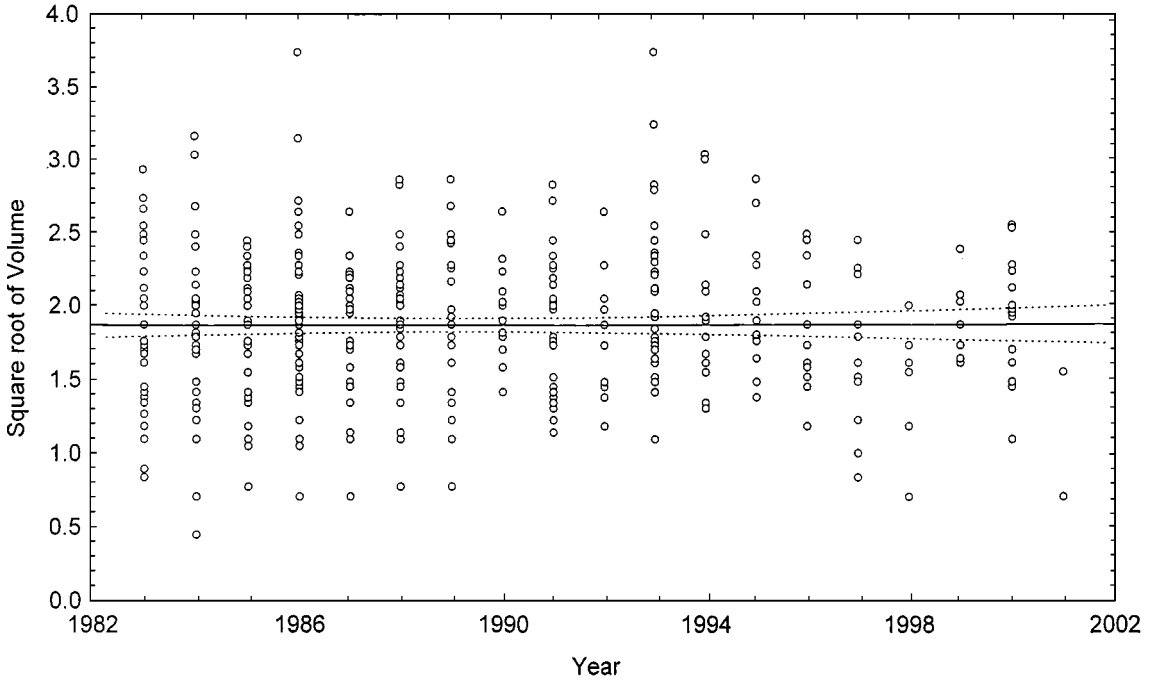

Fig. 3. Regression analysis of the change in ejaculate volume over time. Data are square root transformed. The equation of the regression line ($y = a + bx$) is square root of volume $= 1.85 + 0.0002 \cdot$ Year. The 95% confidence limits of the regression coefficient are 0.0077–0.0081; the correlation coefficient, $r = 0.002$, and $P = 0.97$.

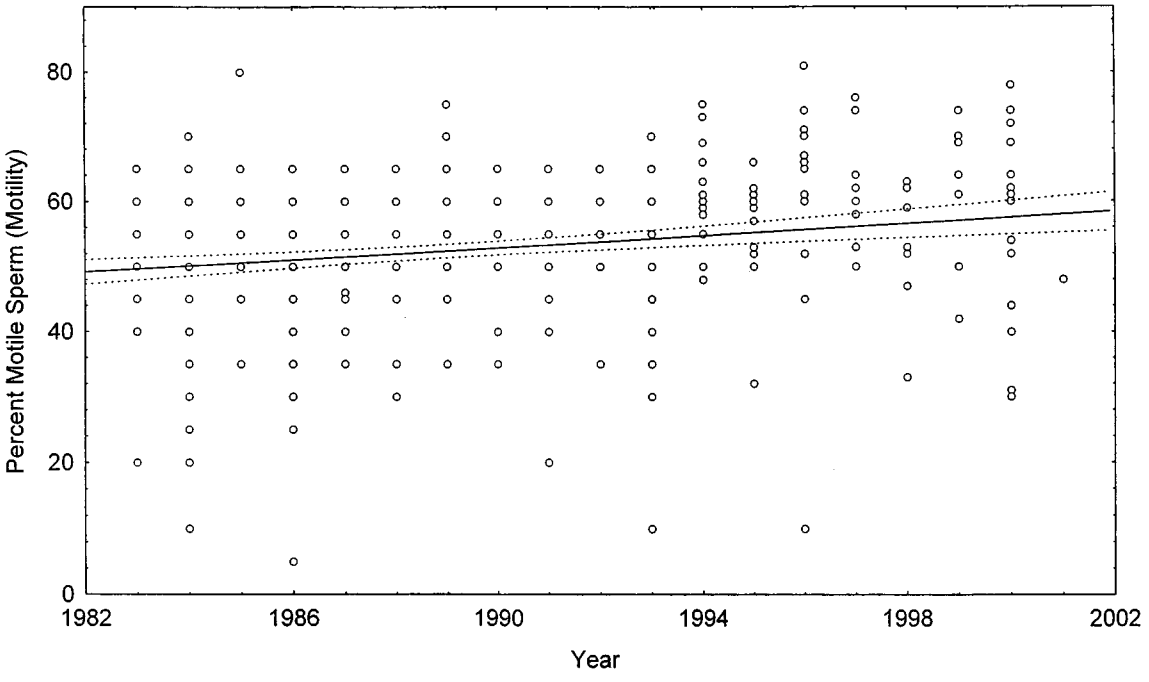

Fig. 4. Analysis of the change sperm motility over time. Spearman Rank correlation coefficient, $R = 0.19$, and $P < 0.0001$.

a confounder. In addition, the comparatively similar duration of abstinence (3 or 4 days) should abolish the confounding effects of this parameter.

A strength of this single centre study is the removal of between-centre method variability of semen analyses. In addition, the head of andrology was laboratory head during the entire study duration, with all staff assessing the semen samples having been trained by him, as well as being subject to regular quality assurance. Sperm count assessments were performed using a Neubauer hemacytometer during the study period. This ensured consistent semen assay methodology and equipment over the entire study period, eliminating or minimising any measurement bias in our study.

While in this study the methodology for semen analysis was well controlled, the sample population may not be representative for the general population. Semen samples from prospective sperm donor volunteers may not truly reflect the parent population (20).

We are aware of only one other published study evaluating the trend in sperm quality over time from Australia, and in fact the Southern Hemisphere. This study by Handelsman in 1997 (20) was also conducted by a single centre in Sydney and reviewed semen analyses obtained from 1980 to 1995 from 509 healthy potential sperm donors. Again, recruitment was by advertising without regard to marital or fertility status. Analysis of the first semen sample individually or when grouped by year of ejaculation showed no significant difference in sperm concentration over time or between years or according to year of birth. These findings from a single centre located in a different geographical area of Sydney are consistent with the results of our study in that there was no decline in sperm count over a similar time period.

The meta-analysis of Carlsen *et al*. (5) published in 1992 began an animated debate on a possible decline in semen quality during the past 50 years. The meta-analysis was based on 61 heterogenous observational studies published between 1938 and 1990, including a total of 14,947 men with proven or unknown fertility, but excluding patients investigated for infertility. The study showed a decrease in mean sperm count from 113 million/mL in 1940 to 66 million/mL in 1990. In the linear regression model, this figure corresponded to an annual decline of 0.93 million/mL. The analysis included 28 studies from the United States, 17 from Western Europe, 7 from Asia, 5 from Africa, 3 from Latin America, and 1 from Australia (21). The changes in sperm counts were calculated for the entire data set and considered as a global phenomenon.

There have been a number of criticisms of the Carlsen study. Several reanalyses of the original meta-analysis have been reported questioning the statistical models of the meta-analysis (22) or uneven geographic distribution of the studies included in the meta-analysis in relation to the time period (23). The conclusions of these analyses were either partial disapproval or confirmation of the conclusions made in Carlsen's original meta-analysis. When Carlson's sperm concentration data were reanalysed, sperm concentration only significantly declined from 1938 to 1972, with no decline in the 20-year period after 1972 (14). A further criticism is whether the various samples are truly reflective of the source populations because semen sampling may be highly biased (24). Other major criticisms directed against the meta-analysis are that significant confounding, measurement, and selection biases could have skewed their results. These biases included failing to account for age and duration of abstinence, methodological inconsistencies with data originating from 61 different laboratories using different techniques and equipment for sperm counting, and geographic variations in semen quality with data from different populations and regions throughout the world (25). The studies were conducted in different countries for various reasons, with different eligibility criteria, and over a long time period.

Since the publication by Carlsen *et al*. in 1992 (5), there have been a number of longitudinal single centre observational studies performed in Europe and America, which have produced conflicting results. Reports that semen quality has declined (8–11,26) are balanced by others showing no decline (12–15,27,28). Semen quality has been reported to have declined in 1351 fertile sperm donors attending a single sperm bank between 1973 and 1992 in Paris, France (8); 23,850 men from infertile couples at three andrological laboratories from 1977 to 1993 in Athens, Greece (9); 577 Scottish volunteer donors for research at a single laboratory from 1984 to 1995 in Edinburgh, Scotland (10); 416 sperm donors from 1977 to 1995 in Ghent, Belgium (11); and 260 partners of infertile women between 1978 and 1983 in London, England (26). On the other hand, no decline in semen quality has been seen in 302 fertile sperm donors at a single centre between 1977 and 1992 in Toulouse, France (12); 510 semen donors participating in clinical studies from 1972 to 1993 in Seattle, USA (14); 849 Finnish men of either proven fertility or who were normal but of unknown fertility (trying to conceive or sperm donor candidates) ranging from 1958 to 1992 (27);

and 5481 men from infertile couples between 1967 and 1994 in Turku, Finland or 238 male partners of couples attempting to conceive who volunteered semen samples during 1984–1986 in Kuopio, Finland (28). Two of the studies reporting no decline actually showed an improvement in semen quality over time. The first of these studies evaluated 1283 men who had banked one or more semen samples prevasectomy at one of three sperm banks in different states in the United States (Minnesota, New York, and California) over the 25-year period from 1970 to 1994 (13). A slight but significant increase in sperm count was found during this study period. The second study analysed the semen quality of 188 first ejaculates of semen donors at a single sperm bank in Jerusalem between 1980 and 1995 and showed a significant increase in total motile sperm count over time (15). Such studies evaluating sperm counts over time fail to address whether any deterioration in semen quality, albeit controversial, is accompanied by a reduction in human fertility. This can be measured by assessing changes in the time taken to achieve a pregnancy (29).

The hypotheses put forth by Sharpe and Skakkebaek (6) deserve attention. They have suggested that pollutants such as environmental contamination by estrogenic substances are responsible for a decline in sperm quality where this has been observed. We have no information with respect to the presence or absence of such toxicants or pollutants in our metropolitan area during the time period of our study. Thus, we are not able to comment on this point. However, the findings of no decline in sperm counts over time from two independent geographically different centres in Sydney in a similar study population over a similar time period, together with similar findings by other investigators from different geographical locations (12–15,27,28), argue against global pollution being responsible for declining sperm counts found by others (5,8–11,26). Further evidence showing unchanged or increasing sperm counts of bulls, boars, and rams over the last six decades (30) is also consistent with the absence of any global biological effect unless it is restricted to humans. Studies performed in Western Europe (27,28) and the United States (13,14) disclose regional differences in human semen quality not only across national borders but also within the same country. It is unknown whether these geographical differences are caused by genetic, environmental, and lifestyle-related factors or simply by the incomparability of populations because of differences in sampling approaches and response rates. It is most likely that all types of mechanisms are operating.

Our study population, like all the available studies to date of men providing semen samples, consisted of self-selected volunteers with various nonneutral motivations. Volunteers for sperm donation or research studies appear to differ from the general population in psychological characteristics including those such as sexuality and risk-taking behaviour, which could influence semen analysis results (31–33). Therefore, it may not be scientifically valid to extrapolate similar findings on sperm counts of self-selected volunteers to the general male community, unless they originate or otherwise constitute a representative sample of that reference population. In standard survey sampling methodology, such inference would ideally be based on random, probabilistic samples of the source population with or without stratification to ensure a representative sample at each stratum. Therefore, a better method of assessing changes in semen quality over time is to select at intervals random samples of males from the population and submit them to fertility tests, including semen analysis. This approach is not possible since few men volunteer for semen analysis, and previous experience indicates that volunteers disproportionately represent those who are curious or concerned about their fertility, either because of previous testicular disorders or suspected infertility (20,24).

However, regardless of the relationship between the study population and the general population, it is likely that the former would be under the same environmental influence as the latter. If the secular trend in sperm count was genuine and due to global pollution, similar effects should not only be evident around the world, but also in all populations, that is, normal reference population and self-selected sperm volunteers. This means that trends in the prospective sperm donor population should be suggestive of similar developments in the general population.

CONCLUSION

We conclude from our data that the semen quality of volunteers for sperm donation presenting to our donor insemination clinic in Sydney has not declined over the past 18 years between 1983 and 2001. Because other studies have shown some deterioration in semen quality, there may be geographic differences in findings of abnormal reproductive health. This possibility could be examined in the form of a multicentre study of varied populations, with the assessment of environmental toxins or pollutants in addition to lifestyle-related factors.

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