Human Reproduction, Vol.26, No.5 pp. 1012–1016, 2011
Advanced Access publication on March 7, 2011 doi:10.1093/humrep/der045

human reproduction **ORIGINAL ARTICLE** ***Andrology***

No secular trend over the last decade in sperm counts among Swedish men from the general population

J. Axelsson[1,2,3,*], L. Rylander[2], A. Rignell-Hydbom[2], and A. Giwercman[1,3]

[1]Reproductive Medicine Centre, Skåne University Hospital, Malmö, 205 02 Malmö, Sweden [2]Division of Occupational and Environmental Medicine, Lund University, 221 85 Lund, Sweden [3]Department of Clinical Sciences, Malmö, Lund University, 205 02 Malmö, Sweden

*Correspondence address. Tel: +46-40 33-21-64; Fax: +46-40-33-82-66; E-mail: jonatan.axelsson@med.lu.se

Submitted on November 22, 2010; resubmitted on January 20, 2011; accepted on February 2, 2011

INTRODUCTION: Based on historical data, a decline in sperm counts during the years 1940–1990 has been suggested and aetiologically linked to a concomitant increase in the incidence of testicular cancer. This study, focusing on possible changes in sperm parameters among young Swedish men, during the past 10 years, was specifically designed in order to answer the question of whether there is a continuing decline in sperm counts.

METHODS: During the period 2008–2010, 295 young (17–20 years; median 18) men born and raised in Sweden were recruited at the age they were supposed to undergo medical examination prior to military service. The participants filled in questionnaires, underwent andrological examination and delivered an ejaculate. Their semen parameters were compared with those of a similar cohort of men ($n = 216$) recruited in the year 2000–2001.

RESULTS: No significant changes (means; 2000–2001 versus 2008–2010) in sperm concentration (78×10^6/ml versus 82×10^6/ml; $P = 0.54$), semen volume (3.1 ml versus 3.0 ml; $P = 0.26$) or total sperm counts (220×10^6 versus 250×10^6; $P = 0.18$) were found. The proportion of progressively motile spermatozoa also remained unchanged.

CONCLUSIONS: Between the years 2000 and 2010 we found no evidence of time-related deterioration of semen parameters among young Swedish men from the general population. This finding does not exclude that such a decrease may have taken place before year 2000. If the risk of testicular cancer is linked to the sperm counts, the increase in incidence of this malignancy should be levelling off in southern Sweden in the next 10–15 years.

Key words: sperm count / semen quality / time trend / general population / Sweden

Introduction

A time-related reduction in sperm counts in the Western world during 1940–1990 (Carlsen *et al.*, 1992) has been suggested and aetiologically linked to a concomitant deterioration of other indices of male reproductive function, including an increased risk of hypospadias, cryptorchidism and testicular germ cell cancer (TGCC) (Skakkebaek *et al.*, 2001). It has been suggested that this secular trend could be related to an increased exposure to chemicals with endocrine-disrupting potential or to lifestyle-related factors (Skakkebaek *et al.*, 2001). Whereas the increase in the incidence of TGCC has been verified by using reliable register data (Richiardi *et al.*, 2004), the quality of data for the other reproductive endpoints has been questioned (Olsen *et al.*, 1995; Fisch *et al.*, 1996, 2010; Saidi *et al.*, 1999; Merzenich *et al.*, 2010). The issue of a possible decline in sperm counts has attracted a lot of attention, from both the scientific community and laymen, possibly because it might have serious consequences for the fertility potential of current and future generations (Carlsen *et al.*, 1992). However, the available literature dealing with secular trends in semen parameters so far is based on analyses of data not specifically collected for the study of time trends. This approach implies a lot of methodological problems since confounding factors, for example interlaboratory variation in sperm concentration assessment, impact of abstinence time and ethnic differences, cannot be properly addressed. Therefore, the need for population-based prospective studies has been highlighted (Merzenich *et al.*, 2010).

In 2000–2001 we performed a study of semen quality among military conscripts in southern Sweden (Richthoff *et al.*, 2002). This cohort represented the general population of adolescent males.

To address the issue of secular trend in semen parameters, a new cohort was recruited in a similar manner in 2008–2010. All samples were analysed at the same laboratory. The idea of including these two cohorts was to investigate whether, during the past 10 years, there was a time-related trend in semen parameters among young men from the most southern part of Sweden.

Materials and Methods

Recruitment procedure

Cohort A: 2000–2001

In 2000–2001 ∼95% of all around 18-year-old Swedish men underwent medical health examination at the National Service Administration in Sweden (NSAS) concerning possible military service (Richthoff *et al.*, 2002). Only men with serious chronic diseases were excluded from the examination. All 2255 men living <60 km from the city of Malmö and who underwent the examination from May to December 2000 were asked to participate. Out of these, 305 accepted and joined the study, which gave a participation rate of 14%. To minimize the effect of any difference of ethnicity between the two cohorts, only the 224 men born and raised in Sweden with mothers born and raised in Sweden were included in the present study. Eight of these men were excluded due to lack of information regarding abstinence time, missing sperm concentration or classification difficulties concerning smoking, which left 216 remaining men. Among those, 200 men (93%) were examined in the year 2000 and 16 men (7%) were examined in 2001.

Table I Main background and examination characteristics of the cohort of men from 2000–2001 and 2008–2010.

Background characteristics	Cohort A: 2000–2001 (*n* = 216)	Cohort B: 2008–2010 (*n* = 295)
Recruitment time	May 2000 to December 2001	December 2008 to May 2010
Way of recruitment	Physical examination prior to military service	76% physical examination prior to military service 24% through advertisement in schools
BMI (kg/m^2)	22.6	23.1
Mean age [range] (years)	18.2 [18–21]	18.0 [17–20]
Cigarette smokers (%)	27	21
Treated for cryptorchidism (%)	2.3	2.0
Spontaneously descended cryptorchid testes (%)	3.8	2.4
Mean abstinence time (h) [SD]	87 [62]	60 [34]
Mean [SD] total testicular volume by orchidometer (ml)	37 [8.4]	43 [7.6]
Varicocele Grade 2 or 3 (%)	7.9	6.1
Fully virilized (%)	81	95

Cohort B: 2008–2010

In 2008–2010, due to savings in the military budget, only 25% of all Swedish men around 18 years old underwent medical health examination at NSAS. During the period from 1 December 2008 to 27 May 2010, all the 1681 men who underwent the examination and who lived <60 km from the city of Malmö and were born and raised in Sweden with mothers born and raised in Sweden were asked to participate. Out of these, 241 accepted and joined the study, giving a participation rate of 14%. To reach a number of ∼300 men in 18 months as in Cohort A, another sub-cohort of 73 men, 17–20 years old, fulfilling the above-mentioned criteria of residence and background were recruited through an advertisement in schools or as friends of participants. Of the total 314 subjects, 19 were excluded due to lack of information regarding abstinence time, missing sperm concentration or classification difficulties concerning smoking. Among the remaining 295 participants, three men (1.0%) were examined in December 2008, 133 men (45%) in 2009 and 159 men (54%) in 2010.

Both in 2000–2001 and in 2008–2010, the subjects were paid 500 SEK (∼55 Euro) for their participation. They signed an informed consent form and the study was approved by the ethical committee of Lund University.

The background characteristics of the two cohorts are given in Table I. The most recent cohort presented with slightly lower average abstinence time and higher body mass index (BMI) as compared with the cohort from 2000–2001.

Physical examination and questionnaire

In Cohort A, one physician examined ∼90% of the men and another physician examined the remaining 10% (Richthoff *et al.*, 2002). In Cohort B, two experienced physicians examined 94% of the men, whereas two other physicians examined the remaining 6.0%. The examination included assessment of weight, height and virilization, and careful genital examination (Table I).

All participants were asked to fill in a questionnaire prior to the examination. The same questionnaire was used in 2008–2010 as in the previous study in 2000–2001. The men were asked for information about factors that might influence their reproductive function such as smoking, history of cryptorchidism and other previous diseases.

Semen analysis

The men were asked to keep 48–72 h of abstinence but in each case actual abstinence time was recorded. The proportion of subjects with abstinence time <48 h was 17% in Cohort A versus 39% in Cohort B. For 48–72 h, the proportions were 39% versus 36% and for >72 h proportions were 44% versus 25%, respectively. All men delivered a semen sample by masturbation into a wide-mouthed plastic container in a room at the laboratory. The samples were weighed to obtain the semen volume in millilitres. Following liquefaction, they were analysed according to the World Health Organization guidelines from 1999 (World Health Organization, 1999) and the ESHRE manual on Basic Semen Analysis (ESHRE, 2002), including duplicate assessments with comparisons of concentration and motility. Sperm concentration was assessed by use of a haemocytometer with improved Neubauer ruling. Positive displacement pipettes were used for proper dilution of the ejaculate. Laboratory assistants performed the analyses of the ejaculates in the laboratory, which is a reference laboratory for ESHRE-NAFA quality control.

Statistical methods

For continuous semen variables, linear regression analyses were used for estimating mean differences with 95% confidence intervals (CIs) between the two cohorts (A versus B) with abstinence time (five categories: <48, 49–72, 73–96, 97–120 and >120 h), smoking status (smoking cigarettes or not) and BMI (as a continuous variable), included in the models as potential confounders. Analyses were performed including the total Cohort B and also for the sub-cohort of Cohort B presenting for health examination at NSAS. In the same way, the two different sub-cohorts of Cohort B were compared with each other. Finally, we also compared Cohort A and Cohort B after having excluded men with the shortest abstinence time (<48 h) as in the original 2000–2001 conscript study (Richthoff et al., 2002).

For dichotomized semen parameters, we used logistic regression models, giving odds ratios (ORs) as the effect estimates. The same potential confounders as mentioned above were included in the models. The following semen parameters were dichotomized: sperm concentration (cut-off limits: 20×10^6/ml and 40×10^6/ml, respectively [the former level corresponds to the WHO 1999 lower range of normal sperm concentration (World Health Organization, 1999) and the latter to the limit of fully normal fecundity (Bonde et al., 1998; van der Steeg et al., 2010)] and progressive sperm motility (cut-off limit: 50%).

Fisher's exact test was used when we compared the proportions of men in both cohorts having a history of surgical treatment for cryptorchidism after exclusion of subjects with missing data (six men from Cohort A and three from Cohort B). The same test was used for comparing the two cohorts with regard to proportions of men with a history of spontaneously descending cryptorchid testes, after excluding men not answering or not knowing (26 men from Cohort A and 24 from Cohort B).

SPSS version 17 and PASW version 18 were used for analyses.

Results

Semen volume, sperm number and motility

No statistically significant (all *P*-values ≥0.18) differences were observed between Cohort A and Cohort B regarding semen volume (mean difference: 0.15 ml lower in Cohort B; 95% CI: −0.11 to 0.41 ml), sperm concentration (mean difference: 3.7×10^6/ml higher in Cohort B than in cohort A; 95% CI: -8.0 to 15×10^6/ml) or total sperm counts (mean difference: 25×10^6 higher in Cohort B; 95% CI: -11 to 61×10^6) [Fig. 1 (though unadjusted) and Table II]. The proportion of progressively motile spermatozoa also did not differ between the two cohorts.

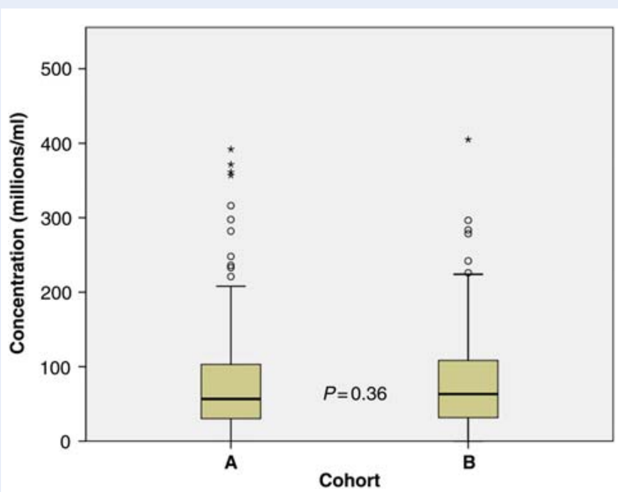

Figure 1 Box plot diagram of the unadjusted sperm concentrations in Cohort A and Cohort B. The diagram represents from bottom to top: minimum, first quartile, median, third quartile and maximum value that is not an outlier. Outliers are indicated as points and extreme outliers as stars. Outliers correspond to values between 1.5 interquartile ranges (IQRs) and 3 IQRs from the end of the box. Extreme outliers are defined as values >3 IQRs from the end of the box.

Analysing only men with an abstinence time of 48 h or more did not show any significant differences between Cohort A and Cohort B in semen volume (mean difference: 0.043 ml higher in Cohort A; 95% CI: −0.27 to 0.36 ml), sperm concentration (mean difference: 3.5×10^6/ml higher in Cohort B; 95% CI: -11 to 18×10^6/ml) or total sperm count (mean difference: 29×10^6 higher in Cohort B; 95% CI: -17 to 74×10^6).

None of the semen parameters in Cohort B differed between the sub-cohort recruited at NSAS and the sub-cohort recruited at schools or through already recruited friends (results not shown).

Comparing Cohort A with the sub-cohort of Cohort B consisting of only those recruited at NSAS gave similar results to those for the whole Cohort B (results not shown).

As compared with Cohort B, the proportions of men having a sperm concentration $>20 \times 10^6$/ml or $>40 \times 10^6$/ml did not statistically differ between the two cohorts (OR for Cohort A with Cohort B as reference: 1.0; 95% CI: 0.62–1.7 and 1.1; 95% CI: 0.77–1.7, respectively). The same was true for the proportion of men having progressive sperm motility at or above 50% [WHO 1999 lower limit (World Health Organization, 1999)] (OR: 1.1; 95% CI: 0.73–1.6).

Risk of genital pathologies

Five men (2.3%) in Cohort A and 6 men (2.0%) in Cohort B ($P = 1.0$) had a history of treatment of cryptorchidism. Spontaneously descending cryptorchid testes were reported by 8 men (3.8%) in Cohort A and 7 men (2.4%) in Cohort B ($P = 0.43$).

Discussion

The major finding of our study is lack of any statistically significant difference in seminal volume, sperm number and progressive motility when comparing adolescent men from the general Swedish population investigated in 2000–2001 and 2008–2010. These data, based on men from the general population and collected specifically with the aim of addressing the issue of secular trend in sperm parameters, indicate that no deterioration in major parameters of semen quality has taken place in southern Sweden during the past 8–10 years.

The major strength of the present study was use of standardized and similar recruitment procedures for collection of data from the two cohorts. This means that we only included men with very similar ages and from the same area. Standardized questionnaires for collecting information regarding potential confounders were used and sperm parameters were assessed in the same laboratory following WHO guidelines and having a continuous quality control. In line with the finding of unchanged semen parameters are the data showing a similar proportion of men with a history of cryptorchidism.

However, some potential weaknesses of the study still have to be taken into consideration. The participation rates were low in both

Table II Results of comparison in semen quality between 2000–2001 and 2008–2010.

Cohort	A: 2000–2001 (*n* = 216)			B: 2008–2010 (*n* = 295)			Mean difference of adjusted means B − A (95% CI)
	Crude mean [SD]	Adjusted mean[a] [SD]	Median [range]	Crude mean [SD]	Adjusted mean[a] [SD]	Median [range]	
Sperm concentration (10^6/ml)	73 [60]	78 [72]	53 [0.1–39]	71 [70]	82 [84]	56 [0.0–40]	3.7 (−8.0 to 15) $P = 0.54$
Semen volume (ml)	3.2 [1.3]	3.1 [1.6]	3.2 [0.3–7.6]	2.9 [1.5]	3.0 [1,9]	2.7 [0.4–14]	−0.15 (−0.41 to 0.11) $P = 0.26$
Total sperm count (10^6)	210 [190]	220 [221]	170 [0.5–1200]	210 [220]	250 [258]	150 [0.0–1700]	25 (−11 to 61) $P = 0.18$
Fraction of progressive sperm (%)	53 [17]	53 [19]	56 [0.0–81]	53 [17]	54 [22]	58 [0.0–86]	0.42 (−2.7 to 3.5) $P = 0.80$

SD, standard deviation; 95% CI, 95% confidence interval of difference between adjusted mean values for Cohort A and Cohort B.
[a]Adjusted for BMI, abstinence time and smoking status.

cohorts (∼14%) but, since adolescent men in general are not expected to have any knowledge or considerations regarding their reproductive capacity, selection bias based on fertility is unlikely. In a study similar to this with 16% of men delivering semen for analysis, the levels of the reproductive hormones FSH and Inhibin B were found to be the same in participants and non-participants (Andersen *et al.*, 2000). The fact that in 2008–2010 only 25% of young men went through medical examination prior to military service, compared with nearly 95% in 2000–2001, could be considered as a source of potential selection of the most fit. However, the selection was not based on reproductive health, and men with serious health problems, which might affect even their reproductive capacity, were also excluded from military service in the early 2000s. Furthermore, the fact that BMI was higher in the later cohort, similar to the general time trend in Sweden, argues against a selection bias related to fitness and rather indicates that the groups were representative for the general adolescent populations. This assumption is even supported by finding similar semen parameters in men coming for health examination prior to military service and those recruited through either schools or participating friends.

Analysing only one semen sample from each man has been claimed insufficient due to significant intra-individual variation. However, two recent studies have shown that one ejaculate is fairly representative for the semen quality of a subject (Stokes-Riner *et al.*, 2007; Rylander *et al.*, 2009).

The findings of this study are in agreement with those of an earlier survey from the same area in Sweden based on semen samples from 718 men in infertile couples investigated from 1985 to 1995 (Berling and Wolner-Hanssen, 1997). In the comparison also, no significant change in sperm concentration be seen. Other findings that may strengthen our results are those of no decline in fecundability from 1983 to 2002 (Scheike *et al.*, 2008) and in fertility from 1983 to 1999 (Akre *et al.*, 1999) in Swedish couples.

In conclusion, during the last 10 years in southern Sweden, no obvious changes in semen quality seem to have taken place among young men from the general population. This does not exclude that such a decrease may have occurred before year 2000. If the risk of testicular cancer is linked to sperm counts, since the mean age for this malignancy is between 30 and 35 years, the continuous increase in the incidence of male gonadal cancer should be levelling off in this region in the next 10–15 years.

Authors' roles

J.A. had full access to the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. He is guarantor. A.G., L.R. and A.R.H. were involved in the study design. J.A. and A.G. were responsible for the data collection. All authors contributed to the writing and revision of the manuscript and are able to take responsibility for its content. J.A. carried out the analyses with guidance from A.G. and L.R.

Acknowledgements

Thanks to Mania Winitsky, Cecilia Tingsmark, Jolita Ruckaite and all other laboratory staff members for analysing semen samples. We also wish to thank Pliktverket (NSAS), especially Erna Jeppson-Stridsberg and colleagues in Kristianstad for recruiting study subjects.

Funding

The study was supported by the Swedish Research Council (Grant No. 2007-2590); the Swedish Governmental Funding for Clinical Research, Skane county council's research and development foundation, MAS Funds. All had the role of general funding for the study except the Skane county foundation, funding only salary for research time.

Competing interests

All authors have completed the Unified Competing Interest form at (www.icmje.org/coi_disclosure.pdf) (available on request from the corresponding author) and declare that (i) they have no relationships with companies that might have an interest in the submitted work; (ii) their spouses, partners or children have no financial relationships that may be relevant to the submitted work and (iii) no authors have any non-financial interests that may be relevant to the submitted work.

Data sharing

Additional primary data are available on request.

References

Akre O, Cnattingius S, Bergstrom R, Kvist U, Trichopoulos D, Ekbom A. Human fertility does not decline: evidence from Sweden. *Fertil Steril* 1999;**71**:1066–1069.

Andersen AG, Jensen TK, Carlsen E, Jorgensen N, Andersson AM, Krarup T, Keiding N, Skakkebaek NE. High frequency of sub-optimal semen quality in an unselected population of young men. *Hum Reprod* 2000;**15**:366–372.

Berling S, Wolner-Hanssen P. No evidence of deteriorating semen quality among men in infertile relationships during the last decade: a study of males from Southern Sweden. *Hum Reprod* 1997;**12**:1002–1005.

Bonde JP, Ernst E, Jensen TK, Hjollund NH, Kolstad H, Henriksen TB, Scheike T, Giwercman A, Olsen J, Skakkebaek NE. Relation between semen quality and fertility: a population-based study of 430 first-pregnancy planners. *Lancet* 1998;**352**:1172–1177.

Carlsen E, Giwercman A, Keiding N, Skakkebaek NE. Evidence for decreasing quality of semen during past 50 years. *BMJ* 1992; **305**:609–613.

ESHRE. Manual on basic semen analysis 2002. *ESHRE Monogr* 2002; **2002**:1–24.

Fisch H, Goluboff ET, Olson JH, Feldshuh J, Broder SJ, Barad DH. Semen analyses in 1,283 men from the United States over a 25-year period: no decline in quality. *Fertil Steril* 1996;**65**:1009–1014.

Fisch H, Hyun G, Hensle TW. Rising hypospadias rates: disproving a myth. *J Pediatr Urol* 2010;**6**:37–39.

Merzenich H, Zeeb H, Blettner M. Decreasing sperm quality: a global problem? *BMC Public Health* 2010;**10**:24.

Olsen GW, Bodner KM, Ramlow JM, Ross CE, Lipshultz LI. Have sperm counts been reduced 50 percent in 50 years? A statistical model revisited. *Fertil Steril* 1995;**63**:887–893.

Richiardi L, Bellocco R, Adami HO, Torrang A, Barlow L, Hakulinen T, Rahu M, Stengrevics A, Storm H, Tretli S *et al.* Testicular cancer incidence in eight northern European countries: secular and recent trends. *Cancer Epidemiol Biomarkers Prev* 2004;**13**:2157–2166.

Richthoff J, Rylander L, Hagmar L, Malm J, Giwercman A. Higher sperm counts in Southern Sweden compared with Denmark. *Hum Reprod* 2002;**17**:2468–2473.

Rylander L, Wetterstrand B, Haugen TB, Malm G, Malm J, Bjorsvik C, Henrichsen T, Saether T, Giwercman A. Single semen analysis as a predictor of semen quality: clinical and epidemiological implications. *Asian J Androl* 2009;**11**:723–730.

Saidi JA, Chang DT, Goluboff ET, Bagiella E, Olsen G, Fisch H. Declining sperm counts in the United States? A critical review. *J Urol* 1999; **161**:460–462.

Scheike TH, Rylander L, Carstensen L, Keiding N, Jensen TK, Stromberg U, Joffe M, Akre O. Time trends in human fecundability in Sweden. *Epidemiology* 2008;**19**:191–196.

Skakkebaek NE, Rajpert-De Meyts E, Main KM. Testicular dysgenesis syndrome: an increasingly common developmental disorder with environmental aspects. *Hum Reprod* 2001;**16**:972–978.

Stokes-Riner A, Thurston SW, Brazil C, Guzick D, Liu F, Overstreet JW, Wang C, Sparks A, Redmon JB, Swan SH. One semen sample or 2? Insights from a study of fertile men. *J Androl* 2007;**28**:638–643.

van der Steeg JW, Steures P, Eijkemans MJ, Dik J, Habbema F, Hompes PG, Kremer JA, van der Leeuw-Harmsen L, Bossuyt PM, Repping S *et al.* Role of semen analysis in subfertile couples. *Fertil Steril* 2010.

World Health Organization. *WHO Laboratory Manual for the Examination of Human Semen and Sperm-Cervical Mucus Interaction*, 4th edn. Cambridge, UK; New York, NY: Published on behalf of the World Health Organization [by] Cambridge University Press, 1999.