Semen quality in welders before and after three weeks of non-exposure

Jens Peter Bonde

Abstract

In a cross sectional field study concerning the male reproductive system in metalworkers, the major findings were a moderate deterioration of semen quality in mild steel welders and less reliable changes in semen quality in low exposed stainless steel welders. In the present study, a longitudinal design was adopted to deal with methodological drawbacks inherent in the cross sectional approach. The study relies on the assumption that the effect of welding is causal and reversible. The semen quality of 19 mild steel welders, 18 stainless steel welders and 16 non-welding metalworkers, was examined before and three, five, and eight weeks after a three week break in exposure (summer vacation). No consistent improvement in any semen parameter in the follow up period relative to the prevaccation period was found in either mild steel or stainless steel welders. The results indicate either a non-causal nature of reported associations between welding exposure and poor semen quality, or that the effect of welding is non-reversible within the rather short non-exposure period.

In a cross sectional field study concerning the male reproductive system in metalworkers, the major findings were a moderate deterioration of several semen parameters and increased concentrations of follicle stimulating hormone in mild steel welders, and some less reliable changes of semen quality in low exposed stainless steel welders.¹ Because of the extensive and worldwide use of metal welding and the possible risk of infertility due to reduced semen quality, additional studies are needed to verify the suggested effects. Longitudinal designs may be preferable in order to overcome bias of results inherent in cross sectional sperm studies with low participation rates. Experience from follow up

studies of humans indicates that partial or complete recovery of spermatogenesis occurs within weeks to years after discontinuation of a spermatotoxic exposure unless severe damage to the germinal cells of the tubuli seminiferi has occurred.²⁻⁶ The half lives³ in humans of most toxic metals in welding fume particulates are short (range < 1 to 14 days).⁷ Assuming that welding is causally related to increased risk of reduced semen quality, and that the effects are reversible, a follow up study of semen quality in a subset of the cross sectional study population previously reported¹ was undertaken. The purpose was to investigate if any improvement of semen quality occurred in the first two months after three weeks of non-exposure (summer vacation).

Subjects and methods

SELECTION OF PARTICIPANTS AND SEMEN SAMPLING

As part of a cross sectional study¹ 53 of 81 workers employed at 1 July 1987 at three plants agreed to participate in a follow up study. The three plants produce mild steel constructions for industry, equipment in stainless steel for the food industry and pumps in stainless steel. Neither the study organisers nor the participants had any knowledge of the prevaccation semen quality at the time of planning the follow up. Table 1 presents the characteristics of exposure and participants. All participants in the follow up group delivered three semen samples at monthly intervals in the prevaccation period March to June 1987. Additional semen samples were collected three, five, and eight weeks after the last day of the summer vacation 1987. The semen samples were delivered by masturbation after preferably three days of abstinence. All samples were analysed within two hours of collection by the same experienced laboratory assistant in accordance with the World Health Organisation guidelines for examination of human semen.⁸ A detailed description of semen collection and examination has been given.¹

ANALYSIS

The analysis was designed to detect changes in semen parameters in the postvacation period relative to the prevaccation period. Two different analytical approaches were adopted with the purpose of addressing

Department of Occupational Medicine, Hospital of Aalborg, and Institute of Social Medicine, University of Aarhus, Denmark
J P Bonde

Table 1 Characteristics of the follow-up population

	Mild steel welders (n = 19)	Stainless steel welders (n = 18)	Referents (n = 16)
Welding method	MMA and/or MAG†	TIG†	
Welding fume exposure (mg/m ³ ; mean, (SD))	3.2 (1.0)	1.3 (0.8)	
Years of welding (mean (SD))	15.3 (8.8)	10.4 (7.9)	4.6 (5.3)*
Age (y); (mean (SD))	35.1 (10.0)	31.2 (9.0)	38.8 (7.3)
Smokers (%)	58	56	38
Alcoholic > 20 drinks a week (%)	11	33	13
History of urogenital disorder (%)	0	6	13
Spillage at ejaculation (% of samples)	11.3	24.0	12.1
Fever during previous three months (% of samples)	3.0	3.0	0
Leucocytospermia (% of samples)	5.7	14.0	6.6
Abstinence period (days; mean (SD))	3.7 (1.8)	4.4 (9.6)	3.5 (1.4)
Time from semen sample collection to analysis (hours; mean (SD))	2.4 (0.4)	2.3 (0.5)	2.4 (0.5)

*Most referents had former welding experience.

†MMA = manual metal arc; MAG = metal active gas; TIG = tungsten inert gas.

two different patterns of change in semen quality which could be expected in accordance with the broad hypothesis stated. Firstly, the change relative to the prevacation level of each of the three follow up times was analysed independently. This approach analysed the possibility of a temporary increase in semen quality at a particular point in time after the exposure free period, which would reflect a particular vulnerability of a specific stage in the development and maturation of the spermatozoa. An effect limited to a late stage would be reflected by an increase in semen quality in the first postvacation sample only. Conversely, an effect limited to an early stage would be detectable only in the last postvacation sample. The analyses were performed by application of a two sided paired test.⁹ Secondly, an analysis of postvacation changes relative to prevacation levels was performed. This approach considered the possibility that several stages of spermatogenesis are vulnerable to welding exposure. The analysis was performed by application of a general linear model⁹ in case the data suggested a monotonic trend. The independent variable was time, taking the values of nought, three, five, and eight weeks. Whether the individual trends were significantly different was tested first. If this was not the case, a test for trend for the whole group was performed with adjustments for the subjects' individual trends. A number of covariates were included in the regression models (history of fever, leucocytospermia, abstinence period, and the age of sample). In all analyses, the prevacation reference value of each subject was determined by calculating the arithmetic mean value of the parameters in the three samples in the prevacation period.

Results

In mild steel and stainless steel welders, no significant improvements in any of the semen

parameters were observed at either three, five, or eight weeks after vacation relative to prevacation levels (paired *t* test; table 2). Similarly, no consistent trends in improvement of semen quality in the follow-up period relative to the prevacation period were found (test for trend § table 2).

In the referents, a significant increase in sperm concentration and proportion of normally shaped sperm in the second and third samples was found, and the increase in proportion of normally shaped sperm cells was also highly significant.

The follow up sample of mild steel welders had a relatively high semen quality in the prevacation period compared to all mild steel welders. The follow up sample of referents, on the contrary, had rather low parameters of semen quality (table 2), although no significant differences were found. For this reason, an analysis for trend with the exclusion of prevacation values was undertaken. In welders, the only finding was a trend for increasing sperm concentration with time in mild steel welders (test for trend, *p*** table 2).

An analysis of the other semen parameters examined (sperm count, semen volume, linear penetration rate, degree of motility, and immature sperm forms) did not produce any consistent evidence supporting the hypothesis that the semen quality improves after a period of non-exposure.

Discussion

This study was carried out to evaluate the assumptions that welding exposure has a deleterious effect on spermatogenesis and that the effect is reversible with discontinuation of exposure. The first assumption originates from the results of a cross sectional study.¹ The second assumption is compatible with the biological nature of spermiogenesis¹⁰ and is supported by a large body of empirical evidence. Longitudinal studies of humans exposed to dibromochloropropane,² alkylating chemotherapeutic drugs,³

Table 2 Prevaccination levels of semen parameters and changes relative to prevaccination levels at three, five, and eight weeks after vacation

	Prevaccination level		Postvaccination change			<i>p</i> values§	<i>p</i> value**
	All mean (SE)†	Follow-up mean (SE)†	Three weeks mean (SE)‡	Five weeks mean (SE)‡	Eight weeks mean (SE)‡		
Mild steel welders:							
Abstinence period (days)	3.8 (0.3)	3.8 (0.3)	-0.15 (0.31)	-0.33 (0.32)	+0.41 (0.66)	—	—
Sperm concn (mill/ml)	61.7 (4.5)	64.0 (5.4)	-10.3 (5.1)	-3.5 (4.1)	+10.3 (9.8)	—	<0.05
Normal sperm forms (%)	61.0 (3.1)	67.3 (3.8)	+0.2 (2.3)	-0.2 (3.2)	+1.2 (3.2)	—	—
Motile sperm (%)	53.3 (2.0)	55.8 (2.5)	+2.6 (4.1)	+6.3 (3.5)	-0.3 (4.4)	—	—
Stainless steel welders:							
Abstinence period (days)	4.7 (1.0)	4.2 (2.9)	-1.1 (0.36)	-1.6 (0.87)	-1.4 (0.90)	—	—
Sperm concn (mill/ml)	58.4 (2.8)	59.5 (4.9)	-4.2 (5.8)	+1.7 (5.0)	-2.5 (5.8)	—	—
Normal sperm forms (%)	65.0 (2.6)	62.5 (4.0)	+1.7 (5.3)	+4.8 (4.7)	+3.7 (2.7)	NS	NS
Motile sperm (%)	51.0 (2.7)	50.4 (3.4)	+4.6 (5.4)	+1.1 (4.4)	-3.1 (5.7)	—	—
Referents:							
Abstinence period (days)	3.8 (0.2)	3.5 (0.9)	+0.05 (0.39)	+0.11 (0.38)	+0.18 (0.28)	NS	NS
Sperm concn (mill/ml)	58.6 (3.3)	52.0 (4.6)	+1.6 (6.7)	+9.1* (3.2)	+9.8* (3.6)	NS	NS
Normal sperm forms (%)	66.7 (2.4)	63.0 (3.0)	+4.2 (3.2)	+9.4* (3.9)	+10.8* (4.0)	<0.01	<0.05
Motile sperm (%)	57.7 (2.0)	54.0 (2.9)	-2.3 (3.0)	+0.4 (5.1)	+0.7 (5.8)	NS	NS

*p < 0.05, postvaccination change relative to prevaccination level, paired *t* test.

†Standard error of the group mean (unpaired analysis).

‡Standard error of the mean difference (paired analysis).

§Test for linear increase in semen parameters with time after vacation including prevaccination values. Subject adjusted analysis.

**Test for linear increase in semen parameters with time after vacation excluding prevaccination values. Subject adjusted analysis.

—Test not performed.

radiation,⁴ heat,^{5,6} and sulphalazine¹¹ indicate that recovery of spermatogenesis takes place after discontinuation of exposure unless azoospermia has been induced. The rate of recovery depends on duration of exposure and intensity. Partial or complete recovery after exposure to dibromochloropropane, chemotherapeutic drugs, and radiation takes place within 12–15 months. A study of lead exposure at moderate levels showed an increase in several semen parameters within a few months after reduction in exposure (S Viskum. Semen quality in lead exposed battery workers. Department of Occupational health, Hospital of Aalborg, Denmark (unpublished observations)). Recovery after heat occurs within weeks. Hence, it is not unlikely that some recovery after minor toxic effects associated with welding could take place after a relatively short period.

The major finding of the present study was that no significant improvement relative to the prevaccination level of any semen parameter in welders took place during the follow up. The estimates of postvaccination changes in semen quality were sufficiently accurate relative to the changes expected according to the magnitude of effects detected in the cross-sectional study. For all relevant semen parameters, the upper 95% confidence limits of the mean differences representing the changes during follow up were less than the difference between exposed and non-exposed subjects in the cross sectional study. This implies that the study had sufficient statistical power and a false negative result due to random variation is unlikely.

Surprisingly, the referents had a significant time dependent increase in sperm concentration and proportion of normal sperm forms during the follow up. This could not be explained by changes in time of sexual abstinence, urogenital infection, or fever in the preceding three months. The referents were employed at three different plants but the effects observed did not correlate to a specific plant, a specific exposure, or job category. Some authors have described a circannual rhythm in human semen,¹² but according to this a decrease and not an increase should be expected in early autumn compared with winter or spring.

The follow up population was selected independently of quality of prevaccination semen. For this reason the phenomenon of "regression to the mean"¹³ was not expected to bias the results. Nevertheless, the prevaccination levels of several semen parameters in the follow up sample of mild steel welders were relatively high compared to the whole group, whereas the sample of referents had rather low prevaccination levels (table 2). In mild steel welders an obvious trend of improvement with time in postvaccination sperm concentration was observed (*p* < 0.05, table 5). It might be hypothesised that the initial fall relative to the prevaccination level is due to a "regression to the mean" effect. This interpretation is, however, speculative.

The pronounced difference in semen quality among welders and referents during the follow up might alternatively be interpreted to be the result of a "vacation effect" improving the semen quality

among non-exposed subjects, but not among welders because of a lasting suppression of spermatogenesis. Exactly the opposite pattern was to be expected, however, according to the original hypothesis and, furthermore, no evidence has been reported suggesting a "vacation effect" on semen quality.

In summary, no consistent evidence was found to support the hypothesis that semen quality in welders improves after a three week break in exposure. The results indicate either a non-causal nature of reported associations between exposure to welding and poor semen quality, or that the effect of welding is non-reversible within the rather short non-exposure period. Further studies are needed to differentiate between these two explanations.

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