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Sperm Biology

Relationship between self-reported residential indoor remodeling and semen quality: a case-control study

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The present study examined the association between residential indoor remodeling and poor semen quality. Sperm donors aged 18–45 years old were recruited in Shanghai, China. Semen specimens were collected and analyzed. An in-person interview was conducted to obtain information on the history of indoor remodeling and potential confounders. A total of 70 participants with abnormal semen quality (case group) and 68 controls were examined. A total of 20 subjects reported indoor remodeling in the recent 24 months, and among them 17 subjects reported indoor remodeling in the recent 12 months. Compared with participants with no history of indoor remodeling, participants with a history of indoor remodeling in the recent 24 months were more than three times as likely to have poor sperm quality (adjusted odds ratio = 3.8, 95% confidence interval: 1.3–12.0) after controlling for potential confounders. The association was strengthened when the analysis was restricted to those who had indoor remodeling in the recent 12 months. Our findings provide preliminary evidence that indoor remodeling has an adverse effect on semen quality.

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INTRODUCTION

Public interest in indoor air pollution has been increasing in the last few decades.^{1,2} A growing body of scientific evidence shows that indoor air pollution has a significant impact on health because people generally spend the majority of their time indoors, and thus, such pollution is an important public health issue.³ Many diseases have been reported to be correlated with indoor air pollution, such as irritation phenomena, allergic sensitization, acute and chronic respiratory disorders, and lung function impairment.²

Most studies on indoor air pollution have focused on coal and biomass fuels;⁴ however, indoor air quality may be affected by indoor remodeling as well. Remodeling materials, including paint, adhesives, and finishes, may emit chemicals such as carbonyl compounds (formaldehyde, aldehyde, acetone, i-pentanal, butyraldehyde, etc.), benzene, toluene, xylene, ammonia, and other volatile organic compounds.^{5–7} Although, indoor remodeling is supposed to be safe when good-quality remodeling materials are used, evidence exists that indoor remodeling is associated with self-reported optical, nasal, and gular symptoms, which were collectively named as sick building syndrome.^{8–10} More importantly, some harmful chemicals have been detected in homes up to 22 months after the remodeling is finished,^{9,11} which makes this problem of great public health significance.

Semen quality is one aspect of health that might be affected by indoor remodeling; however, few studies examining the effects of indoor remodeling on health have focused on it. Semen quality may be more vulnerable than other health endpoints to the effects of chemicals

and life-style-factors.¹² There is evidence that chemicals related to remodeling material may have harmful effects on semen quality: first, formaldehyde, a chemical widely contained in remodeling-related materials, building materials and household products, has been shown to induce histopathological and morphometric changes in testes (where sperm is produced) in rats.¹³ Second, an occupational epidemiological study found that benzene, another chemical, which may be present in paint and was found to be in higher concentrations in indoor than outdoor air,^{6,14} causes damage to the sperm DNA of workers exposed to it.¹⁵ Semen quality has also been shown to be associated with other remodeling-related chemicals, including acetone, toluene, and xylene.^{16,17} In China, exposure to indoor air of the newly decorated apartment has been found to induce heritable DNA mutations in mice.¹⁸ Since most remodeled houses have more than one source of indoor air pollution, there can be a cumulative effect of several chemicals on health endpoints like semen quality.

Against this background, the present study conducted an exploratory analysis on the association between residential indoor remodeling and semen quality in a population-based case-control study.

MATERIALS AND METHODS

Study population

The potential eligible participants of this study were sperm donors from the Shanghai Sperm Bank in 2007. Those who were 18–45 years old and residing in the Shanghai metropolitan area at the time of recruitment were eligible for the present study and invited to participate. All participants

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were asked to provide two semen specimens for analysis with the interval between two samples ranging from 7 to 21 days. All participants were required to abstain from sex for at least 2 days, but not exceeding 7 days, before semen collection. Semen specimens were analyzed using computer-assisted semen analysis (CASA; ZKPACS-E Analyzer) to obtain data on sperm motility and count. Sperm morphology was determined manually by the same trained technician who performed CASA. Collection and examination of semen samples strictly followed the World Health Organization (WHO) standards and requirements.

Eligible participants were those for whom both semen specimens met at least one of the following WHO criteria (1999) for poor semen quality:

1. Sperm motility: below 50% showing forward movement within 60 min of ejaculation and below 25% showing rapid forward movement in a straight line;
2. Sperm morphology: <15% normal sperm;
3. Sperm concentration: $<20 \times 10^6 \text{ ml}^{-1}$

Eligible controls were donors for whom both specimens did not meet any of the above criteria.

Subjects with a known cause of poor semen quality were ineligible for the study, such as those with occupations that involved exposure to high temperature or organic solvents, benzene, pesticides, insecticides, and heavy metals. All those who agreed to participate to the study gave written consent.

In-person interview and investigation of indoor remodeling

Once the subjects agreed to participate in the study, a questionnaire interview was conducted to collect information on demographic characteristic and potential confounders such as smoking status, alcohol consumption, medical history, and reproductive history.

Subjects were regarded as having a history of residential indoor remodeling if the following conditions were met: (1) They had had their residence remodeled in the recent 24 months, with at least two of the following items included: wall (with paint or wallpaper), floor (with ceramic tiles or wood), and furniture (newly bought or repainted); (2) The average time spent in the remodeled residence was 8 h or more per day; (3) They did not have significant life-style changes during the previous 3 months, such as taking vacations or changing residence. A supplemental questionnaire was administered to obtain detailed information about remodeling, such as the interval between remodeling and semen collection, the material used in the remodeling, and whether new furniture was used.

Data analysis

Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using logistic regression to examine the risk of poor semen quality in relation to the history of residential indoor remodeling. Covariates were included in the logistic model to calculate adjusted ORs (aORs) if they lead to a change of more than 10% on the association between indoor remodeling and poor semen quality. Through this strategy, only body mass index (BMI) was adjusted for.

Participants who reported indoor remodeling were divided into two subgroups according to the interval between remodeling and semen collection (>12 months and ≤ 12 months). Then, an analysis similar to the above was performed. However, it was not possible to calculate ORs for the > 12 -month group due to the small sample size. All statistical tests were two-tailed, with a significance level of 0.05.

RESULTS

Among the 127 invited cases and 95 invited controls, 70 and 68 respectively agreed to participate in the study and reported their remodeling history. None of the participants reported having been

exposed to hazardous substances listed in the ineligible criteria. Among the participating cases, 73% ($n = 51$) had abnormal sperm motility alone, 13% ($n = 9$) had abnormal sperm motility and morphology, and the remaining 14% ($n = 10$) had abnormal sperm morphology alone. None had abnormal sperm concentration.

Most of the participants were undergraduate students, residing in the city, and unmarried, a distribution similar to that of sperm donors in China in general. Only about 10% reported consumption of tobacco or alcohol. The case and control groups had similar mean ages and BMI, as well as distributions of family income levels (Table 1).

Detailed analysis of indoor remodeling showed that among those who had indoor remodeling, 41% of the participants had their school dormitory remodeled, and the rest had their parents' or their own house remodeled. Among those who had walls remodeled, most (82%) used plaster and whitewash, and the rest used oil-based paint. Among those who had the floor remodeled, ceramic tiles were used by 37%, and the rest used wood. Further, 59% of the participants who had indoor remodeling had bought new furniture, and the rest had their old furniture repainted (data not shown).

Of the 70 cases identified to have poor semen quality in this study, 15 reported a history of remodeling. In contrast, only 5 of the 68 controls had a history of remodeling. Participants with a history of indoor remodeling in the recent 24 months were 3.8 times as likely to have poor semen quality than participants with no such history (95% CI: 1.3–12.0), after BMI was controlled for. Those who had their residence remodeled in the recent 12 months showed a higher risk of poor semen quality (OR = 5.9; 95% CI: 2.3–25.1) (Table 2). Similar results were obtained when analyses were restricted to participants with abnormal motility, the most common abnormality in the cases: aORs were 4.4 (1.4–14.7) for those who had experienced remodeling in the recent 24 months and 8.2 (1.9–35.2) for those who had experienced remodeling in the recent 12 months (data not shown).

Table 1: Characteristics of subjects in the case and control groups

	Case (%)	Control (%)
Education ^a		
College, University	55 (78.6)	48 (71.6)
Graduate	15 (21.4)	19 (28.4)
Residence		
Urban	66 (94.3)	62 (91.2)
Rural	4 (5.7)	6 (8.8)
Marital status		
Unmarried	62 (88.6)	64 (94.1)
Married or cohabitating	8 (11.4)	4 (5.9)
Family income ^a (RMB per person)		
<10 000	29 (41.4)	31 (46.9)
10 000–19 000	20 (28.6)	18 (27.3)
≥ 20 000	21 (30.0)	17 (25.8)
Smoking		
Yes	7 (10.0)	10 (14.7)
No	63 (90.0)	58 (85.3)
Alcohol consumption		
Yes	7 (10.0)	5 (7.3)
No	63 (90.0)	63 (92.7)
Age (mean, year)	23.9 (s.d.=3.8)	23.4 (s.d.=3.9)
BMI (mean, kg m^{-2})	22.2 (s.d.=2.0)	22.0 (s.d.=2.1)

^aAmong subjects in the control group, one subject did not report education level and two subjects did not report family income. s.d.: standard deviation; BMI: body mass index; RMB: Renminbi

Table 2: Relationship between residential indoor remodeling in the recent 24 months and poor sperm quality

	Case (%)	Control (%)	OR	95% CI	aOR ^b	95% CI
Remodeling history ^a						
No	53	62	1			
Yes	15	5	3.5	1.2-10.3	3.8	1.3-12.0
Interval between remodeling and semen collection						
>12 months	1	2	-	-	-	-
≤12 months	14	3	5.5	1.5-20.0	5.9	2.3-25.1

^aOne subject in the control group and two in the case group did not report remodeling history; ^bAdjusted for BMI. BMI: body mass index; CI: confidence interval; OR: odds ratio

DISCUSSION

In the present study, a history of indoor remodeling in the recent 24 months was associated with an increased risk of poor semen quality. We performed a subgroup analysis according to the interval between remodeling and semen collection, with an assumption that the shorter the interval, the higher the dosage of harmful chemicals that subjects might be exposed to during the period of spermatogenesis (up to the previous 3 months) relevant to semen quality at the time of the study.^{19,20} The results supported the association between indoor remodeling and poor semen quality, with those who had had their residence remodeled in the recent 12 months having a higher risk of poor semen quality.

A study conducted in mice showed that the exposure to indoor air of the newly decorated apartment induced heritable DNA mutations.¹⁸ In contrast, a study on 10 subjects with a history of unexplained male infertility showed that the purification of indoor air did not produce improvements in either semen parameters or reproductive hormones.²¹ However, the reliability of that study's conclusion is questionable owing to its small sample size of 10 subjects and the nature of its study population.

Of the several chemicals used in indoor remodeling, formaldehyde and benzene have been more frequently studied owing to their high potential of exposure.^{6,7,22} Both of these, as well as some other remodeling-related chemicals like toluene and xylene, have been reported to have reproductive toxicity, including sperm DNA damage.^{13,15-17} In addition, exposure to organophosphate flame retardants, chemicals widely used in furnitures, textiles, electronic and insulation, have also been reported to be associated with semen quality.^{23,24} A possible explanation of our study results was that the increased risk of poor semen quality in people with a history of indoor remodeling was due to the cumulative effects of chemicals such as those above. However, individuals' exposure to chemicals following indoor remodeling, like formaldehyde exposure from new furniture, may vary considerably, depending on the amount and concentration of chemicals, air changes, and the duration of exposure, which may lead to non-differential misclassification to the observed association.

The present study had several strengths. First, unlike clinic-based studies, which are subject to self-selection bias, all the participants were recruited from sperm donors, and most of them were undergraduate students. Thus, the study population was relatively homogeneous in terms of social and demographic characteristic, and this reduces the impact of potential participation bias. Second, all the participants were unaware of the study purpose and their case-control status at the time of recruitment and interview; this further reduces the likelihood of information bias. However, the small sample size was a big limitation of the present study, which lowered the accuracy of the estimation of OR, and the small number in the exposure group

limited our ability to perform further subgroup analysis. Another important limitation is the indirect method of measuring exposure. We used "indoor remodeling history" as a proxy of exposure; individual internal doses may vary widely due to the great diversity in the putative materials of interest and in exposure duration. For the same reason, we were unable to rule out the possibility that outcomes may be explained by demographic or life-style-factors that accompanied remodeling, instead of the chemicals emitted.

Nevertheless, to our knowledge, the present study provides the first epidemiological evidence of an association between indoor remodeling and poor semen quality. Because indoor remodeling is such a ubiquitous opportunity for exposure to chemicals that may affect semen quality, even small additional risks may have important public health implications. Further research is needed to corroborate the present findings regarding the effects of indoor remodeling on semen quality.

AUTHOR CONTRIBUTIONS

MHM was in charge of the data analysis and manuscript writing; WY and DKL contributed to the study design and manuscript writing; ZL has been involved in the study design and field work organization; BY, HL, ELZ and HWD participated in the data collection..

COMPETING INTERESTS

The authors declare that they have no competing interests.

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