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The occupations at increased risk of decreased semen quality in Eastern China: an observational study of 12,301 semen donors

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Abbreviations: CI: confidence interval; IT: information technology
Article category: occupational epidemiology

Novelty and Impact: This study was conducted in a large sample of semen donors in Eastern China. The major novelty of this study was that we found the association of different professions with deleterious semen quality for the first time. The workers in the finance or insurance industry and unemployed men had elevated risks for semen quality. The soldiers and police had the highest semen volume but the lowest sperm motility. This study revealed that sedentary work, unemployed status, and intensive sports might contributed to the changes in the semen parameters. Our findings added valuable information on the effects of adverse workstyles on semen quality in China. Hence, our study was of high importance in public health and human fertility.

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Abstract

Objectives

This study aims to examine the association of modifiable factors to semen quality in semen donors in Eastern China.

Methods

We recruited 12,301 semen donors from 2006 to 2020 as a studying population. A self-designed questionnaire was applied for collecting the lifestyle and workstyle information. Semen samples were analyzed according to the World Health Organization guidance. A crude and adjusted linear regression model was used to analyze the association between occupational factors and semen quality.

Results

College students accounted for 38.3% of all semen donors. The majority (82.9%) of semen donors were between 18 and 30 years. The soldiers and police had the highest semen volume (the median value = 3.8 ml), however, they had the lowest semen motility (53.6%). The workers in the finance or insurance had an elevated risk of low semen volume, sperm density, and total sperm count (*OR* = 1.43, 1.57, and 1.98, respectively). The unemployed men had a high risk of low sperm density and low total sperm count (*OR* = 1.84, and 1.58, respectively). Workers in the IT industry had a deleterious effect on the progressive motility of sperm (*OR* = 1.27, 95%CI = 1.03-1.57).

Conclusion

Our study indicated that sedentary workstyle and intensive sports in certain professions had deleterious effects on semen quality. We report evidence of becoming unemployed on the damage of semen quality. Hence, we advocate a healthy work style to improve the semen quality in China.

Strengths and Limitations of this study

- This was the first study in China to assess the association between occupational factors and semen quality with a large sample size of 12,301 semen donors.
- We identified that certain professions had lower semen quality in China.
- We did not exhaust all the measurement methods to assess semen quality.

Introductions

Male infertility affected approximately 7% of the male population worldwide [1]. An international study estimated that 72.4 million people of reproductive age were infertile [2]. Many causes could result in male infertility, including male diseases [3], genetic, or lifestyle factors [4]. Semen quality is the cornerstone of male infertility studies. A previous report [5] suggested that the semen quality could serve as a useful predictor of male fertility. Previous studies have focused on the semen quality among semen donors [6], young men [7], male partners in infertile couples [8], and fertile men [9]. However, the semen quality has declined in several developed and developing countries in the past years [10]. A systematic review [11] reported that semen counts decreased by 50%-60% between 1973 and 2011, meanwhile, male infertility has increased in these years. The results of the Global Burden of Disease Survey showed that the age-standardized prevalence of infertility increased by 0.291% each year in men and by 0.37% in women [11]. However, the reasons for the decline of semen quality over the past decades are still not resolved worldwide.

The current knowledge about the factors associated with semen quality is often contradictory. Some data suggest that the risk factors for poor semen quality include excessive alcohol consumption, cigarette smoking, the wearing of tight-fitting underwear, being fat, and the use of recreational drugs [12]. However, the factors for poor semen quality vary between different populations and regions [13]—eg., cigarette smoking has an overall detrimental effect on semen quality [14], while another study found that smoking was not associated with semen motility [15]. Even for some well-recognized factors, there are still some controversies about the impact degree of factors with different intensities and frequencies. Most studies suggested that physical activity was an important risk factor for sperm count and concentration in the young men of the white population [16]. However, a meta-analysis showed that elite physical activity hurts semen quality [17]. Hence, researchers are not sure that whether these findings of risk factors or preventive measures can be applied worldwide and in the local population.

Occupational hazards are potential risk factors that might influence semen quality. A previous study [18] reported that occupational exposure to polycyclic aromatic hydrocarbons was associated with decreased sperm DNA integrity among the coke oven workers. Physical or chemical hazards in the workplace may be the main cause of male infertility [19]. Some data suggested that high exposure level of formaldehyde among autopsy service workers had an adverse effect on abnormal sperm progressive motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) and abnormal total sperm motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) [20]. A previous study [21] indicated a negative relationship between pesticide exposure or radiation and reduction of sperm motility and concentration. Occupational exposure to heat was also negatively associated with semen quality [22].

The plausible mechanism for the association between occupational exposure and semen quality has been proposed from some recent studies. A study in Mexico [23] revealed that exposure to polycyclic aromatic hydrocarbons could lead to DNA damage, and then was negatively associated with semen quality. A recent study [24] found a positive association between 5hmC of the sperm ACHE gene and occupational exposure to bisphenol A, indicating the adverse impact of occupational hazards on the human semen quality. However, the association between occupations

and semen quality was not well clarified.

Hence, in order to clarify the occupational risk factors for decreased semen quality, we carried out an observational study to examine the association of occupational factors to semen quality in semen donors in eastern China.

Methods

Study design

We recruited volunteers for semen donation as a studying population from 2006 to 2020. The donors were aged over 18 years old across Zhejiang Province in eastern China. Donors were included if they had an education level of junior college or above. Donors were excluded if they had an infectious disease, or if they had sexual abstinence for less than 3 days, or they had a fever. Initially, we included 14,636 semen donors. Then we deleted 2,335 subjects without the data of laboratory examination data. Finally, 12,301 semen donors were included in the study.

Questionnaire surveillance

Once the volunteer was recruited, he was asked to complete a questionnaire. The questionnaire included factors such as alcohol consumption, use of tobacco, the period of abstinence since last ejaculation, and the current occupation. Alcohol consumption was defined as alcohol use $\geq$ 1 time per week in the past year. Use of tobacco was defined as current tobacco smoking at least once per month in the past year. The current occupation was self-reported by the semen donors.

Health examination

Height and weight were measured for each donor to calculate body mass index (BMI). According to the guidelines of the World Health Organization (WHO), BMI was calculated, and the donors were categorized as normal (18.5-24.9 kg/m^2) and overweight (25-29.9 kg/m^2) or obesity (≥30 kg/m^2). The systolic and diastolic blood pressure were examined with three measurements. Hypertension was defined for systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg.

Chromosome examination

The peripheral blood lymphocytes were isolated by chromosome examination and cultured in RPMI 1640 medium for 72 h. The cells were routinely collected for G-banding. Karyotype analysis was performed according to the international nomenclature of human cytogenetics (ISCN). Chromosome normality was defined as 23 pairs of normal chromosome according to the standard of WHO, while the chromosome normality was defined as abnormalities in chromosome numbers or structures.

Semen sample analysis

The participants were asked to provide a semen sample in a private room after 3-6 days of sexual abstinence. The semen sample was collected with a plastic container, and evaluated according to World Health Organization guidance [25]. The semen samples were liquefied in an incubator (37℃) for 30 min, and then the motility and concentration of semen samples were examined in 60

minutes after semen donation. The semen volume was measured using the balance weighing method. The semen concentration was calculated using a hemocytometer on a single dilution. The progressive motility of sperm was analyzed by the computer-assisted semen analysis.

Statistical analyses

Semen quality parameters were shown as median (25% quantile — 75% quantile). Categorical variables were shown as frequency and percentage. Kruskal-Wallis H test was used to compare the difference in semen quality between different professions. And if there was any significant difference between them, the Nemenyi test was used for the post-hoc comparison. Factors that may affect the semen quality were selected as independent variables, and a binary logistic regression model using the entering method was used to estimate the influencing factors of each semen quality parameter. The regression models were showed as the crude model and adjusted model. The semen parameters were classified as qualified/unqualified according to the WHO manuals, and these new binary variables were set as the dependent variables in these models. The risk of decreased semen quality in each occupation was calculated compared with the college students. The partial regression coefficient of each adjusted model was adjusted for age, education level, marriage status, and childbearing history. A *P*-value that was equal or less than 0.05 was considered 'statistically significant'. All statistical analyses were performed using R version 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria).

Ethnic consideration

The current study was approved by the medical ethics committee of Zhejiang maternal, child and reproductive health center (Ref. No. 2019-002).

Results

Characteristics of semen donors

The majority (81.3%) of semen donors were between 18 and 30 years old, whereas only 1.9% were above 40 years old (Supplementary Table 1). The donors were mainly from universities, with 51% from junior college and 11.1% from undergraduate or higher. In total, 81.6% of the semen donors were not married, and 18.1% of them were married. Meanwhile, 87.1% of them did not have any children. Smoking or excessive drinking habit was rarely reported among the studying population. Overweight or fat was diagnosed in 3,901 semen donors, and ten subjects had hypertension. Only two semen donors had a history of testicular surgery. Additionally, college students accounted for 38.3% of all semen donors. The period of abstinence since the last ejaculation was 4.5(4-5.5) d.

Semen quality was decreased in certain professions

The percentage of chromosome abnormality was 0.8% among 5,510 semen donors with available data. In a total word, the semen quality varied between different professions (Figure 1). There was a significant difference in the semen volume between semen donors with different professions (χ^2 = 83.45, $P < 0.001$; Figure 1-A). The soldiers and police had the highest semen volume (the median value = 3.8 ml). The workers in the architectural engineering industry had significantly higher semen volume (the median value = 3.6 ml) than the college students (the median value = 3.3 ml; $P = 0.004$). Meanwhile, the semen donors in the service industry had a higher semen volume (the median value = 3.7 ml), compared with the college students ($P = 0.01$). Additionally, a significant

difference was found in the sperm concentration between donors with different professions (χ^2 = 66.06, P < 0.001; Figure 1-B). The businessmen and the subjects in the Information Technology (IT) industry had a lower sperm concentration than the college students (P < 0.001, and P = 0.04, respectively). The soldiers and police had the lowest sperm concentration (the median value = 53.6%). Meanwhile, there was a significant difference in the total sperm count between different professions (χ^2 = 52.42, P < 0.001; Figure 1-C). The total sperm count of the businessman (the median value = 213×10^6/ml) was significantly lower than that of the college students (the median value = 226×10^6/ml). Finally, the progressive motility of sperm changed much in different professions (χ^2 =97.61, P < 0.001; Figure 1-D). Workers in the IT industry and commercial service had higher progressive motility of sperm (the median value = 47%) than the college students (the median value = 49%; P < 0.001).

The risk of the decrease of semen volume was found among the subjects in the finance or insurance

The percentage of the sperm volume abnormality was 4%. The semen donors in the finance or insurance had a significant risk for the decrease of semen volume in the crude model (*OR* = 1.56, P = 0.05; Figure 2), and they had a marginal significant risk for reduced semen volume in the adjusted model (*OR* = 1.43, P = 0.08).

Some professions had higher risks of decreased sperm density

Of all the semen donors, 3.3% had a decrease in sperm density. In the crude model, the reduced sperm density was moderately associated with the occupation of finance or insurance (*OR* = 1.62, P = 0.05 in the crude model, and OR = 1.57, P = 0.08 in the adjusted model; Figure 3). The unemployed men had a significantly elevated risk of deceased sperm density (*OR* = 1.92, P = 0.002). Furthermore, this risk for unemployed men was slightly elevated after adjusting for the age, education level, marriage status, and childbearing history (*OR* = 1.84, 95%*CI* = 1.18-2.77). Additionally, the workers in the entertainment and sports industry had an elevated risk of low sperm density compared with the college students (*OR* = 1.86, P = 0.04).

Workers in the finance or insurance and unemployed men had a high risk of the reduction of the total sperm count

There were 440 semen donors whose total sperm count was less than the WHO recommended value of 39×10^6/ml. The abnormality of the total sperm count was 3.6%. Working in finance or insurance had an elevated risk for the total sperm count in the adjusted model (*OR* = 1.98, 95%CI = 1.24-3.03; Figure 4). Meanwhile, the association between unemployed men and the decrease of the total sperm count was significant (*OR* = 1.82, 95%CI = 1.18-2.70 in the crude model, and *OR* = 1.58, 95%CI = 1.02-2.37 in the adjusted model).

Working in the IT industry was associated with the elevated risk for the reduction of progressive motility of sperm

The reduction of progressive motility of sperm was found among 11.6% of all semen donors. The workers in the IT industry had a moderately elevated risk for the reduction of progressive motility of sperm in the adjusted model (*OR* = 1.3, 95%CI = 1.06-1.6; Figure 5). After we adjusted for the confounding factors, the risk remained significant, but the odds ratio was slightly lower down (*OR*

= 1.27, 95%CI = 1.03-1.57).

Discussion

In the current study of 12,301 semen donors, we identified that certain professions had lower semen quality in China. Working in the finance or insurance industry was associated with the decreased semen volume, sperm density and total sperm count. Workers in the IT industry had an elevated risk for the reduction of the progressive motility of sperm. Unemployed men had a higher risk for the reduction of sperm density, and total sperm count. Furthermore, working in entertainment and sports was associated with an elevated risk for sperm density, while working in the transportation industry was associated with a high risk for the total sperm count. Most of these associations were robust in regression models, and the results were not modified by age, education level, marriage status, and childbearing history. To the best of our knowledge, this was the first study in China to quantitatively assess the association between occupational factors and semen quality with large sample size. Hence, our results provided new insights into the semen quality in Eastern China.

We found that the soldiers and police had the highest semen volume. Surprisingly, their progressive motility of sperm was the lowest. The soldiers and police were always considered as “strong” men, however, their semen quality was not as good as we expected from the results of our research. A previous study [26] in China supported our findings that 62.5% of the soldiers had at least one semen parameter below critical values of WHO recommendations in 2010. The etiology of low motility might be due to surgery-related diseases, Sertoli-cell only syndrome, and some idiopathic causes [27]. Besides, the high intensity of job stress [28] might play an important role in the decrease of semen motility in the soldiers and police. However, due to the limited sample in the population of soldiers and police, our obtained results should be confirmed in longitudinal studies.

We found that workers in the IT industry had the risk of the reduction of the sperm progressive motility. It was well known that most of the workers in the IT industry were programmers, and they had a long-time sedentary work style. As we have known, germ cells were quite sensitive to localized warming of the testes. So the underlying reason for this elevated risk might be due to the localized high temperature in the testes of IT workers. A previous study in Poland [29] documented that heat stress after sedentary work could double the risk of sperm DNA damage. The possible mechanism might be that long-time sedentary workstyle in the IT industry increased testicular temperature, and triggered reactive oxygen species (ROS) and DNA damage [30], leading to the destruction of germ cells by apoptosis. On the other hand, heat stress could induce altered chromatin condensation during spermatogenesis [31]. An experimental study [32] found that spermatozoa at post-meiotic stages of development were more sensitive to heat stress, and suggested that DNA methylation reprogramming could play an important role in the process. Conclusively, we conferred that heat exposure might be a crucial factor for deleterious semen quality among workers in the IT industry. In the same way, our study demonstrated that working in the financial industry was related to sedentary work. Furthermore, either working in the IT industry or the financial industry radiation needed the prolonged video operation. The association

between video operation and semen quality has not been well studied in previous studies. Controversially, more physical activity and less TV watching were significantly associated with improved sperm count and sperm concentration. Furthermore, whether the sedentary job and video manipulation had a joint harmful effect on semen quality needs to be confirmed by further research.

Importantly, we found that working in finance or insurance was significantly linked with decreased semen quality, especially with the semen volume, sperm density, and sprem count. The reason for why working in finance or insurance could affect semen quality was not fully understood. There were some plausible reasons. First, the workers in finance or insurance, for example, the bank employees, always spend the majority of their working time sitting in front of the computer and engaged in sedentary work [33]. Their sedentary working characteristics increased the temperature of their testis, just like the fact in the workers of IT industry. Hence, our data supported the association between sedentary working behavior in finance or insurance and decreased semen quality. Therefore, more strategies should be applied to make the workers shift from a sedentary workstyle to a more active workstyle [34]. Secondly, the current data suggested that the job of finance or insurance involved high levels of job stress [35]. A previous study in India [36] found that 75.5% of the bank employees had a high and very high level of job stress. A study in China [37] believed that the high job stress in the financial workers was related to high concentration of attention during working. Hence, the association between working in finance or insurance and decreased semen quality might also be explained by the synergistic effect of local temperature in testis and high job stress. More effect should be provided to improve the work initiative, to shorten the working hours per day, and improve the social support for workers in the finance or insurance industry [38]. However, these results needed to be proved by better study design, and be confirmed in further studies.

Our study found that unemployment was associated with a decrease of sperm density and total sperm count. One possible explanation for this association might be that unemployment was associated with the decreased health [39]. The unemployed men formed a very specious group, however, various demographic and lifestyle factors might result in the negative effects of the well-being of the unemployed. Previous studies reported that unemployed men could have more physically deleterious behaviors, such as living in an unhealthy diet, alcohol abuse, and smoking [40-42]. Moreover, unemployment had a detrimental effect on mental health. Therefore, the decrease in semen quality among unemployed men could also be explained by depression and distress [43]. Hence, interventions, therapeutic methods, and job-search training might be beneficial for the increase of employment [44], and then provide useful help for improving the semen quality.

We found an elevated risk of decreased sperm density among the semen donors in the entertainment and sports industry, consistent with a previous study in the USA [45]. However, a previous study in China [46] supported our results that the processive physical activity could improve semen quality parameters among healthy men. Several explanations existed for this association between working in the entertainment and sports industry and the decreased semen quality. First, there was a large difference in the amount of the sports between athletes and

ordinary persons. Undoubtedly, moderate exercise was beneficial for a healthy man. A systematic review and meta-analysis [17] pointed that physical activity was beneficial for men's reproductive health. However, intensive sports practices could have a negative effect on semen quality, such as DNA fragmentation [47]. On the contrary, restricting sports activity in the athletes could reduce the deleterious effect of sports on semen quality [48]. Hence, we speculated that it was the excessive physical activity discrepancy that leads to the increase in the semen quality among the workers in entertainment and sports. The second possible reason for the elevated risk might be the use of anabolic-androgenic steroids, which were testosterone derivatives usually used by the workers in the entertainment and sports industry to improve the sports performance or enhance the appearance.

Our study had notable advantages. Our findings provided new insight into the association between occupational factors and semen quality. We gave an intuitive understanding of what occupation tented to damage semen quality. We found a novel association between working in the finance or insurance industry and the elevated risk of damaged sperm quality. The unemployed men were at high risk of decreased sperm density and total sperm count. Workings in the IT industry was associated with an elevated risk for the progressive motility of sperm. Interestingly, we found that the soldiers and police had the highest semen volume but the lowest sperm motility. In a word, the results of our study highlighted the need and importance to avoid adverse occupational hazards to maintain satisfied semen quality.

Although we used a large sample of semen donors, our study does have some disadvantages. We did not exhaust all the measurement methods to assess semen quality. For example, data of sperm morphology and DNA fragment measurement were not applied in our study, because of incomplete data in these indexes. A prospective cohort study is needed to improve the study quality. On the other hand, there was some selection bias in this study. We selected semen donors in a province as the studying population, while some studies studied infertile men [49]. Inevitably, there was a selection bias in either of the two populations. However, a study in the USA [50] proved that the use of semen donors did not raise the risk of selection bias in male fertility studies. Moreover, it is not possible to get an unbiased sample that represent the whole male population. Hence, our study population could be a good representation of male fertility studies. Finally, we did not include the smoking habit and drinking habit in the current study because we only investigated a few semen donors about their smoking and drinking habit. Moreover, the number of men with drinking habits was only seven, leading to the instability of our models. Hence, a prospective cohort study was warranted, and the association between smoking and semen quality in China needed to be verified in further studies.

To sum up, our study provided new insight into the impact of occupations on semen quality in China. We found deleterious effects in some professions, reflecting the impact of adverse workstyle on semen quality. In other words, workstyle factors contributed to the changes in the semen parameters of semen donors. We should pay more attention to the semen quality of the sedentary workers, unemployed men, the workers in the entertainment and sports industry, and the IT industry. Our findings highlight the need and importance to keep good work styles in occupational activities, and our study is of high public health significance for human fertility.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

Data Sharing Statement

Data will not be deposited.

Contributorship

FT and ZJ drafted the manuscript.
ZJ and HS contributed to the interpretation and discussion of the results.
JL contributed to the study design.
LX contributed to the supervision of the study.
ZJ, MJ, HS, LF, JC, YL, and JH contributed to data collection.
ZJ and MJ performed data analysis.
All authors read and approved the final manuscript.

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Figure legend

Figure 1. Semen quality parameters among different professions

IT: Information Technology

Figure 2. The risk of professions on the semen volume

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 3. The risk of professions on the sperm density

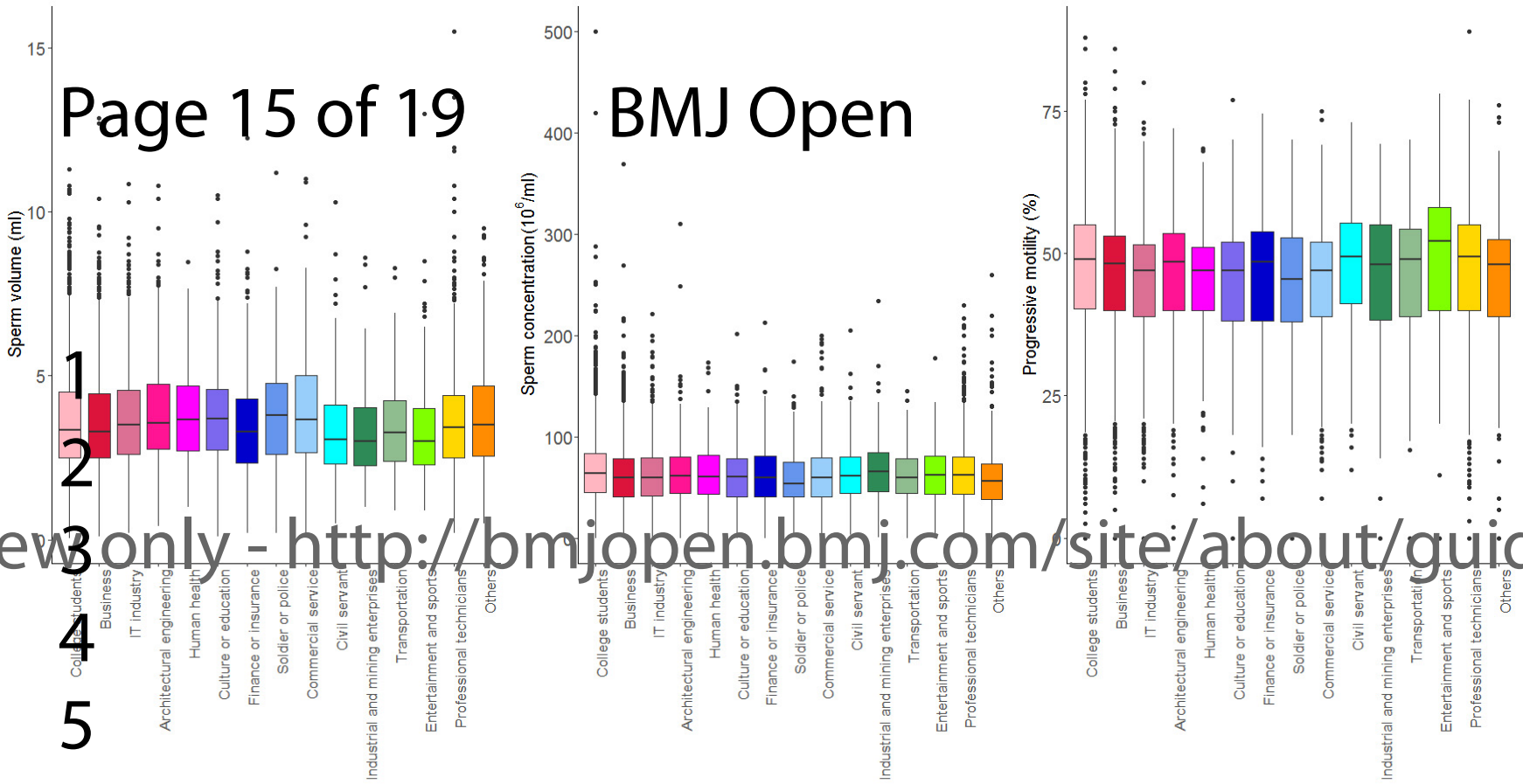
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

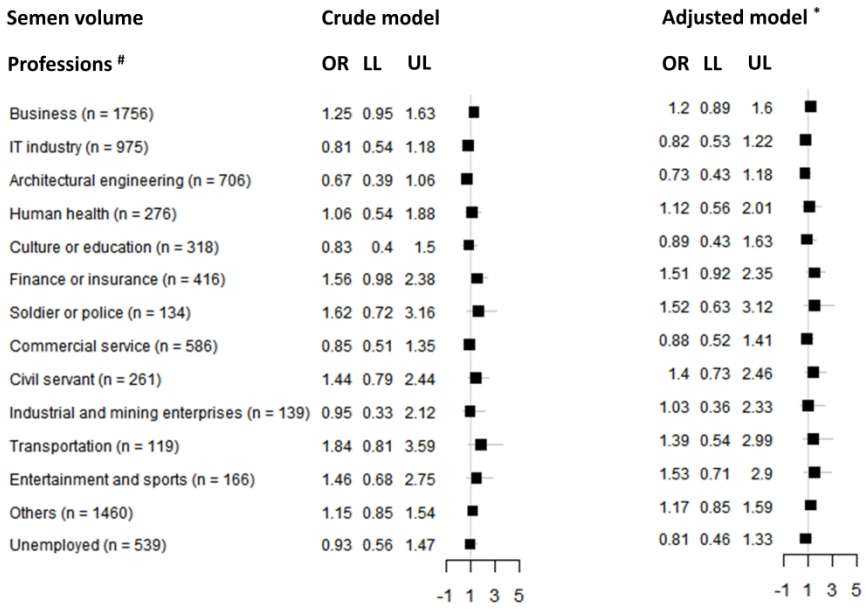
Figure 4. The risk of professions on the total sperm count

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 5. The risk of professions on the progressive motility of sperm

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).





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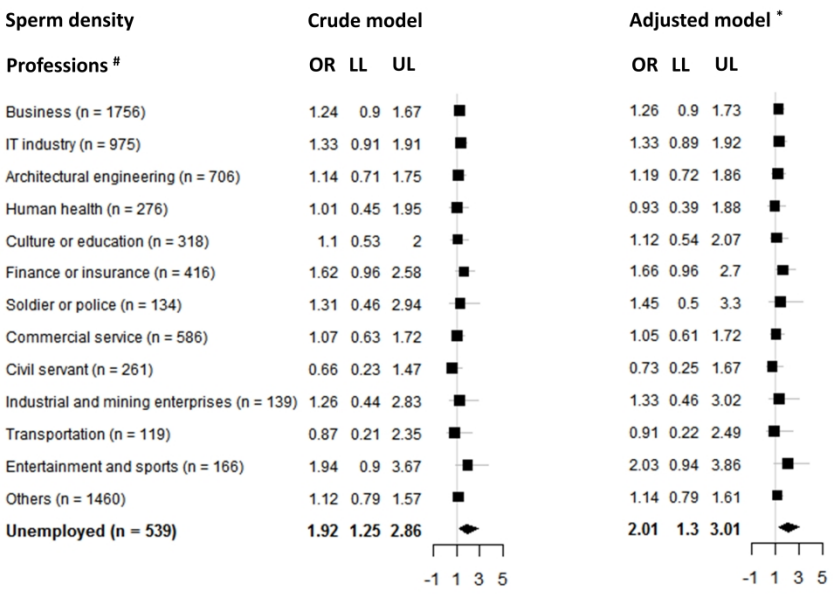

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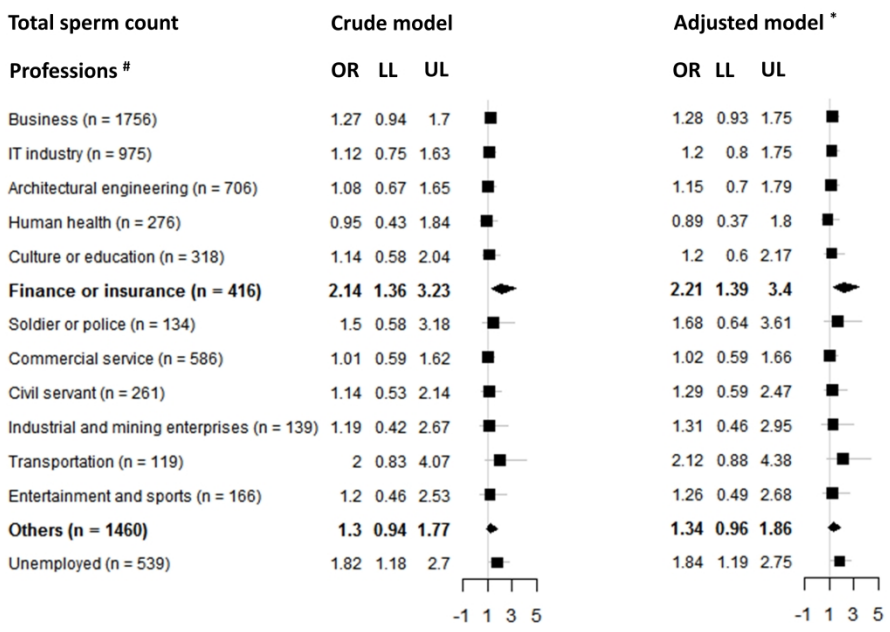

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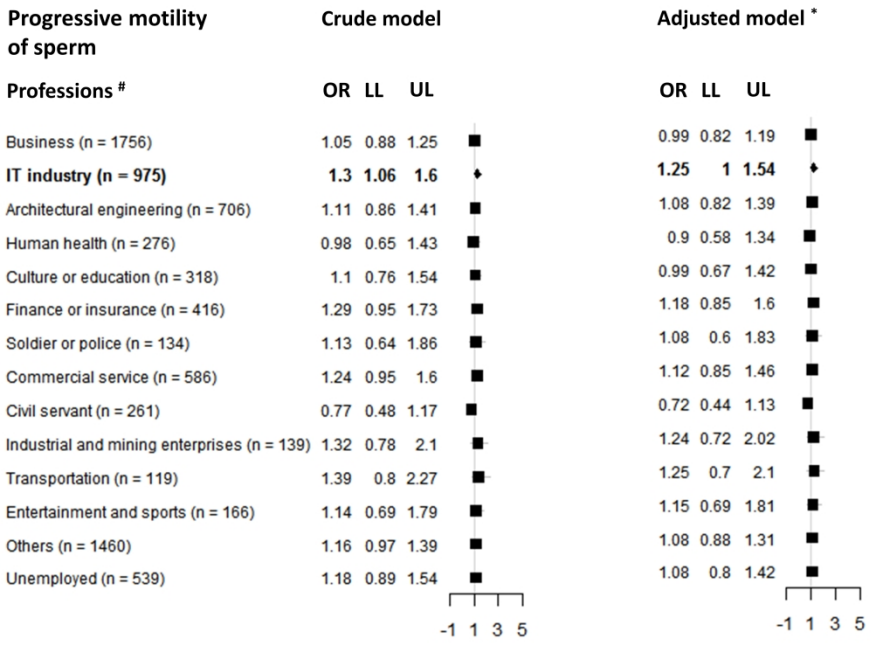

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Supplementary table 1. Geographic characteristics, life habits, and disease histories of 12,301 semen donors

Characteristic	n (%)
Age, years	
18-30	9996 (81.3)
30-39	2062 (16.8)
40-50	239 (1.9)
Ethnicity	
Han	12054 (98.0)
Others	247 (2.0)
Education	
High school	4669 (38.0)
Junior college	6272 (51.0)
Undergraduate or higher	1360 (11.1)
Marital status	
Unmarried	10033 (81.6)
Married	2169 (17.6)
Divorced	99 (0.8)
Childbearing history	
Never	10720 (87.1)
Ever	1581 (12.9)
Native geographical region	
South	9151 (74.4)
North	3150 (25.6)
Smoking habit	
Non-smoker	4327 (35.2)
Smoker	186 (1.5)
NA	7788 (63.3)
Drinking habit	
Never	4506 (36.6)
Ever	7 (0.1)
NA	7788 (63.3)
Overweight or fat	
No	3901 (31.7)
Yes	608 (5.0)
NA	7792 (63.3)
Hypertension	
No	4495 (36.5)
Yes	10 (0.1)
NA	7796 (63.4)
History of testicular surgery	
No	4511 (36.7)
Yes	2 (0.0)
NA	7788 (63.3)

NA: not available

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Association of occupations with decreased semen quality in Eastern China: a cross-sectional study of 12,301 semen donors

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Key words: occupation, semen quality, sperm
Abbreviations: CI: confidence interval; IT: information technology
Article category: occupational epidemiology

Novelty and Impact: This study was conducted in a large sample of semen donors in Eastern China. The major novelty of this study was that we found the association of different professions with deleterious semen quality for the first time. The workers in the finance or insurance industry and unemployed men had elevated risks for semen quality. The soldiers and police had the highest semen volume but the lowest sperm motility. This study revealed that sedentary work, unemployed status, and intensive sports might contributed to the changes in the semen parameters. Our findings added valuable information on the effects of adverse workstyles on semen quality in China. Hence, our study was of high importance in public health and human fertility.

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Abstract

Objectives: This study aims to examine the association of modifiable factors to semen quality in semen donors in eastern China. **Methods:** We recruited 12,301 semen donors from 2006 to 2020 as a studying population. A self-designed questionnaire was applied for collecting the lifestyle and workstyle information. Semen samples were analyzed according to the World Health Organization guidance. A crude and adjusted linear regression model was used to analyze the association between occupational factors and semen quality. **Results:** College students accounted for 38.3% of all semen donors. The majority (82.9%) of semen donors were between 18 and 30 years. The soldiers and police had the highest semen volume (the median value = 3.8 ml), however, they had the lowest semen motility (53.6%). The workers in the finance or insurance had an elevated risk of low semen volume, sperm density, and total sperm count (*OR* = 1.43, 1.57, and 1.98, respectively). The unemployed men had a high risk of low sperm density and low total sperm count (*OR* = 1.84, and 1.58, respectively). Workers in the IT industry had a deleterious effect on the progressive motility of sperm (*OR* = 1.27, 95%CI = 1.03-1.57). **Conclusion:** Our study indicated that sedentary workstyle and intensive sports in certain professions had deleterious effects on semen quality. We report evidence of becoming unemployed on the damage of semen quality. Hence, we advocate a healthy work style to improve the semen quality in eastern China.

Strengths and limitations of this study

- Our study focused on the association between occupations and the decreased semen quality for the first time in eastern China.
- We investigated both the lifestyle and workstyle factors on the semen quality.
- We recruited 12,301 semen donors from 2006 to 2020, which is a large sample.
- We did not exhaust all the measurement methods to assess semen quality such as the measurement of sperm morphology and DNA fragment.

Introductions

Male infertility affected approximately 7% of the male population worldwide (1). An international study estimated that 72.4 million people of reproductive age were infertile (2). Many causes could result in male infertility, including male diseases (3), genetic, lifestyle factors (4), or environmental exposure due to living in high polluted areas (5). Semen quality is the cornerstone of male infertility studies. A previous report (6) suggested that the semen quality could serve as a useful predictor of male fertility. Previous studies have focused on the semen quality among semen donors (7), young men (8), male partners in infertile couples (9), and fertile men (10). However, the semen quality has declined in several developed and developing countries in the past years (11). A systematic review (12) reported that semen counts decreased by 50%-60% between 1973 and 2011, meanwhile, male infertility has increased in these years. The results of the Global Burden of Disease Survey showed that the age-standardized prevalence of infertility increased by 0.291% each year in men and by 0.37% in women (12). However, the reasons for the decline of semen quality over the past decades are still not resolved worldwide.

The current knowledge about the factors associated with semen quality is often contradictory. Some data suggest that the risk factors for poor semen quality include excessive alcohol consumption, cigarette smoking, the wearing of tight-fitting underwear, being fat, and the use of recreational drugs (13). However, the factors for poor semen quality vary between different populations and regions (14)—eg., cigarette smoking has an overall detrimental effect on semen quality (15), while another study found that smoking was not associated with semen motility (16). Even for some well-recognized factors, there are still some controversies about the impact degree of factors with different intensities and frequencies. Most studies suggested that physical activity was an important risk factor for sperm count and concentration in the young men of the white population (17). However, a meta-analysis showed that elite physical activity hurts semen quality (18). Hence, researchers are not sure whether these findings of risk factors or preventive measures can be applied worldwide and in the local population.

Occupational hazards are potential risk factors that might influence semen quality. A previous study (19) reported that occupational exposure to polycyclic aromatic hydrocarbons was associated with decreased sperm DNA integrity among the coke oven workers. Physical or chemical hazards in the workplace may be the main cause of male infertility (20). Some data suggested that high exposure level of formaldehyde among autopsy service workers had an adverse effect on abnormal sperm progressive motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) and abnormal total sperm motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) (21). A previous study (22) indicated a negative relationship between pesticide exposure or radiation and reduction of sperm motility and concentration. Occupational exposure to heat was also negatively associated with semen quality (23).

The plausible mechanism for the association between occupational exposure and semen quality has been proposed in some recent studies. A study in Mexico (24) revealed that exposure to polycyclic aromatic hydrocarbons could lead to DNA damage, and then was negatively associated with semen quality. A recent study (25) found a positive association between 5hmC of the sperm

ACHE gene and occupational exposure to bisphenol A, indicating the adverse impact of occupational hazards on the human semen quality. However, the association between occupations and semen quality was not well clarified.

Hence, in order to clarify the occupational risk factors for decreased semen quality, we carried out an observational study to examine the association of occupational factors to semen quality in semen donors in eastern China.

Methods

Study design

We recruited volunteers for semen donation as a studying population from 2006 to 2020. The donors were aged over 18 years old across Zhejiang Province in eastern China. Donors were included if they had an education level of junior college or above. Donors were excluded if they had an infectious disease, if they had sexual abstinence for less than 3 days, or if they had a fever. Initially, we included 14,636 semen donors. Then we deleted 2,335 subjects without the data of laboratory examination data. Finally, 12,301 semen donors were included in the study. All the subjects have provided written consent.

Questionnaire surveillance

Once the volunteer was recruited, he was asked to complete a questionnaire. The questionnaire included factors such as alcohol consumption, use of tobacco, the period of abstinence since the last ejaculation, and the current occupation. Alcohol consumption was defined as alcohol use ≥ 1 time per week in the past year. The use of tobacco was defined as current tobacco smoking at least once per month in the past year. The current occupation was self-reported by the semen donors.

Health examination

Height and weight were measured for each donor to calculate body mass index (BMI). According to the guidelines of the World Health Organization (WHO), BMI was calculated, and the donors were categorized as normal (18.5-24.9 kg/m^2) and overweight (25-29.9 kg/m^2) or obesity (≥30 kg/m^2). The systolic and diastolic blood pressure were examined with three measurements. Hypertension was defined as systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg.

Chromosome examination

The peripheral blood lymphocytes were isolated by chromosome examination and cultured in RPMI 1640 medium for 72 h. The cells were routinely collected for G-banding. Karyotype analysis was performed according to the international nomenclature of human cytogenetics (ISCN). Chromosome normality was defined as 23 pairs of normal chromosomes according to the standard of WHO, while chromosome normality was defined as abnormalities in chromosome numbers or structures.

Semen sample analysis

The participants were asked to provide a semen sample in a private room after 3-6 days of sexual abstinence. The semen sample was collected with a plastic container, and evaluated according to World Health Organization guidance (26). The semen samples were liquefied in an incubator (37℃) for 30 min, and then the motility and concentration of semen samples were examined 60 minutes after semen donation. The semen volume was measured using the balance weighing method. The semen concentration was calculated using a hemocytometer on a single dilution. The progressive motility of sperm was analyzed by computer-assisted semen analysis.

Statistical analyses

Semen quality parameters were shown as median (25% quantile — 75% quantile). Categorical variables were shown as frequency and percentage. Kruskal-Wallis H test was used to compare the difference in semen quality between different professions. And if there was any significant difference between them, the Nemenyi test was used for the post-hoc comparison. Factors that may affect the semen quality were selected as independent variables, and a binary logistic regression model using the entering method was used to estimate the influencing factors of each semen quality parameter. The regression models were shown as the crude model and adjusted model. The semen parameters were classified as qualified/unqualified according to the WHO manuals, and these new binary variables were set as the dependent variables in these models. The risk of decreased semen quality in each occupation was calculated compared with the college students. The partial regression coefficient of each adjusted model was adjusted for age, education level, marriage status, and childbearing history. A *P*-value that was equal to or less than 0.05 was considered 'statistically significant'. All statistical analyses were performed using R version 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical consideration

The current study was approved by the medical ethics committee of Zhejiang maternal, child, and reproductive health center (Ref. No. 2019-002).

Patient and public involvement

No patient involved.

Results

Characteristics of semen donors

The majority (81.3%) of semen donors were between 18 and 30 years old, whereas only 1.9% were above 40 years old (Supplementary Table 1). The donors were mainly from universities, with 51% from junior college and 11.1% from undergraduate or higher. In total, 81.6% of the semen donors were not married, and 18.1% of them were married. Meanwhile, 87.1% of them did not have any children. Smoking or excessive drinking habit was rarely reported among the studying population. Overweight or adiposity was diagnosed in 3,901 semen donors, and ten subjects had hypertension. Only two semen donors had a history of testicular surgery. The period of abstinence since the last ejaculation was 4.5(4-5.5) d.

Semen quality was decreased in certain professions

The percentage of chromosome abnormality was 0.8% among 5,510 semen donors with

available data. In a total word, the semen quality varied between different professions (Supplementary Table 2). There was a significant difference in the semen volume between semen donors with different professions (χ^2 = 83.45, P < 0.001). The soldiers and police had the highest semen volume (the median value = 3.8 ml). The workers in the architectural engineering industry had significantly higher semen volume (the median value = 3.6 ml) than the college students (the median value = 3.3 ml; P = 0.004). Meanwhile, the semen donors in the service industry had a higher semen volume (the median value = 3.7 ml), compared with the college students (P = 0.01). Additionally, a significant difference was found in the sperm concentration between donors with different professions (χ^2 = 66.06, P < 0.001). The businessmen and the subjects in the Information Technology (IT) industry had a lower sperm concentration than the college students (P < 0.001, and P = 0.04, respectively). The soldiers and police had the lowest sperm concentration (the median value = 53.6%). Meanwhile, there was a significant difference in the total sperm count between different professions (χ^2 = 52.42, P < 0.001). The total sperm count of the businessman (the median value = 213×10^6/ml) was significantly lower than that of the college students (the median value = 226×10^6/ml). Finally, the progressive motility of sperm changed much in different professions (χ^2 =97.61, P < 0.001). Workers in the IT industry and commercial service had higher progressive motility of sperm (the median value = 47%) than the college students (the median value = 49%; P < 0.001).

The risk of the decrease in semen volume was found among the subjects in the finance or insurance

The percentage of the sperm volume abnormality was 4%. The semen donors in the finance or insurance had a significant risk for the decrease of semen volume in the crude model (*OR* = 1.56, P = 0.05; Figure 1), and they had a marginal significant risk for reduced semen volume in the adjusted model (*OR* = 1.43, P = 0.08).

Some professions had higher risks of decreased sperm density

Of all the semen donors, 3.3% had a decrease in sperm density. In the crude model, the reduced sperm density was moderately associated with the occupation of finance or insurance (*OR* = 1.62, P = 0.05 in the crude model, and OR = 1.57, P = 0.08 in the adjusted model; Figure 2). The unemployed men had a significantly elevated risk of decreased sperm density (*OR* = 1.92, P = 0.002). Furthermore, this risk for unemployed men was slightly elevated after adjusting for the age, education level, marriage status, and childbearing history (*OR* = 1.84, 95%*CI* = 1.18-2.77). Additionally, the workers in the entertainment and sports industry had an elevated risk of low sperm density compared with the college students (*OR* = 1.86, P = 0.04).

Workers in the finance or insurance and unemployed men had a high risk of the reduction of the total sperm count

There were 440 semen donors whose total sperm count was less than the WHO recommended value of 39×10^6/ml. The abnormality of the total sperm count was 3.6%. Working in finance or insurance had an elevated risk for the total sperm count in the adjusted model (*OR* = 1.98, 95%CI = 1.24-3.03; Figure 3). Meanwhile, the association between unemployed men and the decrease in the total sperm count was significant (*OR* = 1.82, 95%CI = 1.18-2.70 in the crude model, and *OR* = 1.58, 95%CI = 1.02-2.37 in the adjusted model).

Working in the IT industry was associated with an elevated risk for the reduction of progressive motility of sperm

The reduction of progressive motility of sperm was found among 11.6% of all semen donors. The workers in the IT industry had a moderately elevated risk for the reduction of progressive motility of sperm in the adjusted model (*OR* = 1.3, 95%CI = 1.06-1.6; Figure 4). After we adjusted for the confounding factors, the risk remained significant, but the odds ratio was slightly lower (*OR* = 1.27, 95%CI = 1.03-1.57).

Discussion

In the current study of 12,301 semen donors, we identified that certain professions had lower semen quality in China. Working in the finance or insurance industry was associated with decreased semen volume, sperm density, and total sperm count. Workers in the IT industry had an elevated risk for the reduction of the progressive motility of sperm. Unemployed men had a higher risk for the reduction of sperm density and total sperm count. Furthermore, working in entertainment and sports was associated with an elevated risk for sperm density, while working in the transportation industry was associated with a high risk for the total sperm count. Most of these associations were robust in regression models, and the results were not modified by age, education level, marriage status, and childbearing history. To the best of our knowledge, this was the first study in China to quantitatively assess the association between occupational factors and semen quality with a large sample size. Hence, our results provided new insights into the semen quality in Eastern China.

We found that the soldiers and police had the highest semen volume. Surprisingly, their progressive motility of sperm was the lowest. The soldiers and police were always considered “strong” men, however, their semen quality was not as good as we expected from the results of our research. A previous study (27) in China supported our findings that 62.5% of the soldiers had at least one semen parameter below the critical values of WHO recommendations in 2010. The etiology of low motility might be due to surgery-related diseases, Sertoli-cell only syndrome, and some idiopathic causes (28). Besides, the high intensity of job stress (29) might play an important role in the decrease of semen motility in the soldiers and police. However, due to the limited sample in the population of soldiers and police, our obtained results should be confirmed in longitudinal studies.

We found that workers in the IT industry had the risk of the reduction of sperm progressive motility. It was well known that most of the workers in the IT industry were programmers, and they had a long-time sedentary work style. As we have known, germ cells were quite sensitive to localized warming of the testes. So the underlying reason for this elevated risk might be due to the localized high temperature in the testes of IT workers. A previous study in Poland (30) documented that heat stress after sedentary work could double the risk of sperm DNA damage. The possible mechanism might be that long-time sedentary workstyle in the IT industry increased testicular temperature, and triggered reactive oxygen species (ROS) and DNA damage (31), leading to the destruction of germ cells by apoptosis. On the other hand, heat stress could

induce altered chromatin condensation during spermatogenesis (32). An experimental study (33) found that spermatozoa at post-meiotic stages of development were more sensitive to heat stress, and suggested that DNA methylation reprogramming could play an important role in the process. Conclusively, we conferred that heat exposure might be a crucial factor for deleterious semen quality among workers in the IT industry. In the same way, our study demonstrated that working in the financial industry was related to sedentary work. Furthermore, either working in the IT industry or the financial industry radiation needed the prolonged video operation. The association between video operation and semen quality has not been well studied in previous studies. Controversially, more physical activity and less TV watching were significantly associated with improved sperm count and sperm concentration. Furthermore, whether the sedentary job and video manipulation had a joint harmful effect on semen quality needs to be confirmed by further research.

Importantly, we found that working in finance or insurance was significantly linked with decreased semen quality, especially with the semen volume, sperm density, and sperm count. The reason why working in finance or insurance could affect semen quality was not fully understood. There were some plausible reasons. First, the workers in finance or insurance, for example, the bank employees, always spend the majority of their working time sitting in front of the computer and engaged in sedentary work (34). Their sedentary working characteristics increased the temperature of their testis, just like the fact in the workers of the IT industry. Hence, our data supported the association between sedentary working behavior in finance or insurance and decreased semen quality. Therefore, more strategies should be applied to make the workers shift from a sedentary workstyle to a more active workstyle (35). Secondly, the current data suggested that a job in the finance or insurance involved high levels of job stress (36). A previous study in India (37) found that 75.5% of the bank employees had a high and very high level of job stress. A study in China (38) believed that the high job stress in the financial workers was related to a high concentration of attention during working. Hence, the association between working in finance or insurance and decreased semen quality might also be explained by the synergistic effect of local temperature in testis and high job stress. More effects should be provided to improve the work initiative, shorten the working hours per day, and improve the social support for workers in the finance or insurance industry (39). However, these results needed to be proved by better study design, and be confirmed in further studies.

Our study found that unemployment was associated with a decrease in sperm density and total sperm count. One possible explanation for this association might be that unemployment was associated with decreased health (40). The unemployed men formed a very specious group, however, various demographic and lifestyle factors might result in the negative effects on the well-being of the unemployed. Previous studies reported that unemployed men could have more physically deleterious behaviors, such as living an unhealthy diet, alcohol abuse, and smoking (41-43). Moreover, unemployment had a detrimental effect on mental health. Therefore, the decrease in semen quality among unemployed men could also be explained by depression and distress (44). Hence, interventions, therapeutic methods, and job-search training might be beneficial for the increase of employment (45), and then provide useful help for improving the semen quality.

We found an elevated risk of decreased sperm density among the semen donors in the entertainment and sports industry, consistent with a previous study in the USA (46). However, a previous study in China (47) supported our results that the physical activity could improve semen quality parameters among healthy men. Several explanations existed for this association between working in the entertainment and sports industry and the decreased semen quality. First, there was a large difference in the amount of sports between athletes and ordinary persons. Undoubtedly, moderate exercise was beneficial for a healthy man. A systematic review and meta-analysis (18) pointed out that physical activity was beneficial for men's reproductive health. However, intensive sports practices could have a negative effect on semen quality, such as DNA fragmentation (48). On the contrary, restricting sports activity in athletes could reduce the deleterious effect of sports on semen quality (49). Hence, we speculated that it was the excessive physical activity discrepancy that leads to the increase in the semen quality among the workers in entertainment and sports. The second possible reason for the elevated risk might be the use of anabolic-androgenic steroids, which were testosterone derivatives usually used by the workers in the entertainment and sports industry to improve sports performance or enhance appearance.

Our study had notable advantages. Our findings provided new insight into the association between occupational factors and semen quality. We gave an intuitive understanding of what occupation tented to damage semen quality. We found a novel association between working in the finance or insurance industry and the elevated risk of damaged sperm quality. The unemployed men were at high risk of decreased sperm density and total sperm count. Workings in the IT industry was associated with an elevated risk for the progressive motility of sperm. Interestingly, we found that the soldiers and police had the highest semen volume but the lowest sperm motility.

Although we used a large sample of semen donors, our study does have some methodological disadvantages. Firstly, we did not exhaust all the measurement methods to assess semen quality. For example, data of sperm morphology and DNA fragment measurement were not applied in our study, because of incomplete data in these indexes. A prospective cohort study is needed to improve the study quality. Secondly, there was some selection bias in this study. We selected semen donors in a province as the studying population, while some studies studied infertile men [49]. Inevitably, there was a selection bias in either of the two populations. However, a study in the USA [50] proved that the use of semen donors did not raise the risk of selection bias in male fertility studies. Moreover, it is not possible to get an unbiased sample that represent the whole male population. Hence, our study population could be a good representation of male fertility studies. Thirdly, we investigated some lifestyle and occupational factors; however, we did not focus on environmental exposure due to living in polluted areas or other factors such as stress. A previous study (50) conducted in highly polluted areas has suggested the negative role of environmental pollution on the semen quality. Furthermore, Levine and colleagues (51) reported that semen quality deteriorated during the summer due to a deleterious effect of heat. Hence, it is important to clarify the association between environmental exposure, psychological stress, and semen quality in future studies. Finally, we did not include the smoking habit and drinking

habit in the current study because we only investigated a few semen donors about their smoking and drinking habit. Moreover, the number of men with drinking habits was only seven, leading to the instability of our models. Hence, a prospective cohort study was warranted, and the association between smoking and semen quality in China needed to be verified in further studies.

To sum up, our study provided new insight into the impact of occupations on semen quality in China. We found decreased effects in some professions, reflecting the association of adverse workstyle with semen quality. In other words, workstyle factors might contribute to the changes in the semen parameters of semen donors. The results of our study suggested the need and importance to avoid adverse occupational hazards to maintain satisfactory semen quality. We should pay more attention to the semen quality of the sedentary workers, unemployed men, the workers in the entertainment and sports industry, and the IT industry. Our findings also suggested keeping good work styles in occupational activities, and our study is of valuable public health significance for human fertility.

Contributors

Conceptualization: Z.J., and J.L.
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Project administration: J.L., and L.X.
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Supervision: F.T., H.S., and L.X.
Validation: M.J.
Visualization: M.J., and Z.J.
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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

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Data sharing statement

The data that are used in this study are available from the corresponding author upon reasonable request.

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Figure legend

Figure 1. The risk of professions on the semen volume

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 2. The risk of professions on the sperm density

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 3. The risk of professions on the total sperm count

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 4. The risk of professions on the progressive motility of sperm

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

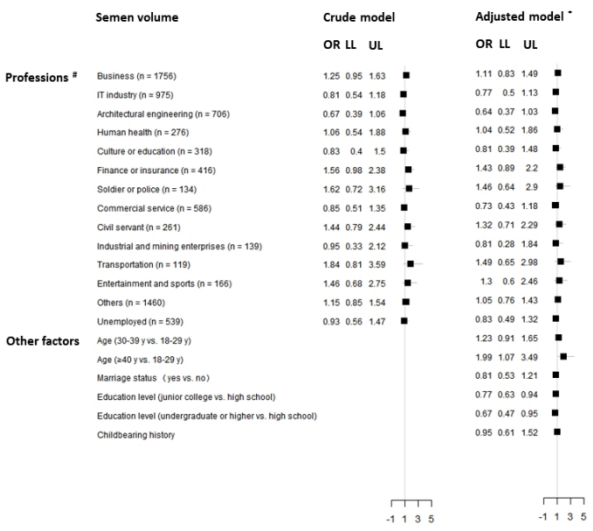

Figure 1. The risk of professions on the semen volume
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

338x190mm (96 x 96 DPI)

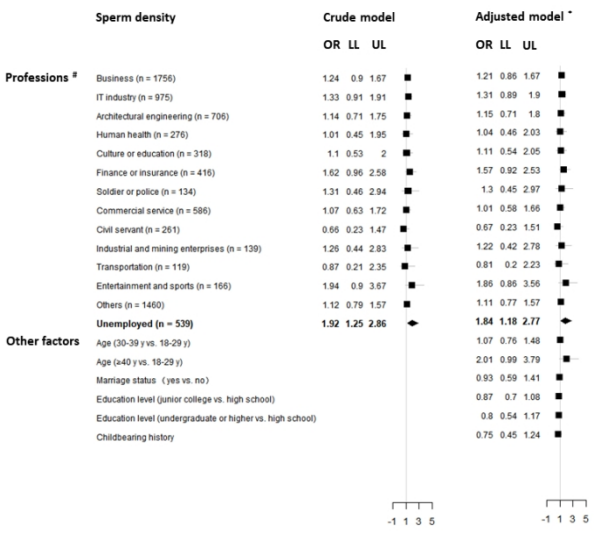

Figure 2. The risk of professions on the sperm density
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

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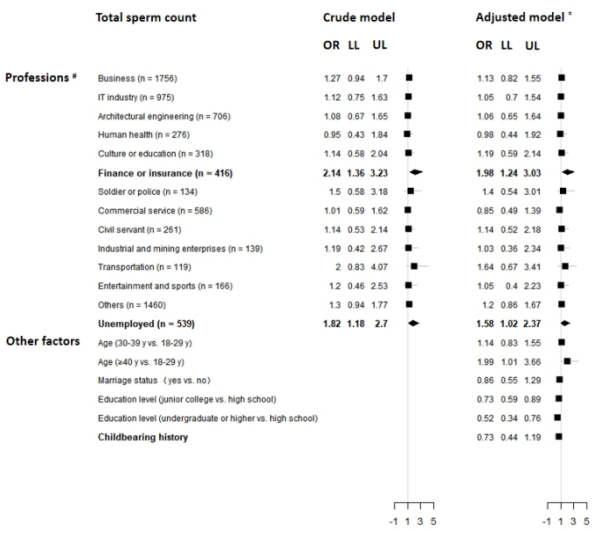

Figure 3. The risk of professions on the total sperm count
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

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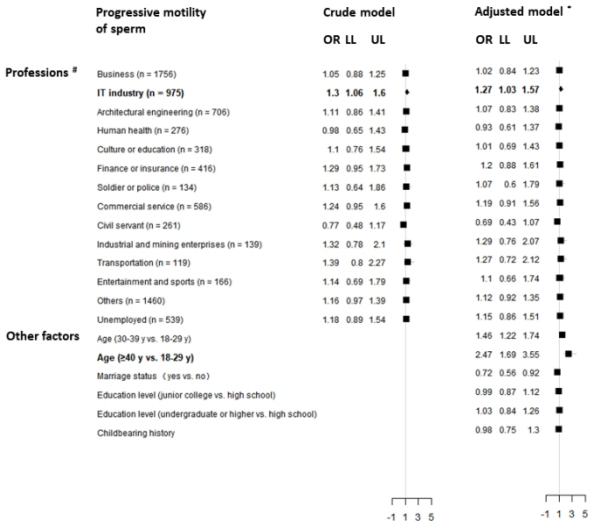

Figure 4. The risk of professions on the progressive motility of sperm
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

338x190mm (96 x 96 DPI)

Supplementary table 1. Geographic characteristics, life habits, and disease histories of 12,301 semen donors

Characteristic	n (%)
Age, years	
18-30	9996 (81.3)
30-39	2062 (16.8)
40-50	239 (1.9)
Ethnicity	
Han	12054 (98.0)
Others	247 (2.0)
Education	
High school	4669 (38.0)
Junior college	6272 (51.0)
Undergraduate or higher	1360 (11.1)
Marital status	
Unmarried	10033 (81.6)
Married	2169 (17.6)
Divorced	99 (0.8)
Childbearing history	
Never	10720 (87.1)
Ever	1581 (12.9)
Native geographical region	
South	9151 (74.4)
North	3150 (25.6)
Smoking habit	
Non-smoker	4327 (35.2)
Smoker	186 (1.5)
NA	7788 (63.3)
Drinking habit	
Never	4506 (36.6)
Ever	7 (0.1)
NA	7788 (63.3)
Overweight or fat	
No	3901 (31.7)
Yes	608 (5.0)
NA	7792 (63.3)
Hypertension	
No	4495 (36.5)
Yes	10 (0.1)
NA	7796 (63.4)
History of testicular surgery	
No	4511 (36.7)
Yes	2 (0.0)
NA	7788 (63.3)

NA: not available

Supplementary table 2. Semen quality parameters among different professions

Occupation	*n* (%)	Semen volume (ml)	Semen concentration (10^6/ml)	Sperm count (10^6)	Sperm mobility (%)
College students	4450 (36.2)	3.3±1.5	65.9±32.0	226±129	46.8±11.8
Business	1756 (14.3)	3.3±1.6	61.7±30.4	213±128	45.8±11.9
IT industry	975 (7.9)	3.5±1.5	62.3±30.3	221±123	44.8±11.4
Architectural engineering	706 (5.7)	3.6±1.6	63.5±30.3	239±139	45.7±12.0
Human health	276 (2.2)	3.7±1.5	63.6±30.0	234±127	45.2±10.3
Culture or education	318 (2.6)	3.7±1.7	61.7±29.8	229±127	45.1±11.0
Finance or insurance	416 (3.4)	3.3±1.6	62.7±31.3	214±128	45.5±12.4
Soldier or police	134 (1.1)	3.8±1.6	59.6±28.7	225±141	44.7±11.7
Commercial service	586 (4.8)	3.7±1.6	62.5±31.3	229±131	44.8±11.5
Civil servant	261 (2.1)	3.1±1.6	63.6±27.9	210±115	48.0±10.7
Industrial and mining enterprises	139 (1.1)	3.0±1.4	66.3±32.2	210±117	45.5±12.9
Transportation	119 (1.0)	3.3±1.6	62.4±28.9	216±132	45.5±12.3
Entertainment and sports	166 (1.3)	3.0±1.6	61.4±29.4	195±108	49.2±13.0
Others	1460 (11.9)	3.4±1.5	64.0±30.8	219±120	46.8±12.2
Unemployed	539 (4.4)	3.5±1.6	58.4±31.7	208±129	45.5±11.6

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Association of occupations with decreased semen quality in Eastern China: a cross-sectional study of 12,301 semen donors

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Association of occupations with decreased semen quality in Eastern China: a cross-sectional study of 12,301 semen donors

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Novelty and Impact: This study was conducted in a large sample of semen donors in Eastern China. The major novelty of this study was that we found the association of different professions with deleterious semen quality for the first time. The workers in the finance or insurance industry and unemployed men had elevated risks for semen quality. The soldiers and police had the highest semen volume but the lowest sperm motility. This study revealed that sedentary work, unemployed status, and intensive sports might contributed to the changes in the semen parameters. Our findings added valuable information on the effects of adverse workstyles on semen quality in China. Hence, our study was of high importance in public health and human fertility.

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Abstract

Objectives: This study aims to examine the association of modifiable factors to semen quality in semen donors in eastern China. **Methods:** We recruited 12,301 semen donors from 2006 to 2020 as a studying population. A self-designed questionnaire was applied for collecting the lifestyle and workstyle information. Semen samples were analyzed according to the World Health Organization guidance. A crude and adjusted linear regression model was used to analyze the association between occupational factors and semen quality. **Results:** College students accounted for 38.3% of all semen donors. The majority (82.9%) of semen donors were between 18 and 30 years. The soldiers and police had the highest semen volume (the median value = 3.8 ml), however, they had the lowest semen motility (53.6%). The workers in finance or insurance had an elevated risk of low semen volume, sperm density, and total sperm count (*OR* = 1.43, 1.57, and 1.98, respectively). The unemployed men had a high risk of low sperm density and low total sperm count (*OR* = 1.84, and 1.58, respectively). Workers in the IT industry had a deleterious effect on the progressive motility of sperm (*OR* = 1.27, 95%CI = 1.03-1.57). **Conclusion:** Our study indicated that sedentary workstyle and intensive sports in certain professions were associated with decreased semen quality. We report evidence of becoming unemployed on the damage to semen quality. Hence, we advocate a healthy work style to improve semen quality in eastern China.

Strengths and limitations of this study

- Our study focused on the association between occupations and decreased semen quality for the first time in eastern China.
- We investigated both the lifestyle and workstyle factors on semen quality.
- We recruited 12,301 semen donors from 2006 to 2020, which is a large sample.
- We did not exhaust all the measurement methods to assess semen quality such as the measurement of sperm morphology and DNA fragment.

Introduction

Male infertility affected approximately 7% of the male population worldwide (1). An international study estimated that 72.4 million people of reproductive age were infertile (2). Many causes could result in male infertility, including male diseases (3), genetic, lifestyle factors (4), or environmental exposure due to living in highly polluted areas (5). Semen quality is the cornerstone of male infertility studies. A previous report (6) suggested that semen quality could serve as a useful predictor of male fertility. Previous studies have focused on the semen quality among semen donors (7), young men (8), male partners in infertile couples (9), and fertile men (10). However, semen quality has declined in several developed and developing countries in the past years (11). A systematic review (12) reported that semen counts decreased by 50%-60% between 1973 and 2011, meanwhile, male infertility has increased in these years. The results of the Global Burden of Disease Survey showed that the age-standardized prevalence of infertility increased by 0.291% each year in men and by 0.37% in women (12). However, the reasons for the decline of semen quality over the past decades are still not resolved worldwide.

The current knowledge about the factors associated with semen quality is often contradictory. Some data suggest that the risk factors for poor semen quality include excessive alcohol consumption, cigarette smoking, the wearing of tight-fitting underwear, being fat, and the use of recreational drugs (13). However, the factors for poor semen quality vary between different populations and regions (14)—eg., cigarette smoking has an overall detrimental effect on semen quality (15), while another study found that smoking was not associated with semen motility (16). Even for some well-recognized factors, there are still some controversies about the impact degree of factors with different intensities and frequencies. Most studies suggested that physical activity was an important risk factor for sperm count and concentration in the young men of the white population (17). However, a meta-analysis showed that elite physical activity hurts semen quality (18). Hence, researchers are not sure whether these findings of risk factors or preventive measures can be applied worldwide and to the local population.

Occupational hazards are potential risk factors that might influence semen quality. A previous study (19) reported that occupational exposure to polycyclic aromatic hydrocarbons was associated with decreased sperm DNA integrity among coke oven workers. Physical or chemical hazards in the workplace may be the main cause of male infertility (20). Some data suggested that high exposure level of formaldehyde among autopsy service workers had an adverse effect on abnormal sperm progressive motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) and abnormal total sperm motility (*OR* = 4.84; 95%*CI*: 1.83-12.81) (21). A previous study (22) indicated a negative relationship between pesticide exposure or radiation and reduction of sperm motility and concentration. Occupational exposure to heat was also negatively associated with semen quality (23).

The plausible mechanism for the association between occupational exposure and semen quality has been proposed in some recent studies. A study in Mexico (24) revealed that exposure to polycyclic aromatic hydrocarbons could lead to DNA damage, and then was negatively associated with semen quality. A recent study (25) found a positive association between 5hmC of the sperm

ACHE gene and occupational exposure to bisphenol A, indicating the adverse impact of occupational hazards on human semen quality. However, the association between occupations and semen quality was not well clarified.

Hence, to clarify the occupational risk factors for decreased semen quality, we carried out an observational study to examine the association of occupational factors to semen quality in semen donors in eastern China.

Methods

Study design

We recruited volunteers for semen donation as a studying population from 2006 to 2020. The donors were aged over 18 years old across Zhejiang Province in eastern China. Donors were included if they had an education level of junior college or above. Donors were excluded if they had an infectious disease, if they had sexual abstinence for less than 3 days, or if they had a fever. Initially, we included 14,636 semen donors. Then we deleted 2,335 subjects without the data of laboratory examination data. Finally, 12,301 semen donors were included in the study. All the subjects have provided written consent.

Questionnaire surveillance

Once the volunteer was recruited, he was asked to complete a questionnaire. The questionnaire included factors such as alcohol consumption, use of tobacco, the period of abstinence since the last ejaculation, and the current occupation. Alcohol consumption was defined as alcohol use ≥ 1 time per week in the past year. The use of tobacco was defined as current tobacco smoking at least once per month in the past year. The current occupation was self-reported by the semen donors.

Health examination

Height and weight were measured for each donor to calculate body mass index (BMI). According to the guidelines of the World Health Organization (WHO), BMI was calculated, and the donors were categorized as normal (18.5-24.9 kg/m^2) and overweight (25-29.9 kg/m^2) or obese (≥30 kg/m^2). The systolic and diastolic blood pressure were examined with three measurements. Hypertension was defined as systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg.

Chromosome examination

The peripheral blood lymphocytes were isolated by chromosome examination and cultured in RPMI 1640 medium for 72 h. The cells were routinely collected for G-banding. Karyotype analysis was performed according to the international nomenclature of human cytogenetics (ISCN). Chromosome normality was defined as 23 pairs of normal chromosomes according to the standard of WHO, while chromosome normality was defined as abnormalities in chromosome numbers or structures.

Semen sample analysis

The participants were asked to provide a semen sample in a private room after 3-6 days of sexual abstinence. The semen sample was collected with a plastic container, and evaluated according to World Health Organization guidance (26). The semen samples were liquefied in an incubator (37℃) for 30 min, and then the motility and concentration of semen samples were examined 60 minutes after semen donation. The semen volume was measured using the balance weighing method. The semen concentration was calculated using a hemocytometer on a single dilution. The progressive motility of sperm was analyzed by the computer-assisted semen analysis.

Statistical analyses

Semen quality parameters were shown as median (25% quantile — 75% quantile). Categorical variables were shown as frequency and percentage. Kruskal-Wallis H test was used to compare the difference in semen quality between different professions. And if there was any significant difference between them, the Nemenyi test was used for the post-hoc comparison. Factors that may affect the semen quality were selected as independent variables, and a binary logistic regression model using the entering method was used to estimate the influencing factors of each semen quality parameter. The regression models were shown as the crude model and adjusted model. The semen parameters were classified as qualified/unqualified according to the WHO manuals, and these new binary variables were set as the dependent variables in these models. The risk of decreased semen quality in each occupation was calculated compared with the college students. The partial regression coefficient of each adjusted model was adjusted for age, education level, marriage status, and childbearing history. A *P*-value that was equal to or less than 0.05 was considered 'statistically significant'. All statistical analyses were performed using R version 4.0.5 (R Foundation for Statistical Computing, Vienna, Austria).

Patient and public involvement

No patient was involved.

Results

Characteristics of semen donors

The majority (81.3%) of semen donors were between 18 and 30 years old, whereas only 1.9% were above 40 years old (Supplementary Table 1). The donors were mainly from universities, with 51% from junior college and 11.1% from undergraduate or higher. In total, 81.6% of the semen donors were not married, and 18.1% of them were married. Meanwhile, 87.1% of them did not have any children. Smoking or excessive drinking habit was rarely reported among the studying population. Overweight or adiposity was diagnosed in 3,901 semen donors, and ten subjects had hypertension. Only two semen donors had a history of testicular surgery. The period of abstinence since the last ejaculation was 4.5(4-5.5) d.

Semen quality was decreased in certain professions

The percentage of chromosome abnormality was 0.8% among 5,510 semen donors with available data. In a word, the semen quality varied between different professions (Supplementary Table 2). There was a significant difference in the semen volume between semen donors with different professions ($\chi^2 = 83.45$, $P < 0.001$). The soldiers and police had the highest semen volume (the median value = 3.8 ml). The workers in the architectural engineering

industry had significantly higher semen volume (the median value = 3.6 ml) than the college students (the median value = 3.3 ml; P = 0.004). Meanwhile, the semen donors in the service industry had a higher semen volume (the median value = 3.7 ml), compared with the college students (P = 0.01). Additionally, a significant difference was found in the sperm concentration between donors with different professions (χ^2 = 66.06, P < 0.001). The businessmen and the subjects in the Information Technology (IT) industry had a lower sperm concentration than the college students (P < 0.001, and P = 0.04, respectively). The soldiers and police had the lowest sperm concentration (the median value = 53.6%). Meanwhile, there was a significant difference in the total sperm count between different professions (χ^2 = 52.42, P < 0.001). The total sperm count of the businessman (the median value = 213×10^6/ml) was significantly lower than that of the college students (the median value = 226×10^6/ml). Finally, the progressive motility of sperm changed much in different professions (χ^2 =97.61, P < 0.001). Workers in the IT industry and commercial service had higher progressive motility of sperm (the median value = 47%) than college students (the median value = 49%; P < 0.001).

The risk of the decrease in semen volume was found among the subjects in the finance or insurance

The percentage of sperm volume abnormality was 4%. The semen donors in the finance or insurance had a significant risk for the decrease of semen volume in the crude model (OR = 1.56, P = 0.05; Figure 1), and they had a marginal significant risk for reduced semen volume in the adjusted model (OR = 1.43, P = 0.08).

Some professions had higher risks of decreased sperm density

Of all the semen donors, 3.3% had a decrease in sperm density. In the crude model, the reduced sperm density was moderately associated with the occupation of finance or insurance (OR = 1.62, P = 0.05 in the crude model, and OR = 1.57, P = 0.08 in the adjusted model; Figure 2). The unemployed men had a significantly elevated risk of decreased sperm density (OR = 1.92, P = 0.002). Furthermore, this risk for unemployed men was slightly elevated after adjusting for age, education level, marriage status, and childbearing history (OR = 1.84, 95%CI = 1.18-2.77). Additionally, the workers in the entertainment and sports industry had an elevated risk of low sperm density compared with the college students (OR = 1.86, P = 0.04).

Workers in the finance or insurance and unemployed men had a high risk of the reduction of the total sperm count

There were 440 semen donors whose total sperm count was less than the WHO recommended value of 39×10^6/ml. The abnormality of the total sperm count was 3.6%. Working in finance or insurance had an elevated risk for the total sperm count in the adjusted model (OR = 1.98, 95%CI = 1.24-3.03; Figure 3). Meanwhile, the association between unemployed men and the decrease in the total sperm count was significant (OR = 1.82, 95%CI = 1.18-2.70 in the crude model, and OR = 1.58, 95%CI = 1.02-2.37 in the adjusted model).

Working in the IT industry was associated with an elevated risk for the reduction of progressive motility of sperm

The reduction of progressive motility of sperm was found among 11.6% of all semen donors. The

workers in the IT industry had a moderately elevated risk for the reduction of progressive motility of sperm in the adjusted model (*OR* = 1.3, 95%CI = 1.06-1.6; Figure 4). After we adjusted for the confounding factors, the risk remained significant, but the odds ratio was slightly lower (*OR* = 1.27, 95%CI = 1.03-1.57).

Discussion

In the current study of 12,301 semen donors, we identified that certain professions had lower semen quality in China. Working in the finance or insurance industry was associated with decreased semen volume, sperm density, and total sperm count. Workers in the IT industry had an elevated risk for the reduction of the progressive motility of sperm. Unemployed men had a higher risk for the reduction of sperm density and total sperm count. Furthermore, working in entertainment and sports was associated with an elevated risk for sperm density, while working in the transportation industry was associated with a high risk for the total sperm count. Most of these associations were robust in regression models, and the results were not modified by age, education level, marriage status, and childbearing history. To the best of our knowledge, this was the first study in China to quantitatively assess the association between occupational factors and semen quality with large sample size. Hence, our results provided new insights into the semen quality in Eastern China.

We found that the soldiers and police had the highest semen volume. Surprisingly, their progressive motility of sperm was the lowest. The soldiers and police were always considered "strong" men, however, their semen quality was not as good as we expected from the results of our research. A previous study (27) in China supported our findings that 62.5% of the soldiers had at least one semen parameter below the critical values of WHO recommendations in 2010. The etiology of low motility might be due to surgery-related diseases, Sertoli-cell only syndrome, and some idiopathic causes (28). Besides, the high intensity of job stress (29) might play an important role in the decrease of semen motility in the soldiers and police. However, due to the limited sample in the population of soldiers and police, our obtained results should be confirmed in longitudinal studies.

We found that workers in the IT industry had the risk of the reduction of sperm progressive motility. It was well known that most of the workers in the IT industry were programmers, and they had a long-time sedentary work style. As we have known, germ cells were quite sensitive to localized warming of the testes. So the underlying reason for this elevated risk might be due to the localized high temperature in the testes of IT workers. A previous study in Poland (30) documented that heat stress after sedentary work could double the risk of sperm DNA damage. The possible mechanism might be that long-time sedentary workstyle in the IT industry increased testicular temperature, and triggered reactive oxygen species (ROS) and DNA damage (31), leading to the destruction of germ cells by apoptosis. On the other hand, heat stress could induce altered chromatin condensation during spermatogenesis (32). An experimental study (33) found that spermatozoa at post-meiotic stages of development were more sensitive to heat stress, and suggested that DNA methylation reprogramming could play an important role in the process. Conclusively, we conferred that heat exposure might be a crucial factor for deleterious

semen quality among workers in the IT industry. In the same way, our study demonstrated that working in the financial industry was related to sedentary work. Furthermore, either working in the IT industry or the financial industry radiation needed prolonged video operation. The association between video operation and semen quality has not been well studied in previous studies. Controversially, more physical activity and less TV watching were significantly associated with improved sperm count and sperm concentration. Furthermore, whether the sedentary job and video manipulation had a joint harmful effect on semen quality needs to be confirmed by further research.

Importantly, we found that working in finance or insurance was significantly linked with decreased semen quality, especially with semen volume, sperm density, and sperm count. The reason why working in finance or insurance could affect semen quality was not fully understood. There were some plausible reasons. First, the workers in finance or insurance, for example, the bank employees, always spend the majority of their working time sitting in front of the computer and engaged in sedentary work (34). Their sedentary working characteristics increased the temperature of their testis, just like the fact in the workers in the IT industry. Hence, our data supported the association between sedentary working behavior in finance or insurance and decreased semen quality. Therefore, more strategies should be applied to make the workers shift from a sedentary workstyle to a more active workstyle (35). Secondly, the current data suggested that a job in finance or insurance involved high levels of job stress (36). A previous study in India (37) found that 75.5% of bank employees had a high and very high level of job stress. A study in China (38) believed that the high job stress in financial workers was related to a high concentration of attention during working. Hence, the association between working in finance or insurance and decreased semen quality might also be explained by the synergistic effect of local temperature in testis and high job stress. More effects should be provided to improve the work initiative, shorten the working hours per day, and improve the social support for workers in the finance or insurance industry (39). However, these results needed to be proved by better study design, and be confirmed in further studies.

Our study found that unemployment was associated with a decrease in sperm density and total sperm count. One possible explanation for this association might be that unemployment was associated with decreased health (40). The unemployed men formed a very specious group, however, various demographic and lifestyle factors might result in the negative effects on the well-being of the unemployed. Previous studies reported that unemployed men could have more physically deleterious behaviors, such as living an unhealthy diet, alcohol abuse, and smoking (41-43). Moreover, unemployment had a detrimental effect on mental health. Therefore, the decrease in semen quality among unemployed men could also be explained by depression and distress (44). Hence, interventions, therapeutic methods, and job-search training might be beneficial for the increase of employment (45), and then provide useful help for improving semen quality.

We found an elevated risk of decreased sperm density among the semen donors in the entertainment and sports industry, consistent with a previous study in the USA (46). However, a previous study in China (47) supported our results that physical activity could improve semen

quality parameters among healthy men. Several explanations existed for this association between working in the entertainment and sports industry and the decreased semen quality. First, there was a large difference in the intensity of exercise between athletes and ordinary persons. Undoubtedly, moderate exercise was beneficial for a healthy man. A systematic review and meta-analysis (18) pointed out that physical activity was beneficial for men's reproductive health. However, intensive sports practices could have a negative effect on semen quality, such as DNA fragmentation (48). On the contrary, restricting sports activity in athletes could reduce the deleterious effect of sports on semen quality (49). Hence, we speculated that it was the excessive physical activity discrepancy that leads to the increase in semen quality among the workers in entertainment and sports. The second possible reason for the elevated risk might be the use of anabolic-androgenic steroids, which were testosterone derivatives usually used by the workers in the entertainment and sports industry to improve sports performance or enhance appearance.

Our study had notable advantages. Our findings provided new insight into the association between occupational factors and semen quality. We gave an intuitive understanding of what occupation tented to damage semen quality. We found a novel association between working in the finance or insurance industry and the elevated risk of damaged sperm quality. The unemployed men were at high risk of decreased sperm density and total sperm count. Workings in the IT industry was associated with an elevated risk for the progressive motility of sperm. Interestingly, we found that the soldiers and police had the highest semen volume but the lowest sperm motility.

Although we used a large sample of semen donors, our study does have some methodological disadvantages. Firstly, we did not exhaust all the measurement methods to assess semen quality. For example, data on sperm morphology and DNA fragment measurement were not applied in our study, because of incomplete data in these indexes. A prospective cohort study is needed to improve the study quality. Secondly, there was some selection bias in this study. We selected semen donors in a province as the studying population, while some studies studied infertile men [49]. Inevitably, there was a selection bias in either of the two populations. However, a study in the USA [50] proved that the use of semen donors did not raise the risk of selection bias in male fertility studies. Moreover, it is not possible to get an unbiased sample that represents the whole male population. Hence, our study population could be a good representation of male fertility studies. Thirdly, we investigated some lifestyle and occupational factors; however, we did not focus on environmental exposure due to living in polluted areas or other factors such as stress. A previous study (50) conducted in highly polluted areas has suggested the negative role of environmental pollution on semen quality. Furthermore, Levine and colleagues (51) reported that semen quality deteriorated during the summer due to a deleterious effect of heat. Hence, it is important to clarify the association between environmental exposure, psychological stress, and semen quality in future studies. Finally, we did not include the smoking and drinking habits in the current study because we only investigated a few semen donors about their smoking and drinking habit. Moreover, the number of men with drinking habits was only seven, leading to the instability of our models. Hence, a prospective cohort study was warranted, and the association between smoking and semen quality in China needed to be verified in further studies.

To sum up, our study provided new insight into the impact of occupations on semen quality in China. We found decreased effects in some professions, reflecting the association of adverse workstyle with semen quality. In other words, workstyle factors might contribute to the changes in the semen parameters of semen donors. The results of our study suggested the need and importance to avoid adverse occupational hazards to maintain satisfactory semen quality. We should pay more attention to the semen quality of the sedentary workers, unemployed men, the workers in the entertainment and sports industry, and the IT industry. Our findings also suggested keeping good work styles in occupational activities, and our study is of valuable public health significance for human fertility.

Contributors

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

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Data sharing statement

The data that are used in this study are available from the corresponding author upon reasonable request.

Ethics statement

The current study was approved by the medical ethics committee of the Zhejiang maternal, child, and reproductive health center (Ref. No. 2019-002).

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Figure legend

Figure 1. The risk of professions on the semen volume

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 2. The risk of professions on the sperm density

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 3. The risk of professions on the total sperm count

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Figure 4. The risk of professions on the progressive motility of sperm

OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

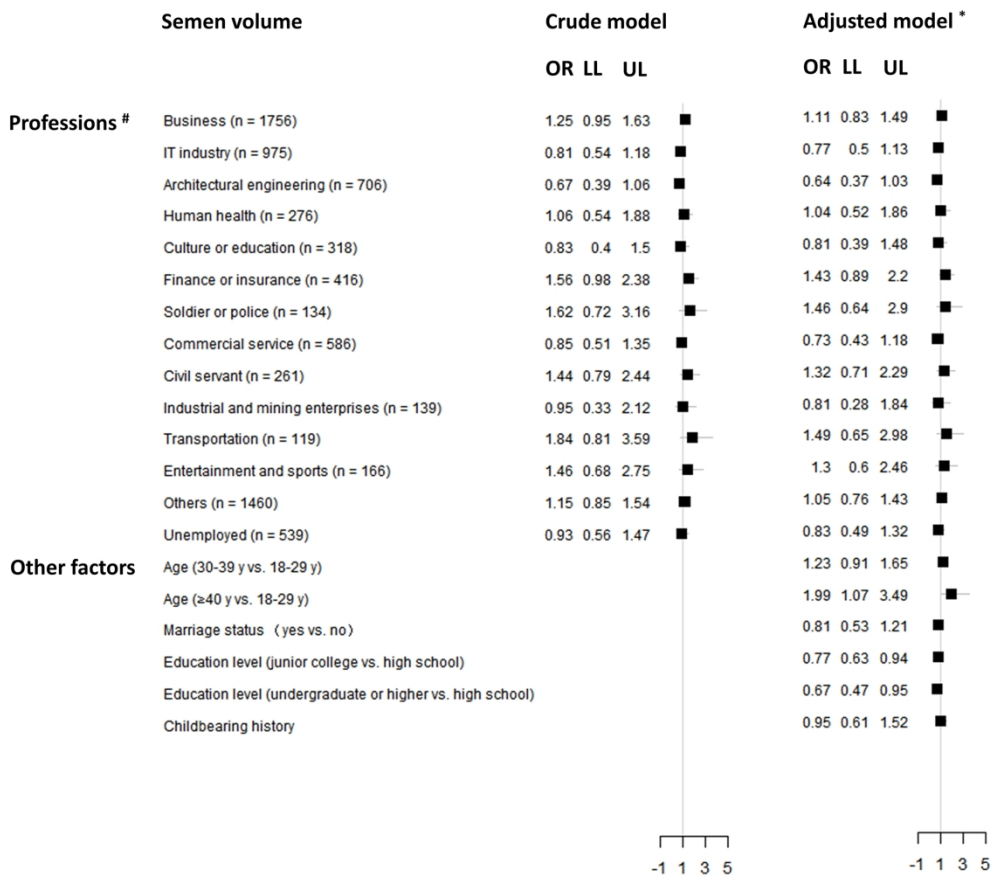

Figure 1. The risk of professions on the semen volume
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

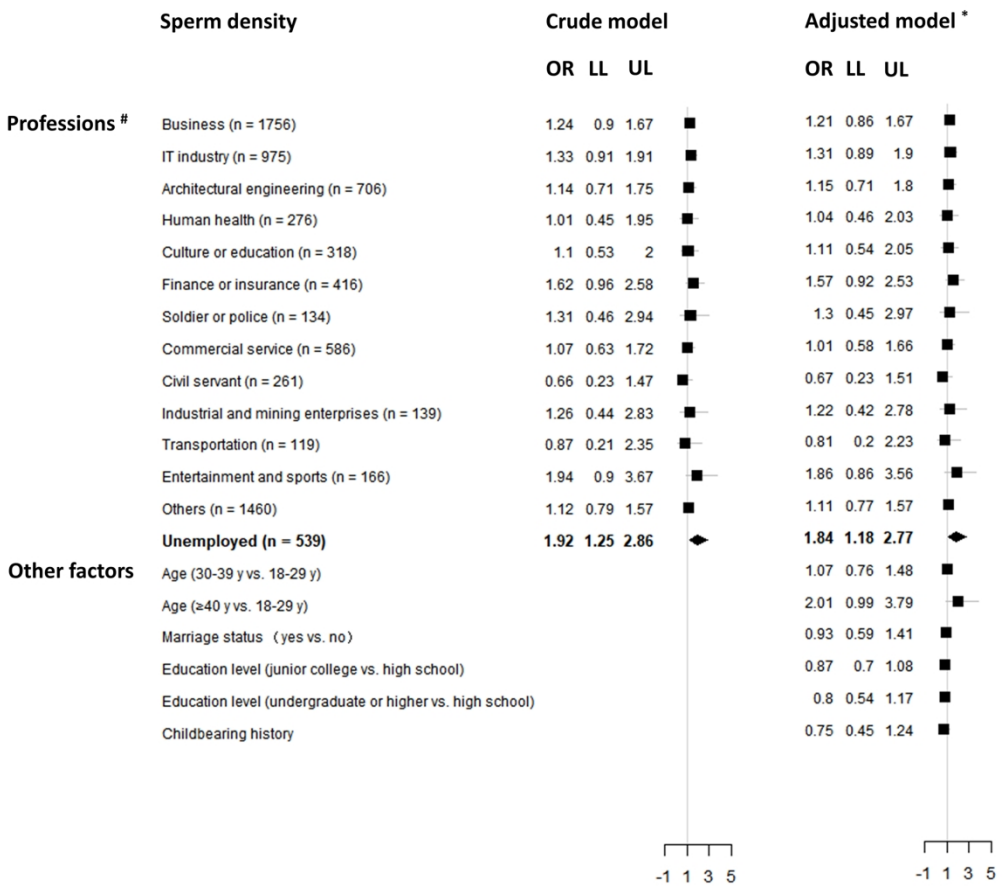

Figure 2. The risk of professions on the sperm density
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

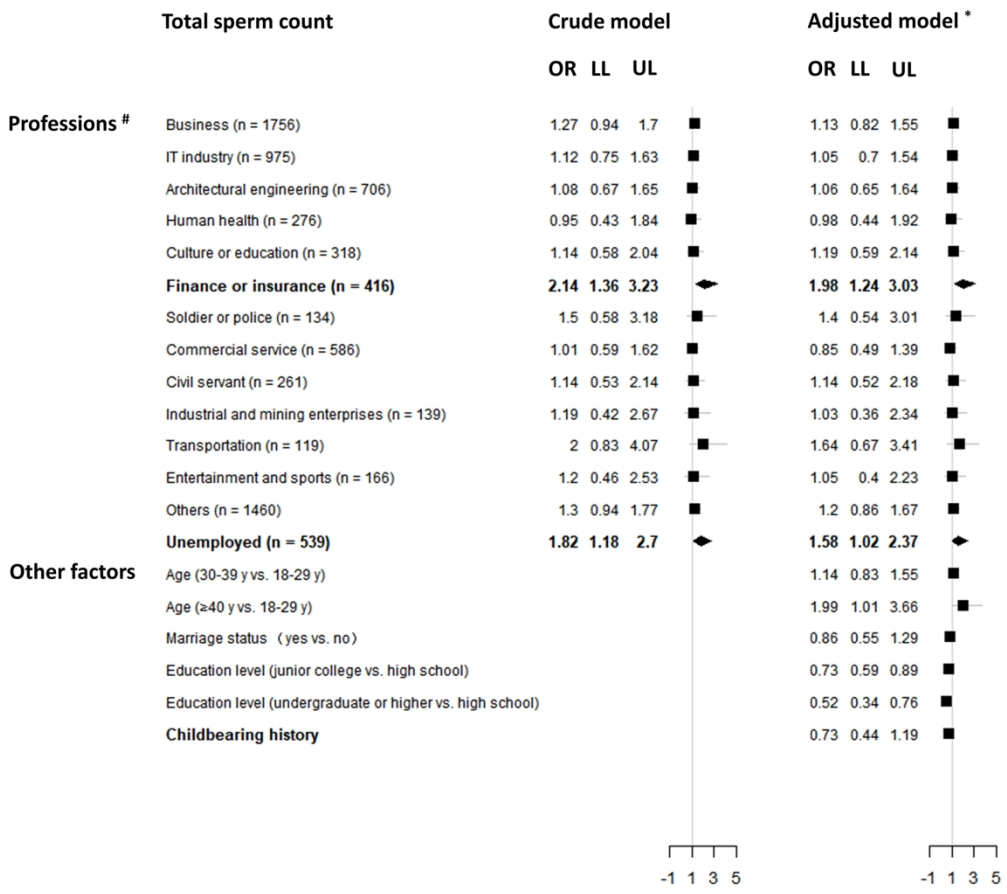

Figure 3. The risk of professions on the total sperm count
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

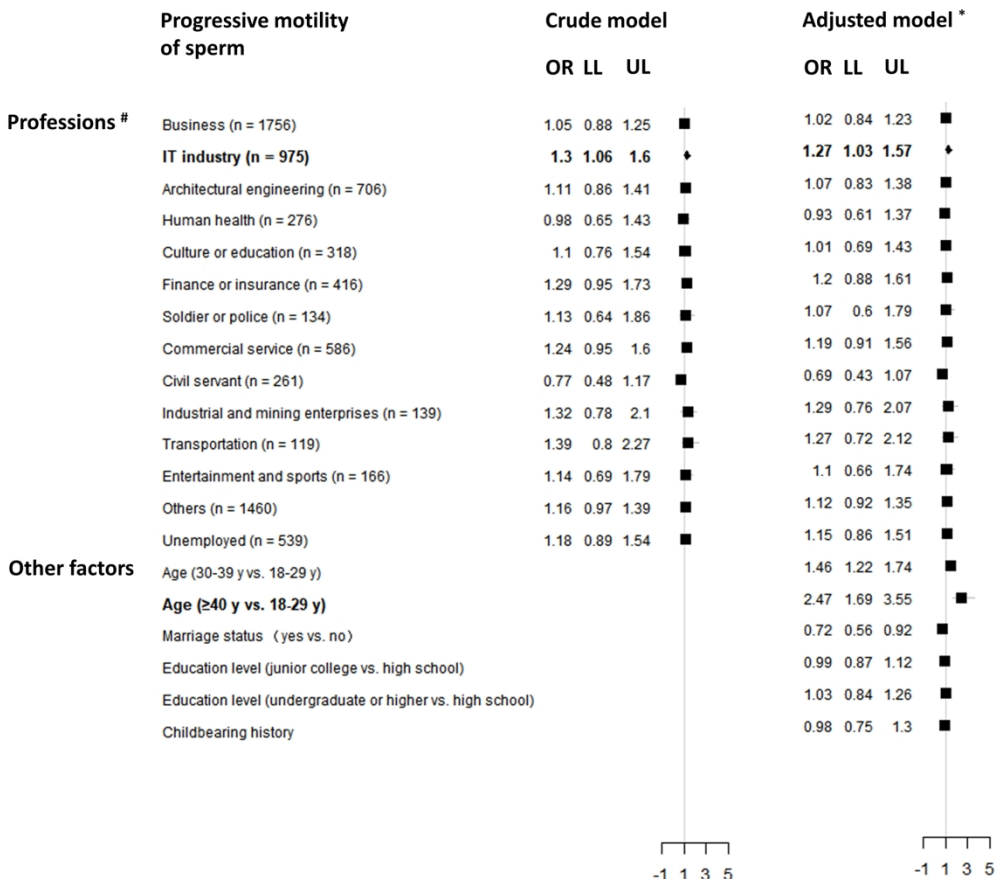

Figure 4. The risk of professions on the progressive motility of sperm
OR: odds ratio; LL: lower level of 95% confidence interval for the odds ratio; UL: upper level of 95% confidence interval for the odds ratio; * adjusted for age, education level, marriage status, and childbearing history; smoking habit, drinking habit, and hypertension were not included into the model due to the small sample size; # the risk of each profession was compared with college students (n = 4450).

Supplementary table 1. Geographic characteristics, life habits, and disease histories of 12,301 semen donors

Characteristic	n (%)
Age, years	
18-30	9996 (81.3)
30-39	2062 (16.8)
40-50	239 (1.9)
Ethnicity	
Han	12054 (98.0)
Others	247 (2.0)
Education	
High school	4669 (38.0)
Junior college	6272 (51.0)
Undergraduate or higher	1360 (11.1)
Marital status	
Unmarried	10033 (81.6)
Married	2169 (17.6)
Divorced	99 (0.8)
Childbearing history	
Never	10720 (87.1)
Ever	1581 (12.9)
Native geographical region	
South	9151 (74.4)
North	3150 (25.6)
Smoking habit	
Non-smoker	4327 (35.2)
Smoker	186 (1.5)
NA	7788 (63.3)
Drinking habit	
Never	4506 (36.6)
Ever	7 (0.1)
NA	7788 (63.3)
Overweight or fat	
No	3901 (31.7)
Yes	608 (5.0)
NA	7792 (63.3)
Hypertension	
No	4495 (36.5)
Yes	10 (0.1)
NA	7796 (63.4)
History of testicular surgery	
No	4511 (36.7)
Yes	2 (0.0)
NA	7788 (63.3)

NA: not available

Supplementary table 2. Semen quality parameters among different professions

Occupation	*n* (%)	Semen volume (ml)	Semen concentration (10^6/ml)	Sperm count (10^6)	Sperm mobility (%)
College students	4450 (36.2)	3.3±1.5	65.9±32.0	226±129	46.8±11.8
Business	1756 (14.3)	3.3±1.6	61.7±30.4	213±128	45.8±11.9
IT industry	975 (7.9)	3.5±1.5	62.3±30.3	221±123	44.8±11.4
Architectural engineering	706 (5.7)	3.6±1.6	63.5±30.3	239±139	45.7±12.0
Human health	276 (2.2)	3.7±1.5	63.6±30.0	234±127	45.2±10.3
Culture or education	318 (2.6)	3.7±1.7	61.7±29.8	229±127	45.1±11.0
Finance or insurance	416 (3.4)	3.3±1.6	62.7±31.3	214±128	45.5±12.4
Soldier or police	134 (1.1)	3.8±1.6	59.6±28.7	225±141	44.7±11.7
Commercial service	586 (4.8)	3.7±1.6	62.5±31.3	229±131	44.8±11.5
Civil servant	261 (2.1)	3.1±1.6	63.6±27.9	210±115	48.0±10.7
Industrial and mining enterprises	139 (1.1)	3.0±1.4	66.3±32.2	210±117	45.5±12.9
Transportation	119 (1.0)	3.3±1.6	62.4±28.9	216±132	45.5±12.3
Entertainment and sports	166 (1.3)	3.0±1.6	61.4±29.4	195±108	49.2±13.0
Others	1460 (11.9)	3.4±1.5	64.0±30.8	219±120	46.8±12.2
Unemployed	539 (4.4)	3.5±1.6	58.4±31.7	208±129	45.5±11.6

IT: Information Technology