Decline in semen quality among 30,636 young Chinese men from 2001 to 2015

Chuan Huang, Ph.D.,[a] Baishun Li, B.S.,[b] Kongrong Xu, M.S.,[a] Dan Liu, M.S.,[a] Jing Hu, M.S.,[b] Yang Yang, B.S.,[b] HongChuan Nie, M.D., Ph.D.,[b] Liqing Fan, M.D., Ph.D.,[a,b] and Wenbing Zhu, M.D., Ph.D.[a,b]

[a] Institute of Reproductive and Stem Cell Engineering, Basic Medicine College, Central South University; and [b] Reproductive and Genetic Hospital of CITIC-Xiangya, Changsha, Hunan, People's Republic of China

Objective: To provide information of semen quality among young Chinese men in the past 15 years.
Design: Retrospective cross-sectional study.
Setting: Sperm bank.
Patient(s): A total of 30,636 young adult men who applied to be sperm donors at the Hunan Province Human Sperm Bank of China in 2001–2015 were included in the study.
Intervention(s): Physical examination and analysis of blood and semen samples.
Main Outcome Measure(s): Semen parameters, such as semen volume, sperm concentration, total sperm count, progressively motile sperm count, sperm progressive motility, sperm morphology, and round cells.
Result(s): Many of the semen parameters showed a decreasing trend over the 15-year observation period. The sperm concentration and percentage of sperm with normal morphology decreased from 68 $\times$ 10^6/mL to 47 $\times$ 10^6/mL and from 31.8% to 10.8%, respectively. Although sperm progressive motility showed irregular variation, the progressively motile sperm count decreased from 34 $\times$ 10^6 to 21 $\times$ 10^6 over the 15-year period. Furthermore, the rate of qualified donors fell from 55.78% in 2001 to 17.80% in 2015, and the rate for 2015 was approximately threefold lower than the corresponding rates in 2001.
Conclusion(s): The semen quality among young Chinese men has declined over a period of 15 years, especially in terms of sperm concentration, total sperm count, sperm progressive motility, and normal morphology. (Fertil Steril® 2017;107:83–8. ©2016 by American Society for Reproductive Medicine.)
Key Words: Chinese young men, semen parameters, semen quality

Discuss: You can discuss this article with its authors and with other ASRM members at https://www.fertstertdialog.com/users/16110-fertility-and-sterility/posts/12173-22765

Semen quality is related to the quality of reproductive health and is a very important factor that reflects male reproductive health. In recent years, numerous reports have indicated that the semen quality in normal men is declining. In the early 1990s, Carlsen et al. (1) reviewed more than 60 papers worldwide and found a trend of decreasing sperm count and seminal fluid volume over the past 50 years. Many researchers were skeptical about the results, and several researchers were prompted to study trends in their own countries. Swan et al. (2) reviewed 101 studies in the literature and verified that there was indeed a decline in sperm count over time. Likewise, Huang et al. (3) reviewed 115 studies from 1985 to 2009 reporting the manual sperm counts of 23,126 healthy Chinese men and reported a possible decline in the semen concentration over that 25-year period. Papers reported heterogeneous findings, with some studies confirming a decreasing trend in semen quality while others did not. For example, Jorgensen et al. (4) showed an increasing trend in sperm concentration and total sperm count in 4,867 young men in Copenhagen, Denmark. Similarly, Zhu et al. (5) reviewed 36 papers and analyzed the semen parameters from 2,318 healthy Chinese men and showed no significant decline in sperm density and semen volume over a 13-year period. Despite differences, several studies have reported relatively poor semen quality in their study populations (6–8), and

Received July 13, 2016; revised and accepted September 16, 2016; published online October 25, 2016.
C.H. has nothing to disclose. B.L. has nothing to disclose. K.X. has nothing to disclose. D.L. has nothing to disclose. J.H. has nothing to disclose. Y.Y. has nothing to disclose. H.N. has nothing to disclose. L.F. has nothing to disclose. W.Z. has nothing to disclose.
Supported the Fundamental Research Funds for the Central Universities of Central South University (grant 2015zzts102).
Reprint requests: Wenbing Zhu, M.D., Ph.D., Reproductive and Genetic Hospital of CITIC-Xiangya, No. 87, Xiangya Road, Changsha, Hunan 410008, People's Republic of China (E-mail: zhuwenbing0971@sina.com).

Fertility and Sterility® Vol. 107, No. 1, January 2017 0015-0282/$36.00

http://dx.doi.org/10.1016/j.fertnstert.2016.09.035

very few long-term studies on the trends in semen quality have been carried out in the same laboratory in China.

To our knowledge, no long-term studies on semen quality in the Chinese population have been published so far. The present study aimed to investigate whether the semen parameters in young Chinese men have declined over the past 15 years. To this end, we retrospectively reviewed the semen parameters of a population of young adult men applying for consideration as sperm donors in Hunan, China, from 2001 to 2015.

MATERIALS AND METHODS

Study Population

In this retrospective study, we reviewed the semen analysis database of young adult men who applied to be sperm donors at the Hunan Province Human Sperm Bank of China from August 30, 2001, to December 31, 2015. Relevant demographic and clinical information of all of the men was collected and analyzed. Demographic information included age, height, weight, smoking and drinking history, and duration of abstinence. Clinical information included semen parameters and the date of semen analysis.

All donors signed informed consent forms during their first visit to the human sperm bank, agreeing that their semen samples or data could be used by the human sperm bank for scientific research. The present study was approved by the Ethics Committee of the Reproductive and Genetic Hospital of CITIC-Xiangya (LL-SC-SG-2015-003).

Semen Analysis

A total of 71,353 specimens from 30,636 young adult men were included in the analysis. Specimens were collected by means of masturbation into a sterile container after 2–7 days of abstinence. All specimens were assessed according to the World Health Organization (WHO) 1999 recommendations (9). After liquefaction and within 1 hour of ejaculation, the samples were analyzed for semen volume and sperm concentration, round cells, normal morphology, and sperm motility (defined as WHO motility grades A, B, C, and D, where grade A indicates fast progressive sperm, B slow progressive sperm, C nonprogressive sperm, and D immotile sperm). Sperm morphology was evaluated by means of the modified Papanicolaou staining method, and apart from the normal forms, any defects in the head, midpiece, and tail were recorded.

Criteria for Screening Sperm Donors in China

The recruitment methods for sperm donors include handing out leaflets, conducting lectures in schools, and network publicity by technicians. The screening of sperm donors is conducted in strict accordance with the standard guidelines published by the Chinese Ministry of Health in 2003. The guidelines are as follows (10): 1) Donors must be from 22 to 44 years of age; 2) donors must have a college degree or above, and height not less than 1.70 m; 3) donors must be in good health, based on the results of both physical examination and psychologic evaluation by qualified doctors, and have no familial history of genetic disease; 4) fresh semen should have a liquefaction time of <60 minutes, sperm concentration $\geq 60 \times 10^6$/mL, progressive sperm motility of $\geq 60\%$, and percentage of normal morphology $>30\%$; 5) post-thaw semen should have a motility of $\geq 40\%$, $\geq 12 \times 10^6$ motile sperm, and a frozen-thaw survival rate of $\geq 60\%$; and 6) potential donors must undergo laboratory testing to exclude individuals at high risk for sexually transmitted infections and genetic diseases, including human immunodeficiency virus 1 and 2, hepatitis B and C, syphilis, gonorrhea, mycoplasma, chlamydia, cytomegalovirus, *Toxoplasma gondii*, rubella virus, herpes simplex virus types 1 and 2, and karyotype analysis. If the patient tests negative for all of the above tests and fulfills the Chinese Ministry of Health guidelines outlined above, the donation process is initiated and the semen samples are cryopreserved. The samples must be cryopreserved for a minimum 6-month quarantine period before rescreening for HIV. The way of recruiting and criteria for screening sperm donors have not been changed over time.

Statistical Analysis

Because semen parameters follow markedly skewed (nonnormal) distributions, unadjusted mean and median values, standard deviation (SD), and 5th to 95th percentiles were calculated for each variable. Percentages coinciding with WHO recommendations (1999, 2010) (9, 11) were also calculated. The study subjects were divided into three groups depending on the investigation periods: 2001–2005, 2006–2010, and 2011–2015. Between-group differences for continuous variables were tested by means of the nonparametric Kruskal-Wallis test. Statistical data were analyzed with the use of the Statistical Package for the Social Sciences (SPSS) 18.0. A P value of $<.05$ was considered to be statistically significant.

RESULTS

Subject Characteristics

The general demographic characteristics of the 30,636 men (including 3,114, 10,386, and 17,136 in the 2001–2015, 2006–2010, and 2011–2015 groups, respectively) are summarized in Table 1. No differences were found between the three groups in age ($P=.79$), height, weight, body mass index, abstinence times, and alcohol drinking and smoking habits over the study period.

Semen Parameters

The semen parameters of the study subjects are described in Table 2. As presented in the table, the semen volume and total count were within the high-normal values (82.3% and 78.2%, respectively, according to the 1999 WHO criteria and 89.6% and 85.4% according to the 2010 WHO criteria). However, the semen parameters, especially sperm progressive motility, among a large proportion of the study subjects were below the lower threshold of the WHO criteria. Additionally, only 50.7% of the semen samples had normal semen parameters according to the WHO 2010 criteria. At least one parameter in ~49.3% and 58.9% of the semen samples was below the

TABLE 1

Demographic characteristics of participants.

Characteristic	2001–2005 (n = 3,114) Mean (SD)	2001–2005 (n = 3,114) Median (5th–95th %ile)	2006–2010 (n = 10,386) Mean (SD)	2006–2010 (n = 10,386) Median (5th–95th %ile)	2011–2015 (n = 17,136) Mean (SD)	2011–2015 (n = 17,136) Median (5th–95th %ile)	Difference among the three groups (*P* value)
Age (y)	21.6 (3.1)	21.0 (19.0–24.0)	21.4 (2.3)	21.0 (19.0–24.0)	21.9 (2.8)	21.0 (19.0–28.0)	.79
Height (m)	1.72 (0.04)	1.72 (1.66–1.80)	1.72 (0.04)	1.72 (1.65–1.80)	1.73 (0.04)	1.72 (1.65–1.81)	.27
Weight (kg)	62.6 (7.0)	62.0 (53.0–74.0)	62.8 (8.9)	62.0 (52.0–75.0)	63.8 (8.3)	63.0 (52.0–80.0)	.53
Body mass index (kg/m^2)	21.1 (2.0)	20.9 (18.4–24.2)	21.1 (5.2)	20.8 (18.2–24.6)	21.3 (2.4)	21.0 (18.0–26.0)	.38
Abstinence (d)	4	4 (2–7)	4	3 (2–7)	4	3 (2–7)	.46
Smokers (%)		7.7		8.2		7.9	.25
Drinkers (%)		36.5		34.7		32.8	.07

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.

normal threshold value according to the WHO 2010 and 1999 criteria, respectively.

Changes in Semen Parameters

Table 3 and Supplemental Figure 1 (available online at www.fertstert.org) present the changes in the semen parameters among the study participants. The semen parameters exhibited a decreasing trend over the past 15 years. The semen volume and round cells did not significantly differ among the three groups ($P=.07$ and $P=.36$, respectively). However, the sperm concentration, total sperm count, and normal sperm morphology decreased and the sperm progressive motility showed erratic changes over the 15-year observation period. The sperm concentration and percentage of sperm with normal morphology were decreased from 68×10^6/mL to 47×10^6/mL and from 31.8% to 10.8%, respectively, whereas the sperm progressive motility showed irregular variations, decreasing from 34×10^6 to 21×10^6 over 15 years.

Donors

As presented in Table 4, the percentage of qualified donors also exhibited a decreasing trend over the 15-year period, from 55.78% in 2001 to 17.80% in 2015. The percentage of qualified donors in 2015 was approximately threefold lower than in 2001 and declined by ~40% in the past 15 years. The main reasons for nonrecruitment was unacceptable semen parameters (97.1%, 19,285/19,865), including low sperm concentration (81.9%, 16,272/19,865), followed by low sperm motility, low semen volume, azoospermia, and hematospermia. Approximately 1.6% (319/19,865) of unqualified candidates tested positive for transmitted diseases, and a minority of patients could not be recruited owing to physical examination abnormalities and hereditary or chromosomal disorders (Supplemental Table 1, available online at www.fertstert.org).

DISCUSSION

The analysis of semen includes tests for semen volume, sperm concentration, sperm motility, and morphology. Although alternate tests based on more functional aspects, such as sperm penetration, capacitation, and acrosome reaction have been developed, semen analysis continues to be used as the primary method to determine male fertility, and it plays an important role in andrology. In the present study, we screened and analyzed 71,353 specimens from 30,636 healthy Chinese men. To our knowledge, this is the largest study focusing on the semen quality of young men from the general

TABLE 2

Summary of semen parameters.

Parameter	n	Mean (SD)	Median	Percentile 5th	Percentile 25th	Percentile 75th	Percentile 95th	Normal semen parameters according to the 1999 WHO recommendations (%)[a]	Normal semen parameters according to the 2010 WHO recommendations (%)[a]
Semen volume (mL)	30,636	2.6 (1.1)	2.3	0.8	1.5	3.0	4.5	82.3	89.6
Sperm concentration (million/mL)	30,636	53.4 (31.7)	50.0	11	35	68	93	69.7	81.9
Total sperm count (million)	30,636	127 (68)	130	13	75	198	267	78.2	85.4
Sperm progressive motility (a + b) (%)	30,476[b]	47.5 (22.1)	46	24	38	55	66	43.3	60.8
Normal sperm morphology (%)	30,476[b]	17.2 (8.7)	15.8	3.1	9.3	24.8	34.5	58.5	79.1

[a] Abnormal values of semen parameters were defined by the World Health Organization (WHO) recommendations (1999 and 2010). The 1999 standards: semen volume <2 mL, sperm concentration $<20 \times 10^6$/mL, sperm total count $<40 \times 10^6$, sperm progressive motility <50%, and normal morphology ≤15%. The 2010 standards: semen volume <1.5 mL, sperm concentration $<15 \times 10^6$/mL, sperm total count $<39 \times 10^6$, sperm progressive motility <32%, and normal morphology ≤4%.
[b] Number of sperm without azoospermia.

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.

TABLE 3

Semen quality of 30,636 young men from the general population in Hunan, China.

Variable	2001–2005 Mean (SD)	2001–2005 Median (5th–95th %ile)	2006–2010 Mean (SD)	2006–2010 Median (5th–95th %ile)	2011–2015 Mean (SD)	2011–2015 Median (5th–95th %ile)	Difference among the three groups (*P* value)
Semen volume (mL)	2.8 (1.1)	3.0 (1.5–4.5)	2.6 (1.1)	2.3 (0.8–4.5)	2.5 (1.2)	2.3 (0.8–4.5)	.07
Sperm concentration (million/mL)	68 (36)	64 (18–130)	58 (32)	60 (12–110)	47 (25)	50 (10–80)	.00
Total sperm count (million)	182 (69)	177 (22–338)	144 (67)	137 (9–297)	119 (74)	114 (13–236)	.00
Progressive motile sperm count (a + b) (million)	34 (20)	31 (7–71)	27 (19)	24 (5–55)	21 (35)	20 (1–39)	.00
Sperm progressive motility (a + b) (%)	50.2 (17.2)	51.6 (25.0–70.8)	43.1 (22.9)	44.8 (24.5–65.2)	47.1 (36.2)	46.0 (25.3–66.4)	.04
Round cells (million)	0.5 (0.4)	0.7 (0.1–3.0)	0.6 (0.9)	0.6 (0.1–2.0)	0.5 (0.7)	0.6 (0.2–2.7)	.36
Normal sperm morphology (%)	31.8 (6.4)	31.0 (22.0–42.0)	20.5 (7.4)	20.1 (11.4–39.4)	10.8 (6.7)	10.6 (2.5–34.6)	.00
Normal semen parameters according to the 1999 WHO recommendations (%)		66.3		47.1		32.9	.00
Normal semen parameters according to the 2010 WHO recommendations (%)		76.7		56.5		42.4	.00

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.

population in China and is the first to report the long-term semen quality trends within a single laboratory in China.

We analyzed the semen quality from 30,636 young men from Hunan Province, China. Our findings were not in complete agreement with the semen parameters observed in several other studies in young Chinese men. The semen quality of the young Chinese men in our study was not optimal, although the mean and median values of semen volume in our study (2.6 and 2.3 mL, respectively) were similar to those reported in previous studies in China (12–17). The mean sperm concentration and total sperm count in our study (53.4×10^6/mL and 127×10^6, respectively) were markedly lower than those reported previously, ranging from $50.2–84.8 \times 10^6$/mL and from $124.1–206.9 \times 10^6$, respectively. The mean normal sperm morphology in our study (15.8%) was also observably lower than in some of the previous studies, where it ranged from 9.5% to 68%. The discrepancies between the previous studies and ours may be because previous studies included young men with a broader age range compared with the participants in our study. The mean sperm progressive motility in our study (47%) was similar to that reported in other studies in young Chinese men. In our study, the semen parameters of only 41.1% of the specimens were completely normal according to the 1999 WHO criteria. More recently, WHO revised the semen reference values in 2010 by studying the semen parameter distributions of men whose partners had a time-to-pregnancy (TTP) of up to and including 12 months; these new WHO criteria (2010) are lower than previous WHO criteria (1999) (18, 19). However, even when the revised (2010) WHO standards were used as reference, semen parameters in only 50.7% of the study participants were all within the normal range. A higher proportion of men in countries had abnormal semen parameters than Chinese men. The mean values of all semen parameters were lower in our study than in studies in other countries in general (4,20–23), especially regarding the mean semen volume, which was lower in Chinese men by 0.6–1.4 mL. The reasons for the reported differences in the semen quality between our study and previously reported studies remain to be understood. It is possible that geographic variations are responsible for the observed differences in semen quality, and these regional variations result from different interactions among lifestyle, other environmental factors, and genetic variations, or a combination of these factors.

Since the founding of the Human Sperm Bank, all of the technicians working in the laboratory have received the same training. All semen samples were analyzed by five well trained laboratory technicians with the use of the same apparatus, and efforts were made to keep the technique of semen analysis unchanged. As such, the change in semen parameters

TABLE 4

Percentage of qualified sperm donors from 2001 to 2015.

Year	New sperm donors, n	Qualified donors, n	Qualified donors, %
2001	95	53	55.78
2002	366	193	52.73
2003	598	314	52.51
2004	803	409	50.93
2005	1,252	611	48.80
2006	1,564	718	45.91
2007	2,244	1,096	48.84
2008	1,925	781	40.57
2009	2,107	979	46.46
2010	2,546	965	37.90
2011	2,628	849	32.31
2012	2,133	823	38.56
2013	3,031	1,019	33.61
2014	4,523	1,103	24.39
2015	4,821	858	17.80

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.

can not be attributed to variations in laboratory technique or laboratory technicians. And internal quality control measures were performed to avoid drift over time.

The debate on declining semen quality is still ongoing (24). In contrast to the findings of the present study, Jørgensen et al. (4) reported that semen quality among young Danish men from the general population of Denmark showed an increasing trend in sperm concentration and total sperm count from 1996 to 2010. Our study clearly indicated that sperm concentration, sperm count, motility, and normal morphology of sperm showed a significant and continuous decrease over the 15-year observation period. This declining tendency was constant throughout but was more evident for sperm concentration. Centola et al. (25) reported a decline in sperm count and motility among young adult men in the Boston area during the past 10 years. Mendiola et al. (26) suggested that the total sperm count and sperm concentration may have declined in young southern Spanish men from 2001 to 2011. Similarly, Rolland et al. (27) showed an annual decrease of 1.9% in the sperm concentration, a significant but not quantifiable decrease in morphologically normal sperm, and a significant increase in total motility over a 17-year period in their study population in France. As presented in Table 4 and Supplemental Table 1, the rate of qualified donors showed a decreasing trend, with the main reason for nonrecruitment being unacceptable semen parameters. Together, these findings indicated that semen quality showed a significant and continuous declining trend over the 15-year study period. On the other hand, a recent comprehensive review of the 1992 meta-analysis and subsequent reports suggested that sperm counts are not declining (28). However, the data reported in the present study are particularly relevant, because the global decline in semen quality may lead to an increase in the numbers of men falling into the subfertile range in terms of semen parameters (29). Indeed, there has been an increasing opinion that the criteria and reference ranges for screening sperm donors in China should be reconsidered.

In the present study, we analyzed the semen quality in a regional homogeneous population, apparently living under the same climatic and environmental conditions. However, the reasons for the decline in semen parameters are unclear from the present study. Some studies (30, 31) have shown that smoking and alcohol consumption have a negative effect on semen parameters, but in the present study there was no significant difference in the semen parameters between men who smoked or drank alcohol and those who did not over the 15 years; therefore, we speculated that there may have been risk factors besides smoking and alcohol consumption that affected the semen quality. Over the past two decades, there has been a rapid pace of economic and social change in China, and this has been followed by increased environmental pollution, including pollution of water, air, and food. This pollution has been reported to have high levels that may alter men sperm quality (32–34). Therefore, we speculated that pollution may be one of the causes of the decline in semen quality. In addition, nowadays, young men experience greater psychologic stress from study, work, and emotional problems, which also adversely affect semen quality (35). Lifestyle changes are another key factor that should not be ignored, and an increasing number of reports have confirmed that the widespread use of mobile phones and wireless technologies by young men has an impact on sperm quality. Yildirim et al. (36) indicated a negative correlation between wireless internet and mobile phone use duration and total sperm count. Similarly, Wang et al. (37) found that mobile phone radiation reduces the progressive motility and viability of human sperm and increases sperm head defects and early apoptosis of sperm cells. In addition, irregular living habits of young men, including staying up late, playing computer games, and staying overnight in bars, also can cause a decline in sperm quality (17). There is no doubt that the reasons for the decline in semen parameters are complex and can include factors such as environmental pollution, increased stress, and lifestyle. More data and statistical analyses are required to study the risk factors for decline in sperm quality.

Limitations of the present study include the lack of questionnaire data (e.g., history of diagnosis and previous treatment received) from the young adult men who participated in this study; therefore, we can not provide strong evidence regarding the influence of various risk factors on semen quality (4). Furthermore, our findings may not be based on a community population, because the study group was young and with a limited age range. This study population represents only one geographical area of China, and may not be representative of China as a whole. More studies of this type are needed.

This is the first study to investigate the semen quality of a large population within the same laboratory in China over a long observation period. Our data clearly illustrate that the semen quality in young men in China has been declining over the past 15 years, especially in terms of the sperm concentration, total sperm count, sperm progressive motility, and normal morphology. Moreover, the percentage of qualified donors also showed a decreasing trend during this time period. Although bulk semen parameters (reflected by 95% confidence intervals) overlap substantially throughout the study period, overall, these findings are a serious reproductive health warning, and further studies are warranted to confirm the findings of this study in China and to determine the factors causing this phenomenon.

Acknowledgments: The authors thank Haibo Dai, Qiang Luo, Ming Zou, Liu Xin, and XinYu Long for their assistance in data collection, HuiLan Wu and XiuHai Huang for data management, and the young men for their participation.

REFERENCES

1. Carlsen E, Giwercman A, Keiding N, Skakkebaek NE. Evidence for decreasing quality of semen during past 50 years. BMJ 1992;305:609–13.
2. Swan SH, Elkin EP, Fenster L. The question of declining sperm density revisited: an analysis of 101 studies published 1934–1996. Environ Health Perspect 2000;108:961–6.
3. Huang LP, Li YF, Xiong HY, Cao J. Trend of change in semen quality in Chinese healthy men over recent 25 years. Reprod Contracept 2011;2:122–39.
4. Jorgensen N, Joensen UN, Jensen TK, Jensen MB, Almstrup K, Olesen IA, et al. Human semen quality in the new millennium: a prospective cross-

sectional population-based study of 4867 men. BMJ Open 2012;2:e000990.
5. Zhu XQ, Shen Y, Zhang XY, Chang Y, Huang X. Trend Analysis of Sperm Quality During the Past 13 Years in China. J Zhejiang Univ 2000;29:173–6.
6. Bonde JP, Ernst E, Jensen TK, Hjollund NH, Kolstad H, Henriksen TB, et al. Relation between semen quality and fertility: a population-based study of 430 first-pregnancy planners. Lancet 1998;352:1172–7.
7. Guzick DS, Overstreet JW, Factor-Litvak P, Brazil CK, Nakajima ST, Coutifaris C, et al. Sperm morphology, motility, and concentration in fertile and infertile men. N Engl J Med 2001;345:1388–93.
8. Slama R, Eustache F, Ducot B, Jensen TK, Jorgensen N, Horte A, et al. Time to pregnancy and semen parameters: a cross-sectional study among fertile couples from four European cities. Hum Reprod 2002;17:503–15.
9. World Health Organization. WHO laboratory manual for the examination and processing of human semen. 4th ed. 1999.
10. Ping P, Zhu WB, Zhang XZ, Li YS, Wang QX, Cao XR, et al. Sperm donation and its application in China: a 7-year multicenter retrospective study. Asian J Androl 2011;13:644–8.
11. World Health Organization. WHO laboratory manual for the examination and processing of human semen. 5th ed. 2010.
12. Junqing W, Qiuying Y, Jianguo T, Wei Y, Liwei B, Yuxian L, et al. Reference value of semen quality in Chinese young men. Contraception 2002;65:365–8.
13. Liu M, Ma C, Tang L, Wen R, Deng S, Wang Q, et al. [Quality analysis of the primary semen samples from 512 donors]. Zhonghua Nan Ke Xue 2004;10:734–6.
14. Gao J, Gao ES, Walker M, Yang Q, Wu JQ, Zhu QX, et al. Reference values of semen parameters for healthy Chinese men. Urol Int 2008;81:256–62.
15. Li Y, Lin H, Ma M, Li L, Cai M, Zhou N, et al. Semen quality of 1346 healthy men, results from the Chongqing area of southwest China. Hum Reprod 2009;24:459–69.
16. Jiang M, Chen X, Yue H, Xu W, Lin L, Wu Y, et al. Semen quality evaluation in a cohort of 28213 adult males from Sichuan area of south-west China. Andrologia 2014;46:842–7.
17. Rao M, Meng TQ, Hu SH, Guan HT, Wei QY, Xia W, et al. Evaluation of semen quality in 1808 university students, from Wuhan, Central China. Asian J Androl 2015;17:111–6.
18. World Health Organization. Laboratory manual for the examination of human semen and semen–cervical mucus interaction. Geneva: World Health Organization; 1999.
19. Cooper TG, Noonan E, von Eckardstein S, Auger J, Baker HW, Behre HM, et al. World Health Organization reference values for human semen characteristics. Hum Reprod Update 2010;16:231–45.
20. Axelsson J, Rylander L, Rignell-Hydbom A, Giwercman A. No secular trend over the last decade in sperm counts among Swedish men from the general population. Hum Reprod 2011;26:1012–6.
21. Mendiola J, Jorgensen N, Andersson AM, Stahlhut RW, Liu F, Swan SH. Reproductive parameters in young men living in Rochester, New York. Fertil Steril 2014;101:1064–71.
22. Jorgensen N, Vierula M, Jacobsen R, Pukkala E, Perheentupa A, Virtanen HE, et al. Recent adverse trends in semen quality and testis cancer incidence among Finnish men. Int J Androl 2011;34:e37–48.
23. Iwamoto T, Nozawa S, Mieno MN, Yamakawa K, Baba K, Yoshiike M, et al. Semen quality of 1559 young men from four cities in Japan: a cross-sectional population-based study. BMJ Open 2013;3.
24. Andersson AM, Jorgensen N, Main KM, Toppari J, Rajpert–de Meyts E, Leffers H, et al. Adverse trends in male reproductive health: we may have reached a crucial "tipping point". Int J Androl 2008;31:74–80.
25. Centola GM, Blanchard A, Demick J, Li S, Eisenberg ML. Decline in sperm count and motility in young adult men from 2003 to 2013: observations from a U.S. sperm bank. Andrology 2016;4:270–6.
26. Mendiola J, Jorgensen N, Minguez-Alarcon L, Sarabia-Cos L, Lopez-Espin JJ, Vivero-Salmeron G, et al. Sperm counts may have declined in young university students in southern Spain. Andrology 2013;1:408–13.
27. Rolland M, Le Moal J, Wagner V, Royere D, de Mouzon J. Decline in semen concentration and morphology in a sample of 26,609 men close to general population between 1989 and 2005 in France. Hum Reprod 2013;28:462–70.
28. Pastuszak AW, Lamb DJ. Counting your sperm before they fertilize: are sperm counts really declining? Asian J Androl 2013;15:179–83.
29. Murray KS, James A, McGeady JB, Reed ML, Kuang WW, Nangia AK. The effect of the new 2010 World Health Organization criteria for semen analyses on male infertility. Fertil Steril 2012;98:1428–31.
30. Pourentezari M, Talebi AR, Mangoli E, Anvari M, Rahimipour M. Additional deleterious effects of alcohol consumption on sperm parameters and DNA integrity in diabetic mice. Andrologia 2016;48:564–9.
31. Sharma R, Harlev A, Agarwal A, Esteves SC. Cigarette smoking and semen quality: a new meta-analysis examining the effect of the 2010 World Health Organization laboratory methods for the examination of human semen. Eur Urol 2016.
32. Fathi Najafi T, Latifnejad Roudsari R, Namvar F, Ghavami Ghanbarabadi V, Hadizadeh Talasaz Z, Esmaeli M. Air pollution and quality of sperm: a meta-analysis. Iran Red Crescent Med J 2015;17:e26930.
33. Deng Z, Chen F, Zhang M, Lan L, Qiao Z, Cui Y, et al. Association between air pollution and sperm quality: a systematic review and meta-analysis. Environ Pollut 2016;208:663–9.
34. Adamopoulos DA, Pappa A, Nicopoulou S, Andreou E, Karamertzanis M, Michopoulos J, et al. Seminal volume and total sperm number trends in men attending subfertility clinics in the greater Athens area during the period 1977–1993. Hum Reprod 1996;11:1936–41.
35. Gollenberg AL, Liu F, Brazil C, Drobnis EZ, Guzick D, Overstreet JW, et al. Semen quality in fertile men in relation to psychosocial stress. Fertil Steril 2010;93:1104–11.
36. Yildirim ME, Kaynar M, Badem H, Cavis M, Karatas OF, Cimentepe E. What is harmful for male fertility: cell phone or the wireless internet? Gaoxiong Yi Xue Ke Xue Za Zhi 2015;31:480–4.
37. Wang D, Li B, Liu Y, Ma YF, Chen SQ, Sun HJ, et al. [Impact of mobile phone radiation on the quality and DNA methylation of human sperm in vitro]. Zhonghua Nan Ke Xue 2015;21:515–20.

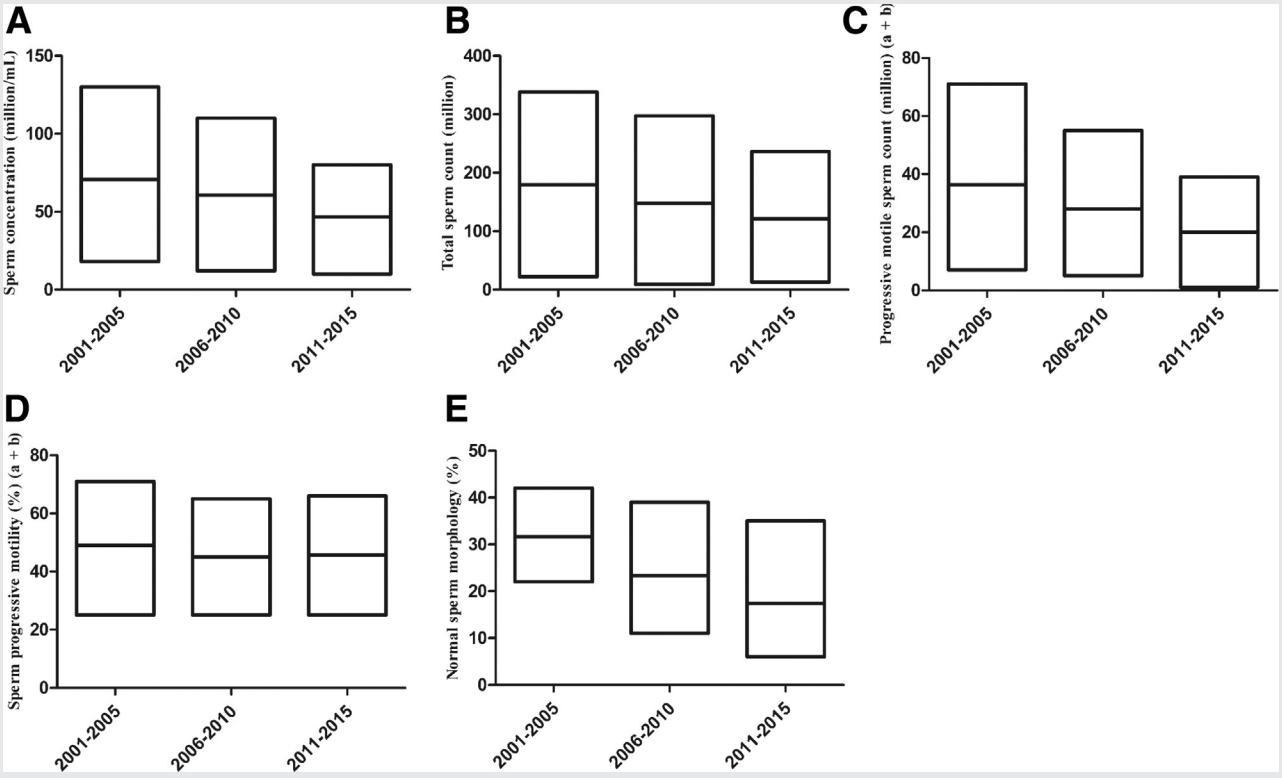
SUPPLEMENTAL TABLE 1

Distribution of 19,865 sperm donors based on reason for exclusion.

Reason for exclusion	n	%
Sperm concentration $<60 \times 10^6$/mL, motility <60%	8,882	44.7
Sperm concentration $<60 \times 10^6$/mL, motility >60%	7,390	37.2
Sperm concentration $>60 \times 10^6$/mL, motility <60%	2,227	11.2
Azoospermia	160	0.8
Semen volume <2 mL	626	3.2
Sexually transmitted diseases	319	1.6
Hereditary or chromosomal disorders	138	0.7
Physical examination abnormality	123	0.6

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.

SUPPLEMENTAL FIGURE 1



Semen quality of 30,636 young men from the general population in Hunan, China. Semen parameters of Chinese young men from the general population. The bars show the 5th to 95th percentiles with median lines. (**A**) Sperm concentration, (**B**) total sperm count, (**C**) progressive motile sperm count, (**D**) sperm progressive motility, and (**E**) normal sperm morphology decreased during the 15-year period.

Huang. Declining semen quality in Chinese men. Fertil Steril 2016.