The Negative Impact of Higher Body Mass Index on Sperm Quality and Erectile Function: A Cross-Sectional Study Among Chinese Males of Infertile Couples

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Abstract
The objective of the current study was to explore the role of body mass index (BMI) in sperm quality and erectile function in Chinese males of infertile couples. A total of 28 fertility centers in different regions of China were enrolled. Patient data were collected from June 1, 2017, through October 31, 2017. Semen analyses and demographic data were collected and the five-item International Index of Erectile Function (IIEF-5) questionnaire was used to evaluate the erectile function in participants with different BMIs. In total, 3,174 Chinese men of infertile couples with an average age of 33.11 ± 6.08 years were enrolled. The occurrence of obesity, overweight, normal weight, and underweight were 5.4%, 36.6%, 56.8%, and 1.2%, respectively. In addition to hypertension and diabetes, primary infertility, a longer course of infertility, and chronic prostatitis were risk factors for obesity. Compared with men of normal weight, adjusted odds ratios (ORs) for men with obesity, overweight, and underweight for semen volume <2 ml were 2.53 (95% CI [1.61, 3.97]), 1.33 (95% CI [1.09, 1.62]), and 0.84 (95% CI [0.29, 2.43]); for sperm progressive motility (A + B) (%) <32, the ORs were 1.60 (95% CI [1.16, 2.22]), 1.30 (95% CI [1.12, 1.51]), and 1.03 (95% CI [0.54, 1.98]); and for IIEF-5 ≤21, the ORs were 1.52 (95% CI [1.10, 2.10]), 1.11 (95% CI [0.96, 1.30]), and 0.62 (95% CI [0.31, 1.26]), respectively. Obesity was associated with lower semen volume, lower sperm motility, and erectile dysfunction in Chinese males of infertile couples.

Keywords
body mass index, erectile function, obesity, sperm motility, sperm volume

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Obesity is a metabolic disorder in which excessive fat has accumulated and may impair overall health. Body mass index (BMI), which is calculated by dividing body mass by the square of body height, is the indicator usually used to evaluate obesity. Individuals are considered overweight when their BMI is >25 kg/m² and obese when the BMI is >30 kg/m². Obesity is associated with multiple diseases and conditions, particularly hypertension, diabetes mellitus, respiratory diseases, osteoarthritis, and certain cancers (Gajalakshmi et al., 2018; Kotsis et al., 2018; Lin et al., 2018; Maccioni et al., 2018; Pozzobon, Ferreira, Blyth, Machado, & Ferreira, 2018; Sharma, Lee, Youssef, Salifu, & McFarlane, 2017). Various studies have focused on the impact of obesity on male infertility, which is...
Materials and Methods

Study Design and Participants

The current cross-sectional and clinical study focused on the male partners of infertile couples who failed to conceive after 1 year of regular intercourse without any contraceptive device. The participating men were recruited from 28 urologic clinics in different regions of China from June 1, 2017, through October 31, 2017. The inclusion criteria of the enrolled participants were (a) men living day to day with their female partners and planning to have a baby; (b) couples failing to conceive after 1 year of unprotected regular intercourse; and (c) men attending urologic clinics for their infertility with semen samples analyzed. The exclusion criteria were (a) men with severe cardiovascular disorders, psychiatric diseases, testicular cancer, or a visible genital malformation; (b) men with factors interfering with sperm quality, such as history of surgery on the vasa deferentia, heat exposure to the testis, testicular trauma, taking antipsychotic or chemotherapeutic drugs, a Y chromosome deletion, varicocele, high semen leukocyte count (<10⁶/ml), or numerical or structural chromosome abnormalities; and (c) men whose female partners had an abnormality of the reproductive system according to a gynecological examination. Ethical approval for this study was obtained from the Medical Research Ethics Committee of (Peking Union Medical College Hospital, China). Participation was completely voluntary and anonymous. All patients in the current study signed informed consents.

Questionnaire Survey and Semen Analyses

All participants completed a questionnaire covering information including age, height, weight, education level, monthly income, current occupational status, smoking, alcohol drinking, marital status (primary or remarried), type of infertility (primary or secondary), duration of infertility, causes for infertility (male, female, mixed factors or unknown), coexisting diseases (hypertension, diabetes, and chronic prostatitis), the five-item International Index of Erectile Function (IIEF-5), intra-vaginal ejaculation latency time (IELT), and sexual desire (high, moderate, or low).

Each enrolled male was required to provide a semen sample by masturbating into a sterile plastic container within 3–7 days of sexual abstinence. Semen analyses were carried out strictly according to the 2010 World Health Organization (WHO) manual. Parameters including semen volume, pH, sperm concentration, and the percentages of sperm with rapid motility (Type A motility, %), progressive motility (Type A + B motility, %), and total motility (Type A + B + C motility, %) were recorded.
Statistical Analysis

The study population was classified into four groups according to their BMI: underweight (<18.5 kg/m²), normal weight (18.5–24.99 kg/m²), overweight (25–29.99 kg/m²), and obese (>30 kg/m²). The χ² test was used to compare categorical data across the four BMI groups. Analysis of variance (ANOVA) test was used for normally distributed continuous data and the Kruskal–Wallis test was used for non-normally distributed continuous data. A multivariable binary logistic regression analysis was performed to obtain adjusted odds ratios (ORs) for possible confounding factors associated with an abnormal BMI. A two-tailed p value <.05 was considered statistically significant. The statistical analysis was performed by SPSS 18 for Windows software (SPSS Inc., Chicago, IL, USA).

Results

Basic Characteristics of the Enrolled Participants

A total of 3,174 males of infertile couples with a mean age of 33.11 ± 6.08 years were included in this study. Their basic characteristics are listed in Table 1. The average BMI of the enrolled participants was 24.58 ± 3.07 kg/m². Among the 3,174 men, 172 were obese (5.4%), 1,161 were overweight (36.6%), 1,803 (56.8%) were normal, and 38 (1.2%) were underweight. Age tended to increase with a higher BMI (p < .001). The incidence of hypertension and diabetes increased in participants with a higher BMI (hypertension: p < .001; diabetes: p = .018). Interestingly, the BMIs of men with primary infertility, a longer course of infertility, or chronic prostatitis were higher than those without (primary infertility: p = .002; longer course of infertility: p < .001; chronic prostatitis: p = .025). Nonsignificant differences were identified in terms of education level, monthly income, smoking, alcohol drinking, occupation, marital status, or cause of infertility between participants with different BMIs.

Association Between BMI and Semen Parameters

As presented in Tables 2 and 3, semen volume varied in the different BMI groups by ANOVA (p = .059). The ORs for men with obesity and overweight for a semen volume ≤2 ml were 1.49 (95% CI [1.04, 2.11]) and 1.17 (95% CI [0.99, 1.39]), respectively, compared with men of normal weight. After adjusting for age, smoking, alcohol drinking, hypertension, diabetes, chronic prostatitis, and duration of infertility, the ORs for men with obesity and overweight for semen volume ≤2 ml were significant (obesity: OR 2.53, 95% CI [1.61, 3.97]; overweight: OR 1.33, 95% CI [1.09, 1.62]).

The results indicated significant differences between the different BMI groups in terms of type A motility, progressive motility, and total motility (type A motility: p < .001; progressive motility: p < .001; and total motility: p = .045). The ORs for men with obesity, overweight, and underweight with sperm progressive motility (A + B) (%) <32 were further calculated. The results indicated significant decreases in progressive sperm motility in patients with obesity and overweight (obesity: OR 1.54, 95% CI [1.11, 2.15]; overweight: OR 1.27, 95% CI [1.09, 1.48]). These results remained significant after adjustment (obesity: OR 1.60, 95% CI [1.16, 2.22]; overweight: OR 1.30, 95% CI [1.12, 1.51]).

No significant differences were reported in terms of sperm concentration and pH value (sperm concentration: p = .886; pH value: p = .832).

Association Between BMI and Sexual Function

The ANOVA results revealed significant differences in the IIEF-5 score between the different BMI groups (p < .001; Table 2). Men with obesity and an IIEF-5 score ≤21 compared with men with normal weight had an OR of 1.48 (95% CI [1.07, 2.05]). This result remained significant after adjustment (OR 1.52, 95% CI [1.10, 2.10]).

No significant differences were found in terms of IELT and sexual desire (IELT: p = .669; sexual desire value: p = .105).

Discussion

Over the past 10 years, many clinical studies have explored the association between semen parameters and obesity; however, the results have been controversial (Bandel et al., 2015; Oliveira et al., 2018; Ramaraju et al., 2018; Shayeb et al., 2011; Taha et al., 2016; Thomsen et al., 2014; Wang et al., 2017). The inconsistency may partly originate from differences in the basic characteristics of the enrolled participants in the different studies, such as ethnicity and the proportion of obese participants. Besides, the study design as well as the inclusion and exclusion criteria also varied among different studies. These differences can result in potential heterogeneity between studies. The huge differences among studies also increased the difficulties for further meta-analyses (Campbell et al., 2015). In the current study, results indicated that obese men of infertile couples were more likely to have a lower semen volume, type A motility, progressive motility (A + B), total motility (A + B + C), and IIEF-5 score than men with normal weight. BMI negatively affected the semen volume, sperm motility, and erectile function in this population.
As a systemic disorder, obesity is associated with various chronic diseases. In the current study, our results indicated that a higher BMI was associated with older subjects, and higher incidence rates of hypertension and diabetes, which was consistent with most studies that have explored the effects of BMI on male reproduction.

### Table 1. Characteristics of the Enrolled Participants According to Different BMI Groups (n = 3,174).

| Parameters                      | Body mass index (kg/m²) |     |     |     | p value |
|---------------------------------|-------------------------|-----|-----|-----|---------|
|                                 | ≤18.5 (n = 38)          | 18.5–24.9 (n = 1,803) | 25.0–29.9 (n = 1,161) | >30 (n = 172) |     |
| Age (years), mean ± SD          | 29.13 ± 3.93            | 32.81 ± 6.01            | 33.72 ± 6.22            | 33.04 ± 5.73 | .001 |
| Education level, n (%)          |                         |                             |                             |               | .853 |
| University and above             | 20 (52.64)              | 921 (51.08)               | 607 (52.28)               | 86 (50.00)    |     |
| High school                      | 9 (23.68)               | 461 (25.57)               | 302 (26.01)               | 40 (23.26)    |     |
| No higher than junior high school| 9 (23.68)               | 421 (23.35)               | 252 (21.71)               | 46 (26.74)    |     |
| Monthly income (W), n (%)       |                         |                             |                             |               | .073 |
| >20,000                          | 1 (2.63)                | 76 (4.21)                 | 54 (4.65)                 | 4 (2.33)      |     |
| 10,001–20,000                    | 5 (13.16)               | 217 (12.04)               | 154 (13.26)               | 16 (9.30)     |     |
| 5,001–10,000                     | 15 (39.47)              | 682 (37.83)               | 401 (34.54)               | 55 (31.98)    |     |
| 2,000–5,000                      | 14 (36.84)              | 681 (37.77)               | 456 (39.28)               | 72 (41.86)    |     |
| <2,000                           | 3 (7.90)                | 147 (8.15)                | 96 (8.27)                 | 25 (14.53)    |     |
| Smoking, n (%)                   |                         |                             |                             |               | .569 |
| No                               | 23 (60.53)              | 959 (53.19)               | 631 (54.35)               | 83 (48.26)    |     |
| Yes                              | 15 (39.47)              | 844 (46.81)               | 530 (45.65)               | 89 (51.74)    |     |
| Alcohol consumption, n (%)       |                         |                             |                             |               | .832 |
| No                               | 28 (73.68)              | 1,018 (56.46)             | 669 (57.62)               | 101 (58.72)   |     |
| Yes                              | 10 (26.32)              | 785 (43.54)               | 492 (42.38)               | 71 (41.28)    |     |
| Occupation, n (%)                |                         |                             |                             |               | .635 |
| Office work                      | 17 (44.74)              | 762 (42.26)               | 498 (42.89)               | 61 (35.47)    |     |
| Manual labor                     | 12 (31.58)              | 763 (42.32)               | 475 (40.91)               | 87 (50.58)    |     |
| Other                            | 9 (23.68)               | 278 (15.42)               | 188 (16.20)               | 24 (13.95)    |     |
| Marital status, n (%)            |                         |                             |                             |               | .095 |
| Primary                          | 33 (86.85)              | 1,540 (85.41)             | 971 (83.63)               | 141 (81.98)   |     |
| Remarried                        | 5 (13.15)               | 263 (14.57)               | 190 (16.37)               | 31 (18.02)    |     |
| Medical history, n (%)           |                         |                             |                             |               | .002 |
| Type of infertility              |                         |                             |                             |               |     |
| Primary                          | 27 (71.05)              | 1,182 (65.56)             | 810 (69.77)               | 130 (75.58)   |     |
| Secondary                        | 11 (28.95)              | 621 (34.42)               | 351 (30.23)               | 42 (24.42)    |     |
| Duration of infertility (years), n (%) |                  |                             |                             |               | .001 |
| ≤2                               | 24 (63.15)              | 882 (48.92)               | 501 (43.15)               | 67 (38.95)    |     |
| >2                               | 14 (36.85)              | 921 (51.08)               | 660 (56.85)               | 105 (61.05)   |     |
| Cause of infertility, n (%)      |                         |                             |                             |               | .108 |
| Known                            | 31 (81.58)              | 1,293 (71.71)             | 833 (71.75)               | 143 (83.14)   |     |
| Unknown                          | 7 (18.42)               | 510 (28.29)               | 328 (28.25)               | 29 (16.86)    |     |
| Hypertension, n (%)              |                         |                             |                             |               | .001 |
| No                               | 38 (100.00)             | 1,724 (95.62)             | 1,071 (92.25)             | 151 (87.79)   |     |
| Yes                              | 0 (0.00)                | 79 (4.38)                 | 90 (7.75)                 | 21 (12.21)    |     |
| Diabetes, n (%)                  |                         |                             |                             |               | .018 |
| No                               | 38 (100.00)             | 1,756 (97.39)             | 1,120 (96.47)             | 163 (94.77)   |     |
| Yes                              | 0 (0.00)                | 47 (2.61)                 | 41 (3.53)                 | 9 (5.23)      |     |
| Chronic prostatitis, n (%)       |                         |                             |                             |               | .025 |
| No                               | 32 (84.21)              | 1,501 (83.25)             | 992 (85.44)               | 153 (88.95)   |     |
| Yes                              | 6 (15.79)               | 302 (16.75)               | 169 (14.56)               | 19 (11.05)    |     |

Note. Data are shown as mean ± standard deviation or n (%). BMI = body mass index.
### Table 2. Semen Analyses and Sexual Function of the Men in Different BMI Groups.

| Parameters and BMI groups | <18.5 (n = 38) | 18.5–24.9 (n = 1,803) | 25.0–29.9 (n = 1,161) | >30 (n = 172) | p value |
|---------------------------|----------------|-----------------------|----------------------|-------------|---------|
| Semen analyses            |                |                       |                      |             |         |
| Semen volume (ml)         | 3.53 ± 0.86    | 3.52 ± 0.85           | 3.46 ± 0.89          | 3.36 ± 0.94 | .059    |
| Sperm concentration (×10⁶) | 35.37 ± 7.78   | 34.77 ± 8.39          | 34.66 ± 8.51         | 34.37 ± 8.34 | .886    |
| Progressive motility (A + B) (%) | 12.61 ± 4.68 | 13.13 ± 5.21          | 11.96 ± 4.35         | 11.67 ± 5.43 | .001    |
| Total motility (A + B + C) (%) | 38.88 ± 13.93 | 38.20 ± 11.01         | 37.02 ± 12.65        | 36.91 ± 15.11 | .045    |
| pH value                  | 7.32 ± 0.65    | 7.35 ± 0.71           | 7.33 ± 0.58          | 7.32 ± 0.61 | .832    |
| Sexual function           |                |                       |                      |             |         |
| IIEF-5                    | 21.39 ± 3.42   | 21.22 ± 3.93          | 20.49 ± 4.01         | 20.47 ± 4.61 | .001    |
| IELT                      | 4.58 ± 1.24    | 4.45 ± 1.38           | 4.44 ± 1.39          | 4.33 ± 1.48 | .669    |
| Sexual desire             |                |                       |                      |             | .105    |
| Weak                      | 4 (10.53)      | 157 (8.70)            | 108 (9.30)           | 18 (10.47) |         |
| Moderate                  | 25 (65.79)     | 1,178 (65.34)         | 780 (67.18)          | 116 (67.44) |         |
| Strong                    | 9 (23.68)      | 468 (25.96)           | 273 (23.52)          | 38 (22.09) |         |

Note. Data are shown as mean ± standard deviation or n (%). BMI = body mass index; IIEF-5 = five-item International Index of Erectile Function; IELT = intravaginal ejaculation latency time.

### Table 3. Association Between Abnormal Semen Parameters or Decreased Sexual Function and BMI in Enrolled Participants.

| Parameters and BMI groups | n/N (%) | Crude odds ratio (95% CI) | p value | Adjusted odds ratio (95% CI) | p value |
|---------------------------|---------|--------------------------|---------|-----------------------------|---------|
| Semen volume <2 ml        | 9/38 (23.68) | 0.98 [0.41, 2.15]       | 1.000   | 0.84 [0.29, 2.43]           | .753    |
| 18.5–24.9                 | 432/1,803 (23.96) | Reference               | –       |                             |         |
| 25.0–29.9                 | 313/1,161 (26.96) | 1.17 [0.99, 1.39]       | .068    | 1.33 [1.09, 1.62]           | .004    |
| >30                       | 55/172 (31.98)   | 1.49 [1.04, 2.11]       | .026    | 2.53 [1.61, 3.97]           | .001    |
| Sperm concentration <15 ×10⁶/ml | 4/38 (10.52) | 0.79 [0.20, 2.25]       | .810    | 0.75 [0.26, 2.14]           | .590    |
| 18.5–24.9                 | 233/1,803 (12.92) | Reference               | –       |                             |         |
| 25.0–29.9                 | 155/1,161 (13.35) | 1.03 [0.83, 1.30]       | .738    | 1.06 [0.85, 1.32]           | .597    |
| >30                       | 25/172 (14.53)   | 1.14 [0.70, 1.80]       | .554    | 1.13 [0.72, 1.79]           | .584    |
| Progressive motility (A + B) (%) < 32 | 19/38 (50.00) | 1.03 [0.51, 2.07]       | 1.000   | 1.03 [0.54, 1.98]           | .912    |
| 18.5–24.9                 | 888/1,803 (49.25) | Reference               | –       |                             |         |
| 25.0–29.9                 | 641/1,161 (55.21) | 1.27 [1.09, 1.48]       | .002    | 1.30 [1.12, 1.51]           | .001    |
| >30                       | 103/172 (59.89)   | 1.54 [1.11, 2.15]       | .008    | 1.60 [1.16, 2.22]           | .004    |
| IELT <2 min               | 4/38 (10.53)     | 0.74 [0.19, 2.09]       | .811    | 0.76 [0.26, 2.16]           | .601    |
| 18.5–24.9                 | 248/1,803 (13.75) | Reference               | –       |                             |         |
| 25.0–29.9                 | 163/1,161 (14.04) | 1.02 [0.82, 1.27]       | .828    | 0.99 [0.80, 1.23]           | .948    |
| >30                       | 29/172 (16.90)   | 1.27 [0.80, 1.95]       | .252    | 1.24 [0.80, 1.90]           | .333    |
| IIEF-5 <22                | 12/38 (31.58)    | 0.61 [0.28, 1.26]       | .186    | 0.62 [0.31, 1.26]           | .189    |
| 18.5–24.9                 | 778/1,803 (43.15) | Reference               | –       |                             |         |
| 25.0–29.9                 | 528/1,161 (45.48) | 1.10 [0.94, 1.28]       | .225    | 1.11 [0.96, 1.30]           | .155    |
| >30                       | 91/172 (52.91)   | 1.48 [1.07, 2.05]       | .016    | 1.52 [1.10, 2.10]           | .010    |

Note. Adjusted odds ratios were obtained after adjusting for age, smoking, alcohol drinking, hypertension, diabetes, chronic prostatitis, and duration of infertility by multivariable binary logistic regression analysis. BMI = body mass index; CI = confidence interval; IIEF-5 = five-item International Index of Erectile Function; IELT = intravaginal ejaculation latency time.
In men of infertile couples, the issue should be a focus. Moreover, IELT and sexual desire were evaluated in this study; however, no significant differences were detected. Androgens are converted to estrogens by the increase of aromatase activity in obese men. Increased levels of estrogens and decreased levels of androgens are associated with a lower sexual desire. This study revealed no significant decrease in sexual desire in obese men of infertile couples. This may have originated from the psychological pressures due to the infertile status of these men, and the percentage of men with high sexual desire in this study was low, which may have influenced the association between sexual desire and BMI.

Several strengths of the current study should be discussed: (a) A large number of overweight and obese men of infertile couples were included in the current study, which reflected the current BMI trends in this population. (b) A larger sample size also enabled adjustment for many potential confounders in the multivariate binary logistic regression analysis. (c) In addition to semen parameters, the IIEF-5, IELT, and sexual desire were evaluated in the current population.

Although a large cohort was included, there were several limitations that should be addressed in the current study: (a) Sperm morphology was not analyzed due to various standards used in the enrolled urologic clinics, which added difficulties during data analyses and interpretation. (b) Hormone levels were not recorded in the current study because of the lack of a standard method to quantify hormone levels in the different diagnostic laboratories across the participating hospitals and centers. (c) Although semen analyses were strictly performed according to the WHO manual, only a single semen sample from each male was obtained in the current study.

Conclusions
Obesity was negatively associated with lower semen volume, lower sperm motility, and ED in Chinese males of infertile couples. Patients with a lower semen volume, lower sperm motility, and ED might benefit from losing weight.

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