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ORIGINAL RESEARCH

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Semen quality and determinants in 1177 male infertility clinic attendees in the central region of China

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Abstract

Background: Infertility affects 15–20% of couples in China, with male factors accounting for nearly half of these cases. This study examines semen quality and its determinants among male infertile patients in Central China, aiming to provide a comprehensive evaluation of semen profiles in this population. **Methods**: A total of 1177 male patients with infertility concerns were analyzed at a specialized reproductive medicine clinic in Central China. Semen analyses were performed, and correlation analyses were conducted based on variables such as age, tobacco use, alcohol consumption, sleep quality and occupation. **Results**: Among the cohort, 46.5% exhibited semen abnormalities. Notably, higher abnormality rates were observed in individuals holding managerial positions and clerical occupations, with a more pronounced effect in the latter. Analysis of single variables revealed a significant association between nocturnal sleep duration and several seminal parameters ($p < 0.05$). Additionally, occupational type significantly influenced progressive motility and the total count of progressively motile spermatozoa ($p < 0.05$). Multifactorial linear regression analysis identified age as a major factor affecting sperm morphology. Furthermore, sleep duration and occupation were significantly correlated with sperm concentration, total sperm count, vitality, progressive motility, and the total count of progressively motile spermatozoa ($p < 0.05$). **Conclusions**: These findings suggest that men of reproductive age in Central China generally have favorable semen quality, potentially due to relatively healthy lifestyles and occupational conditions. To maintain this positive trend, further investigation into lifestyle, occupational and environmental factors is needed. Identifying and addressing potential threats will be essential for protecting male reproductive health in the region.

Keywords

Semen analysis; Male infertility; Lifestyle practices

1. Introduction

Infertility, a major global health challenge and social issue, is defined as the inability to conceive after twelve months of unprotected intercourse. Epidemiological data estimates that infertility affects 10% to 15% of couples worldwide, with male factors contributing to nearly half of these cases [1]. A Global Burden of Disease study reported an annual increase in infertility prevalence of 0.370% among women and 0.291% among men since the 1990s [2], with a significant decline in semen quality as a critical factor contributing to the rising incidence of infertility. In addition, current evidence indicates a persistent downtrend in male semen quality over time [3, 4]. Thus, identifying factors that impair semen quality is essential for developing effective preventative and therapeutic strategies to protect reproductive health.

Male infertility is a complex, multifactorial disorder with diverse phenotypic manifestations. While genetic and iatrogenic factors are well-recognized as primary causes, other factors contributing to male infertility are still being explored. Among these, lifestyle factors such as smoking, alcohol consumption, obesity and sleep duration are considered significant factors [5, 6]. However, there is no consensus on the extent to which these factors impact semen quality, and studies often lack systematic correlative analyses. Present research findings indicate that smoking adversely affects semen quality primarily due to the harmful substances in tobacco, which impair pituitary and testicular function and lead to extensive oxidative stress and apoptosis of reproductive cells or sperm, manifesting as infertility symptoms [7, 8]. In obese individuals, multiple mechanisms may contribute to reduced semen quality, including oxidative stress, increased local testicular temperature, accumulation of toxic substances, decreased function of supporting cells, chronic inflammation, and secondary hypogonadism [9]. Additionally, factors such as sleep duration, occupational chemical exposure, and environmental pollutants may also impact

semen quality. For instance, long-term exposure to polycyclic aromatic hydrocarbons has been linked to damage in sperm chromatin stability and a negative impact on semen quality [10]. Likewise, the quality of sleep has emerged as a potential risk factor for decreased semen quality, though studies on the relationship between sleep duration and semen quality or fertilization rates have produced inconsistent results [11, 12]. Therefore, identifying and addressing these controllable risk factors and optimizing fertility through lifestyle modifications may offer the most practical and cost-effective solutions.

To elucidate the impact of these factors on declining semen quality, we conducted a study at a reproductive center in Central China. This retrospective analysis focused on the semen quality of men seeking conception at their initial visit over the past two years. We examined the relationships between lifestyle factors and various semen parameters to identify potential contributors to semen impairment. The findings aim to provide a theoretical foundation for more targeted approaches in assisted reproductive technologies and andrological diagnostics and treatment.

2. Materials and methods

2.1 Study design and participants

This non-interventional, retrospective cohort study involved 1177 male patients who underwent preconception health assessments at the Reproductive Medicine Center of the Second People's Hospital of Wuhu from September 2021 to May 2023. We included males aged 20–60 years who were seeking evaluation for infertility, with a focus on those from Central China. The study inclusion criteria required participants to have engaged in regular sexual intercourse without contraception for over 12 months without achieving conception. The study also included healthy males from couples experiencing female factor infertility. In addition, all participants needed to have normal physical examinations, including assessments of height, physique, secondary sexual characteristics, hair and subcutaneous fat distribution, and male reproductive organs. The exclusion criteria were: (1) Organic lesions such as testicular, epididymal or vas deferens abnormalities; (2) History of urogenital tract infections, mumps, orchitis, sexually transmitted diseases; (3) Sexual dysfunction, trauma or family history of genetic diseases; (4) Recent history (within the last 3 months) of COVID-19 or other febrile illnesses.

2.2 Questionnaire survey

Trained staff provided the participants with a standardized questionnaire, which collected comprehensive data, including basic demographic information (age, height, body mass), lifestyle habits (such as nighttime sleep duration, smoking status, and drinking habits), medication history, and details of occupational exposure. This standardized approach ensured consistency in data collection across all participants.

2.3 Specimen collection

Participants were instructed to abstain from sexual activity for 2 to 7 days before providing a semen sample via masturbation into a pre-weighed, sterile, wide-mouth collection cup designed for sperm collection. The sample was labeled with the participant's name and the collection time. The color of the specimen was observed, and the semen volume was determined by weighing the collection cup on an electronic scale. The semen's pH was measured using precision test strips. The specimen was then placed in a 37 °C water bath for 20 minutes. After this period, a wet smear was prepared to assess the complete liquefaction of the semen. If liquefaction was not complete after 60 minutes, it was recorded as abnormal, and the sample was either mechanically mixed or treated with bromelain to promote liquefaction. Once fully liquefied, the sample's viscosity was assessed and recorded for any abnormalities.

2.4 Semen quality analysis

A preliminary microscopic examination of the wet semen smear was performed to observe and record sperm agglutination or aggregation to obtain an estimate of sperm concentration and motility, allowing for the determination of the appropriate semen dilution factor for accurate sperm count measurement. The semen sample was thoroughly mixed, and an automated computerized semen analysis system (SQA-Vision, Israel) was used for detailed analysis, measuring parameters such as semen concentration and motility. All semen quality parameters were assessed in accordance with the World Health Organization's "Laboratory Manual for the Examination and Processing of Human Semen (5th Edition)". The reference values included: semen volume $\geq$1.5 mL, pH 7.2–8.0, sperm concentration $\geq 15 \times 10^6$/mL, total sperm count $\geq 39 \times 10^6$, motility $\geq$40%, and progressive motility (PR) $\geq$32%. A semen sample was classified as normal if it met all these criteria; any deviation from these reference values was considered abnormal.

2.5 Statistical analysis

Data were double-entered and verified by dedicated personnel using Excel 2016 (Microsoft Corporation, Redmond, WA, USA) for accuracy. Statistical analysis was performed with SPSS 24.0 software (IBM Corporation, Armonk, NY, USA). Comparisons between two groups were conducted using Student-Newman-Keuls (SNK) and Least Significant Difference (LSD) tests for homogeneity of variance, or Dunnett's T3 test for heterogeneity of variance. Pearson's correlation analysis was used for normally distributed data, while Spearman's correlation analysis was applied for non-normally distributed data, with correlation coefficients denoted by r. Multiple group comparisons were carried out using one-way analysis of variance (ANOVA), with results expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$); frequency (percentage) (n (%)). The χ^2 test was used to compare count data rates among multiple independent groups. A p-value of < 0.05 was considered statistically significant.

3. Results

3.1 Study subjects and semen analysis characteristics

This study included 1177 male patients seeking conception, with a mean age of 30.3 ± 4.9 years. Semen samples were collected after a minimum of 3 days of abstinence in 80% of cases (Table 1). According to the standards outlined in the World Health Organization's "Laboratory Manual for the Examination and Processing of Human Semen (5th Edition)", 630 samples (53.5%) were classified as normal, while 547 samples (46.5%) were classified as abnormal.

Further analysis revealed that while semen volume did not significantly differ between normal and abnormal groups, other parameters such as sperm concentration, total sperm count, total motility, progressive motility and normal morphology rate were significantly reduced in the abnormal semen group. No significant differences in body mass index (BMI) or age were observed between the two groups. Additionally, the proportion of smoking, alcohol consumption, and sleep duration did not significantly differ between the groups. However, occupational exposure appeared to influence semen quality, with a higher rate of abnormalities observed among managers and office workers, particularly office workers. In contrast, military personnel, police officers, and other service industry physical laborers exhibited lower rates of semen abnormalities, with military and police personnel showing a significantly higher number of normal samples compared to other professions. These findings suggest that occupational exposure may be a critical factor contributing to semen abnormalities.

3.2 Univariate analysis of factors influencing semen quality

The Kruskal-Wallis test was employed to assess the influence of various potential risk factors on semen quality. The results indicated significant differences in the normal sperm morphology rate across different age groups, demonstrating a gradual decline with increasing age. However, no statistically significant differences were found in other semen quality parameters among the age groups ($p > 0.05$) (Table 2).

Smoking had a relatively significant effect on semen volume, though other semen quality parameters did not show significant differences related to smoking status. The duration of abstinence significantly affected semen volume, sperm concentration, total sperm count, and total motile sperm count, with longer abstinence correlating positively with these parameters ($p < 0.05$). However, total motility, progressive motility rate, and normal sperm morphology rate did not exhibit significant differences with respect to abstinence duration ($p > 0.05$) (Table 2). Nighttime sleep duration showed a significant correlation with all semen quality parameters. Men with more than 8 hours of sleep had superior semen parameters compared to those with less than 8 hours of sleep (Table 2). Occupational exposure had a notable impact on sperm progressive motility and total motile sperm count ($p < 0.05$), with managers and office workers showing more significant abnormalities compared to military personnel, police officers, and other service industry workers, who had a lower rate of abnormalities. However, body mass index (BMI) and alcohol consumption did not show significant correlations with semen quality parameters ($p > 0.05$) (Table 2).

3.3 Multifactorial correlation analysis of factors influencing semen abnormalities in infertile male patients

Multivariate linear regression analysis was performed with semen abnormalities as the dependent variable and the factors identified as statistically significant in the univariate analysis as independent variables. The results revealed that age is a primary factor affecting sperm morphology. Specifically, an increase in age was significantly associated with a decline in sperm morphology ($p < 0.05$). However, no significant associations were observed between age and other routine semen parameters ($p > 0.05$), and none of the other risk factors showed a significant correlation with these parameters (Table 3). The analysis also demonstrated that sleep duration has a beneficial effect on semen quality. A significant correlation was found between sleep duration and all semen quality parameters, suggesting that longer sleep duration is associated with improved semen quality (Table 3). Regarding occupational category, while no significant correlation was found between occupation and semen volume, significant differences were observed in the associations between occupation and other semen parameters, such as sperm concentration, total sperm count, total motility, progressive motility rate, and total motile sperm count (Table 3), indicating that occupational factors may influence these specific semen parameters.

4. Discussion

The decline in male semen quality over recent decades has been widely documented amidst rapid socio-economic development. Economic advancement has led to increased environmental pollution and unhealthy lifestyles, contributing to deteriorations in semen quality and decreasing global fertility rates [1]. While China lacks comprehensive, multicenter, large-sample epidemiological data to confirm a consistent yearly decline in semen quality, numerous studies have reported suboptimal semen conditions across various provinces and cities [13]. Although the absence of long-term monitoring data from relevant institutions poses a challenge in assessing changes in Chinese male semen quality, the decline observed in some regions is widely acknowledged. Our study, which surveyed 1177 male patients planning for conception in the southern Anhui region along the Yangtze River, found the overall semen quality in this area to be satisfactory. Specifically, the proportion of normal semen samples (53.5%) was 7 percentage points higher than that of abnormal samples (46.5%), surpassing the average level reported in other provinces and cities (47.9%) [14].

Semen analysis remains a key method for assessing male fertility, with abnormalities typically involving low sperm concentration, total count, motility and morphological defects. Male infertility can stem from inherent pathological defects as well as extrinsic factors such as duration of abstinence, environmental exposures, occupational stress, and lifestyle choices [3, 15]. Current research indicates that abstinence

TABLE 1. Basic characteristics of the study population.

Clinical characteristics	Total (n = 1177)	Normal semen samples (n = 630)	Abnormal semen samples (n = 547)	F/χ^2 value	*p*-value
Age (yr), Mean (SD)	30.3 (4.9)	30.6 (4.7)	30.7 (5.1)	2.118	0.146
BMI (kg/m^2), Mean (SD)	22.9 (2.5)	22.9 (2.4)	23.0 (2.5)	2.007	0.157
Abstinence time, n (%)					
<3 d	113 (9.6)	61 (9.6)	53 (9.7)		
3–5 d	947 (80.5)	505 (80.0)	443 (81.0)	0.251	0.616
>5 d	117 (9.9)	65 (10.4)	52 (9.3)		
Smoking status, n (%)					
Non-smoker	674 (57.3)	361 (57.3)	313 (57.2)		
Occasional (<5/d)	171 (14.5)	85 (13.3)	87 (15.9)	2.553	0.110
Frequent (5–10/d)	213 (18.1)	116 (18.4)	97 (17.7)		
Heavy (>10/d)	116 (9.9)	69 (11.0)	50 (9.1)		
Alcohol status, n (%)					
Non-drinker	809 (68.7)	430 (68.3)	388 (70.9)		
Occasional (1–2 times/wk)	303 (25.7)	170 (26.9)	135 (24.7)	0.976	0.323
Frequent (>2 times/wk)	54 (4.6)	30 (4.8)	24 (4.4)		
Sleep time, n (%)					
<4 h	45 (3.8)	19 (3.0)	26 (4.8)		
4–6 h	97 (8.2)	27 (4.3)	70 (12.8)	0.002	0.763
6–8 h	695 (59.1)	389 (61.8)	314 (57.4)		
>8 h	329 (27.9)	195 (30.9)	137 (25.0)		
Career, n (%)					
Manager	144 (12.2)	75 (11.9)	69 (12.6)		
Regular Worker or Service Industry	450 (38.2)	276 (43.8)	184 (33.6)	61.733	<0.001**
Office Worker (Clerical Staff)	362 (30.8)	146 (23.2)	217 (39.7)		
Military or Law Enforcement	92 (7.8)	72 (11.4)	20 (3.7)		
Freelancer	118 (10.0)	61 (9.7)	57 (10.4)		
Semen parameters					
Semen volume (mL), Mean (SD)	3.6 (1.4)	3.6 (1.4)	3.6 (1.5)	0.636	0.425
Sperm concentration (106 per mL), Mean (SD)	70.1 (45.7)	76.1 (43.8)	62.3 (47.2)	11.297	0.001**
Total sperm number (106 per ejaculate), Mean (SD)	237.4 (167.4)	257.9 (158.4)	213.7 (174.3)	18.865	<0.001**
Total motility (%), Mean (SD)	50.5 (15.5)	57.3 (9.3)	42.5 (17.3)	160.209	<0.001**
Progressive motility (%), Mean (SD)	36.6 (14.3)	45.0 (9.0)	26.9 (13.0)	29.903	<0.001**
Normal morphology (%), Mean (SD)	4.0 (2.2)	4.5 (2.1)	3.5 (2.2)	3.544	0.060

***p < 0.01. BMI: body mass index; SD: standard deviation.*

TABLE 2. Univariate analysis of factors affecting semen quality.

Variables	Sperm Concentration	Semen Volume	Total Number of Sperm	Total Motility	Progressive Motility Rate	Number of Progressive Motile Sperm	Rate of Normal Morphology
Age							
≤25 yr	77.85 (46.68)	3.45 (1.39)	256.10 (151.08)	48.83 (14.02)	33.48 (12.98)	100.92 (75.58)	4.26 (2.29)
25–30 yr	68.98 (44.40)	3.57 (1.39)	234.31 (162.20)	50.62 (15.43)	36.71 (14.42)	100.04 (82.71)	4.13 (2.27)
30–35 yr	70.39 (48.39)	3.65 (1.48)	244.49 (185.13)	51.06 (16.22)	37.40 (14.62)	103.51 (84.64)	3.95 (2.17)
≥35 yr	66.80 (41.62)	3.49 (1.43)	215.24 (145.71)	49.27 (14.82)	34.95 (14.00)	92.00 (73.91)	3.58 (1.93)
r	−0.032	0.017	−0.034	0.010	−0.008	−0.001	−0.085
p	0.267	0.561	0.238	0.726	0.780	0.710	0.004**
BMI							
<24	68.79 (45.11)	3.60 (1.42)	235.60 (164.74)	50.38 (15.37)	36.70 (14.10)	100.34 (81.56)	4.00 (2.18)
≥24	71.45 (46.85)	3.52 (1.44)	241.02 (172.64)	50.60 (15.69)	36.35 (14.68)	100.05 (81.57)	4.06 (2.25)
r	−0.008	−0.012	−0.014	0.006	−0.017	−0.008	−0.023
p	0.794	0.670	0.635	0.842	0.552	0.783	0.438
Abstinence Time							
<3 d	62.88 (37.56)	3.37 (1.23)	211.11 (173.86)	50.96 (16.00)	36.60 (15.58)	79.48 (65.59)	3.69 (2.19)
3–5 d	68.85 (45.71)	3.57 (1.42)	231.50 (167.36)	50.39 (15.43)	36.53 (14.29)	97.94 (81.56)	4.07 (2.21)
>5 d	86.83 (61.55)	3.81 (1.61)	310.13 (218.86)	50.49 (14.92)	37.02 (14.47)	138.99 (125.13)	3.90 (2.28)
r	0.113	0.106	0.157	−0.043	0.006	0.151	0.016
p	<0.001**	<0.001**	<0.001**	0.139	0.832	<0.001**	0.585
Smoking Status							
Non-smoker	70.70 (48.00)	3.66 (1.48)	243.33 (177.71)	50.39 (15.14)	36.50 (14.17)	102.55 (85.46)	4.06 (2.19)
Occasional (<5/d)	67.34 (47.70)	3.56 (1.41)	231.35 (161.66)	49.28 (16.86)	35.08 (14.63)	96.17 (81.81)	3.79 (2.16)
Frequent (5–10/d)	69.41 (40.32)	3.41 (1.30)	223.41 (147.82)	50.67 (16.18)	37.09 (15.10)	93.55 (69.25)	3.95 (2.20)
Heavy (>10/d)	71.83 (37.60)	3.41 (1.27)	237.15 (144.55)	52.12 (13.69)	38.34 (12.66)	105.05 (77.97)	4.24 (2.35)
r	0.016	−0.061	−0.014	0.022	0.022	−0.012	−0.017
p	0.590	0.037*	0.634	0.458	0.453	0.690	0.569
Alcohol Consumption							
Non-drinker	68.87 (44.71)	3.59 (1.42)	237.21 (172.66)	50.06 (15.46)	36.07 (14.32)	100.15 (85.22)	4.05 (2.19)
Occasional (1–2 times/wk)	70.56 (44.94)	3.58 (1.43)	234.86 (153.25)	51.85 (15.30)	38.05 (14.00)	99.98 (71.55)	3.92 (2.25)
Frequent (>2 times/wk)	85.87 (59.01)	3.23 (1.41)	253.73 (161.08)	48.44 (16.10)	36.04 (14.84)	103.26 (77.90)	4.04 (2.24)
r	0.025	−0.023	0.012	0.042	0.055	0.024	−0.023
p	0.397	0.441	0.686	0.152	0.061	0.407	0.423

TABLE 2. Continued.

Variables	Sperm Concentration	Semen Volume	Total Number of Sperm	Total Motility	Progressive Motility Rate	Number of Progressive Motile Sperm	Rate of Normal Morphology
Sleep Duration at Night							
<4 h	53.70 (36.85)	3.11 (1.34)	129.02 (70.75)	49.29 (17.95)	37.91 (14.98)	44.50 (12.73)	3.88 (1.97)
4–6 h	50.37 (47.70)	3.31 (1.50)	148.69 (132.29)	39.04 (20.73)	25.87 (13.37)	48.93 (80.39)	3.06 (2.22)
6–8 h	69.62 (43.12)	3.57 (1.38)	238.26 (160.35)	51.50 (14.31)	36.66 (13.37)	103.76 (80.39)	4.04 (2.21)
>8 h	78.96 (48.87)	3.72 (1.48)	276.04 (183.51)	51.73 (14.28)	39.39 (13.53)	115.36 (85.44)	4.28 (2.20)
r	0.166	0.097	0.223	0.127	0.155	0.221	0.104
p	0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
Occupation							
Manager	69.67 (44.79)	3.44 (1.32)	236.74 (166.36)	51.63 (14.25)	36.31 (14.50)	111.18 (94.14)	4.20 (2.44)
Regular Worker or Service Industry	73.36 (44.54)	3.55 (1.41)	242.48 (149.78)	52.60 (12.54)	39.17 (11.60)	102.46 (73.19)	4.04 (2.02)
Office Worker (Clerical Staff)	60.49 (46.60)	3.50 (1.45)	197.28 (164.15)	45.24 (18.97)	30.77 (16.32)	77.39 (78.80)	3.66 (2.26)
Military or Law Enforcement	91.39 (46.53)	4.23 (1.56)	364.29 (209.47)	57.11 (10.80)	47.61 (10.26)	164.27 (85.18)	4.86 (2.14)
Freelancer	70.15 (40.21)	3.53 (1.28)	242.46 (153.06)	51.47 (13.83)	36.15 (11.37)	98.67 (70.22)	4.14 (2.25)
r	0.186	0.700	0.189	0.200	0.285	0.194	0.092
p	0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**

*$p < 0.05$, **$p < 0.01$. BMI: body mass index.

duration significantly impacts semen quality [16]. For example, studies by Chen *et al.* [17] and others found statistically significant differences in semen volume and progressive motility among various abstinence time groups, though no significant differences were noted in sperm morphology. Similarly, Borges *et al.* [18] observed that longer abstinence (>5 days) was associated with lower forward motility and increased sperm concentration compared to shorter abstinence periods. Our study corroborates these findings, showing significant increases in sperm concentration, semen volume, total sperm count, and total motile sperm count with longer abstinence periods. Although there was a gradual decline in total sperm motility, this trend was not statistically significant. Additionally, no significant differences were observed in sperm progressive motility rate and normal morphology rate, which may be attributed to variations in the basic conditions of the study subjects and the relatively small sample size.

Lifestyle factors such as smoking and excessive alcohol consumption are well-established lifestyle risk factors known to adversely affect reproductive health, with substantial evidence highlighting their detrimental impact on male spermatozoa [19, 20]. Nicotine in tobacco has been shown to significantly impair sperm motility. Additionally, heavy smokers often exhibit lower plasma testosterone levels compared to non-smokers, particularly with long-term smoking, as harmful substances from cigarettes enter the bloodstream and negatively affect the development of testicular spermatogenic cells [8, 21]. Similarly, excessive alcohol consumption can lead to prolonged semen liquefaction time, reduced sperm survival rate, and decreased straight-line motility, all of which impact male fertility [3, 22]. However, our study found that smoking was significantly associated only with semen volume, and no significant correlations were observed between smoking, alcohol consumption, and other semen quality parameters. This discrepancy may be attributed to factors such as sample size and population characteristics.

In this study, we evaluated the correlations of age, nighttime sleep duration and occupational categories with semen quality among healthy men in the region, which were found to be significant risk variables influencing abnormal semen quality in infertile male patients. Although male fertility is generally maintained at higher ages compared to females, it does decline with age. It has been reported that sperm quality deteriorates with age, with sperm concentration beginning to decline after the age of 40 [17, 23]. Jimbo *et al.* [24] proposed that 45 years is the critical age threshold for

TABLE 3. Multivariate linear regression analysis of factors affecting male semen quality.

Variables	Partial Regression Coefficient	Standard Error	Standardized Partial Regression Coefficient	*t*-Value	*p*-Value	95% Confidence Interval	
						Lower limit	Upper limit
Sperm Concentration							
Constant	47.831	10.97		4.360	<0.001**	26.308	69.355
Age (yr)	−0.413	0.269	−0.044	−1.533	0.125	−0.941	0.115
Sleep Quality (index)	11.293	1.882	0.173	6.002	<0.001**	7.601	14.985
Occupation (category)	4.113	0.949	0.129	4.335	<0.001**	2.252	5.975
Semen Volume (mL)							
Constant	2.758	0.320		8.632	<0.001**	2.131	3.385
Age (yr)	0.006	0.008	0.021	0.712	0.477	−0.011	0.023
Sleep Quality (index)	0.160	0.061	0.079	2.617	0.009**	0.040	0.280
Occupation(category)	0.047	0.030	0.048	1.572	0.116	−0.012	0.106
Total Number of Sperm (million)							
Constant	92.268	36.439		2.532	0.011*	20.775	163.761
Age (yr)	−1.256	0.962	−0.037	−1.306	0.192	−3.145	0.632
Sleep Quality (index)	44.665	6.971	0.188	6.408	<0.001**	30.989	58.342
Occupation (category)	15.928	3.418	0.137	4.660	<0.001**	9.221	22.635
Total Motility (%)							
Constant	39.769	3.413		11.65	<0.001**	33.071	46.466
Age (yr)	−0.005	0.090	−0.002	−0.058	0.954	−0.182	0.172
Sleep Quality (index)	1.742	0.653	0.079	2.668	0.008**	0.461	3.023
Occupation (category)	1.939	0.320	0.180	6.056	<0.001**	1.311	2.567
Sperm Progressive Motility Rate							
Constant	25.694	3.081		8.339	<0.001**	19.648	31.739
Age (yr)	−0.061	0.081	−0.021	−0.749	0.454	−0.221	0.099
Sleep Quality (index)	1.759	0.589	0.087	2.985	0.003**	0.603	2.916
Occupation (category)	2.617	0.289	0.263	9.054	<0.001**	2.050	3.184
Total Number of Progressively Motile Sperm							
Constant	18.451	17.769		1.038	0.299	−16.411	53.313
Age (yr)	−0.217	0.469	−0.013	−0.461	0.645	−1.137	0.704
Sleep Quality (index)	20.941	3.399	0.181	6.161	<0.001**	14.272	27.610
Occupation (category)	8.279	1.667	0.146	4.967	<0.001**	5.008	11.549
Sperm Normal Morphology Rate							
Constant	4.168	0.491		8.488	<0.001**	3.205	5.132
Age (yr)	−0.044	0.013	−0.097	−3.361	0.001**	−0.069	−0.018
Sleep Quality (index)	0.284	0.094	0.091	3.02	0.003**	0.099	0.468
Occupation (category)	0.108	0.046	0.070	2.335	0.020*	0.017	0.198

$*p < 0.05$, $**p < 0.01$.

declines in sperm concentration and motility. Additionally, Li *et al.* [14] found that while aging does not affect semen volume, it negatively correlates with total sperm count and the percentage of forward-moving sperm. Our findings support these observations, revealing a significant negative correlation between normal sperm morphology and age; as age increases, sperm morphology significantly worsens. However, we did not find significant differences in sperm concentration, total vitality, or the number of forward-moving sperm. This study uniquely included sperm morphology analysis, which is often excluded from assessments due to its subjective nature [25]. To address this, each sample was evaluated by two lab technicians trained in standardized semen analysis procedures, minimizing subjectivity in the results.

In terms of sleep, existing studies show mixed results regarding its impact on semen quality. Wise *et al.* [12] highlighted that sleep duration is significantly related to reduced fertility, making it a critical factor for poor semen quality. Some research has demonstrated that men sleeping less than 6 hours per night experience reduced semen volume, total motility, and forward motility compared to those sleeping more than >8 h/d [26]. Conversely, other studies observed lower total and forward motility rates in men who sleep 8 hours or more [27]. However, our study indicates a positive correlation between longer total nighttime sleep duration and improved semen quality across all parameters. It has also been suggested that poor sleep quality may be associated with decreased serum testosterone levels and damage to spermatogenic tubule supporting cells, indicating that adequate sleep could potentially enhance semen quality. Nevertheless, the precise mechanisms linking sleep duration to semen quality require further investigation.

In this present study, we also investigated the potential correlation between participants' occupations and their semen quality. While existing studies predominantly focus on the effects of chemical pollutants in occupational environments on semen parameters, the data are often contentious, and research on the relationship between specific occupational categories and semen quality is limited. A longitudinal study on fertility and environmental factors suggested that jobs involving strenuous physical activity could lead to spermatogenic disorders, whereas sedentary work does not necessarily impair semen quality [28]. Recent studies, however, have found that although prolonged sitting does not significantly affect semen parameters, it may increase sperm DNA fragmentation, indicating that extended periods of sitting could still negatively impact male fertility [10, 29]. Our study found a higher percentage of normal semen samples among ordinary workers, commercial service employees, and military or police personnel. Conversely, office workers exhibited generally lower semen parameters, potentially due to the prolonged sedentary nature of their work. Germ cells are known to be sensitive to local warming of the testes; prolonged sitting can raise local testicular temperature, potentially inducing thermal stress and leading to the formation of reactive oxygen species and DNA damage, which may contribute to semen parameter anomalies [30, 31]. Interestingly, our study showed that military or police personnel had significantly better semen parameters, including concentration, total count, total motility, progressive motility, total motile sperm count, and normal morphology rate, compared to other occupational categories. This finding partially contrasts with a domestic study by Tang *et al.* [10], which reported the highest semen volume but the lowest forward motility rates among soldiers and police officers. Given the limited sample size of military or police personnel in our study, these results require further validation through longitudinal research. Additionally, while we excluded individuals who had experienced COVID-19 or other symptoms of fever and high temperature in the past three months, the impact of the COVID-19 virus on semen quality remains an area requiring further investigation.

Although semen quality is an important indicator of male fertility, the ultimate measure of fertility is the pregnancy conception rate. Our study did not track the final fertility outcomes of the participants, which limits our ability to directly assess the impact of age, BMI, abstinence time, and specific lifestyle factors on actual fertility. Therefore, further research is needed to explore how these variables relate to semen quality and their overall relevance to male fertility. This study highlights the influence of these critical factors on semen parameters, providing valuable insights for assisted reproduction and andrological diagnostics and treatment. Additionally, our research offers a novel perspective on the impact of occupational categories in China on semen quality. It suggests that the effects of sedentary occupations on semen quality during the reproductive period should be more closely monitored. However, the retrospective nature of this study introduces potential selection bias in the inclusion and exclusion of participants. Moreover, semen analysis, particularly the assessment of sperm morphology, is known for its variability. As our study analyzed only single semen test results, it could not fully account for individual differences among participants, potentially biasing the findings. Despite these limitations, the large sample size of our study provides a significant reference value for understanding semen quality in different occupational settings.

5. Conclusions

In this single-center retrospective analysis, we found that the semen quality among the prospective reproductive health population in Central China has been generally satisfactory over the past two years. However, we observed a significant decline in the rate of normal sperm morphology across different age groups, highlighting the need to carefully manage abstinence duration to avoid negative effects on sperm concentration and total count. Thus, maintaining a healthy lifestyle is the most effective method to ensure good semen quality. In addition, negative lifestyle factors, such as smoking and inadequate sleep, can impair semen parameters and highlight the importance of focusing on both lifestyle and occupational environments for men of reproductive age, and addressing these factors is essential for identifying and mitigating potential risks to reproductive health.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

JC and HY—conceptualised and designed the research study. CWZ—resources. ChaW and CYS—investigation, project administration, visualization. CYS—analyzed the data. JC and CheW—wrote the manuscript, revised and given final approval of the version to be published. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This project was approved by the Reproductive Medicine Ethics Committee of the Second People's Hospital of Wuhu (No. SZ2021002, Anhui, China). Before participating in this survey, written and verbal informed consents were acquired from all individuals taking part.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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