Lifestyle: an underrated but potentially important influencing factor on semen quality

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Abstract
Lifestyle factors play a crucial role in the influence of semen quality, and they are especially significant in the context of traditional Chinese medicine (TCM) clinical treatment for poor semen quality. TCM theory emphasizes the importance of healthy lifestyle habits for overall well-being. Therefore, it is essential to consider lifestyle factors in the clinical management of TCM and semen quality. Lifestyle can act as a bias factor that affects research quality, making it vital to pay special attention to its impact in clinical trial research on male semen quality. This article aims to improve the quality and design of clinical research on male sperm quality by examining the effects of various lifestyle factors on semen quality, including physical activities, dietary patterns, smoking, alcohol consumption, coffee intake, sleep, and psychological stress. Each lifestyle factor has its own distinct influence on semen quality, and there is a synergistic effect when multiple lifestyle factors are combined. These findings emphasize the need for careful consideration of lifestyle factors and their interactions in the design and implementation of TCM clinical trial research.

Keywords: lifestyle factors; semen quality; traditional Chinese medicine; clinical trial research; synergistic effect

Author contributions
Wenkang Chen and Hede Zou drafted the article, Hanfei Liu and Bolin Li made suggestions for revising the article. Jiayou Zhao conceived and designed the study and revised the manuscript. All the authors read and approved the final manuscript.

Competing interests
The authors declare no conflicts of interest.

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Abbreviations
TCM, Traditional Chinese Medicine; PA, physical activity; HPG, hypothalamic-pituitary-gonadal.

Citation

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Introduction

According to recent studies published in journals such as The Lancet, infertility affects 8–12% of couples globally, with male factors accounting for approximately 40% to 50% of the cases [1, 2]. The quality of human semen appears to have declined over recent decades, indicating the chance of achieving fertility is lower than the normal [3]. This decline in semen quality may be attributed to lifestyle changes [4]. Among various factors influencing male sperm quality, lifestyle factors have been found to have a significant impact [5]. Studies have shown that lifestyle, as a potential risk factor, can detrimentally affect semen quality, while lifestyle interventions have the potential to improve it [6]. Consequently, there is increasing attention in the field of clinical research on male semen quality towards investigating the influence of lifestyle factors.

Traditional Chinese medicine (TCM) has gained recognition for its unique advantages in enhancing male fertility, improving semen quality, and regulating sex hormones [7, 8]. For example, some studies showed that TCM may improved the damaged sperm DNA, enhanced sperm motility and quality, increased sperm count and modulated immune function to improve fertility. Moreover, integrating TCM with conventional therapies has been shown to enhance the efficacy of standard treatments [9–11]. However, despite the rapid development of clinical research on TCM, certain challenges persist, such as perceived weaknesses in the design and quality of clinical trials due to potential bias risks [12, 13]. Research [14] has shown that confounding factors, including lifestyle, in the routine data collection process of clinical research can impact the accuracy of research results, thus affecting the overall quality of clinical studies.

As stated in the Inner Canon of Yellow Emperor (475 B.C.E.–6 C.E.), leading a regular lifestyle with regular eating, drinking, sleeping habits, and balanced physical exertion is crucial for maintaining good health. Therefore, lifestyle is an important factor in the clinical treatment of TCM. Recognizing lifestyle as a potential confounder, its impact on various diseases, such as cardiovascular diseases, tumors, diabetes, and infertility, has garnered attention in clinical research [15–17].

This paper focuses on exploring the impact of lifestyle factors, including physical activity, dietary patterns, and other influencing factors such as smoking, alcohol consumption, caffeine intake, sleep, psychological stress, on semen quality. By optimizing the research design and improving the quality of clinical research, we aim to enhance the scientific rigor of clinical trials related to male sperm quality.

The impact of physical activity (PA) on semen quality

Numerous studies have demonstrated a significant association between PA and semen quality, including sperm concentration, motility, morphology, total sperm count, and other sperm parameters [18]. Exercise plays a beneficial role in improving spermatogenesis and semen quality by enhancing testicular antioxidant defense, reducing proinflammatory cytokines, and promoting steroidogenesis [19]. Moreover, the impact of PA on semen quality may vary depending on exercise mode and duration. Research has indicated that compared to elite athletes (exercising 4–5 days per week) and inactive men (no exercise for at least 6 months), recreationally active men (exercising 4–5 hours per week) tend to exhibit healthier semen quality [20, 21]. Long-term moderate-load aerobic exercise has been shown to significantly improve male reproductive indicators. However, engaging in intense activities like extended high-altitude mountaineering or high-intensity cycling may negatively affect male reproductive function [22, 23].

Furthermore, within the same type of exercise, different exercise intensities can have varying effects on semen quality. One study demonstrated that high-intensity exercise led to a decrease in sperm density, motility, and morphology after 24 weeks of exercise [21]. Similar decreases in sperm parameters were observed in subjects engaged in moderate-intensity running; however, these parameters recovered to the previous levels after a recovery period. It is suggested that exercise intensity may impact germ cell metabolism by influencing the expression levels of GLUT-1, GLUT-3, and MCT-4 transporters by affecting the expression levels of GLUT-1, GLUT-3, and MCT-4 transporters [24, 25].

Apart from conventional exercises, traditional exercises based on TCM theory, such as Tai Chi and Qigong, have shown potential in improving semen quality (Table 1). By combining meditation with slow, gentle movements, deep breathing, and relaxation techniques, Tai Chi and Qigong promote the free flow of vital energy throughout the body. These practices may reduce inflammation, address spermatogenesis dysfunction, and alleviate sexual and ejaculatory issues [26]. Research has indicated that a combination of TCM prescription and Tai Chi exercise prescription can significantly improve semen quality parameters, decrease sperm deformation rates, and improve the reproductive endocrine environment and psychological well-being of men with oligozoospermic infertility [27]. However, well-designed randomized clinical trials are necessary to further evaluate the safety, efficacy, and underlying mechanisms of these practices in relation to semen quality.

The influence of dietary patterns on semen quality

Different dietary patterns have varying effects on semen quality. Research has classified five common patterns, including the prudent, Mediterranean, and health-conscious diets as healthy, and the Western and traditional Dutch diets as unhealthy. These patterns have been extensively studied for their impact on semen quality in multiple studies [28, 29].

Healthy diet patterns, such as the prudent diet characterized by high intake of fish, chicken, fruits, vegetables, legumes, and whole grains, are positively associated with progressive motility of sperm [30, 31]. Conversely, the Western diet, with its emphasis on organ meats, potatoes, high-fat dairy products, hydrogenated fats, mayonnaise, and fatty sauces, is associated with higher risks of abnormal total sperm count, progressive motility, and morphology, which can lead to asthenozoospermia [32, 33]. The findings from Iran [34] and Denmark [35] studies also support these conclusions (Table 2).

<table>
<thead>
<tr>
<th>Physical activity</th>
<th>Semen quality parameters</th>
<th>Impact</th>
<th>Research status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic exercise</td>
<td>Sperm concentration</td>
<td>Positive impact</td>
<td>Research supported</td>
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<td></td>
<td>Sperm motility</td>
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<td>Sperm morphology</td>
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<tr>
<td>High-intensity exercise</td>
<td>Sperm motility</td>
<td>Negative impact</td>
<td>Research supported</td>
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<td></td>
<td>Sperm morphology</td>
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<tr>
<td>Moderate-intensity exercise</td>
<td>Sperm motility</td>
<td>Temporary negative impact, recovers after recovery period</td>
<td>Research supported</td>
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<td></td>
<td>Sperm morphology</td>
<td></td>
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<tr>
<td>Tai Chi &amp; Qigong</td>
<td>Sperm parameters</td>
<td>Potential positive impact</td>
<td>Further research needed</td>
</tr>
</tbody>
</table>

Table 1: Impacts of physical activity on semen quality and research status

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### Table 2 Impacts of dietary pattern on semen quality and research status

<table>
<thead>
<tr>
<th>Dietary pattern</th>
<th>Impact on semen quality</th>
<th>Research status</th>
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</thead>
<tbody>
<tr>
<td>Healthy diet pattern</td>
<td></td>
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<tr>
<td>Prudent diet</td>
<td>Positive impact</td>
<td>Research supported</td>
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<td>Mediterranean diet</td>
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<td>health-conscious diet</td>
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<td>Unhealthy diet pattern</td>
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<tr>
<td>Western diet</td>
<td>Negative impact</td>
<td>Research supported</td>
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<tr>
<td>Traditional Dutch diet</td>
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</table>

Adjusting dietary patterns can lead to improvements in semen quality. Studies have shown that weight loss through a low-calorie diet can positively impact sperm concentration and count in obese men [36]. The composition of fatty acids and antioxidants in the diet plays a role in spermatogenesis. Antioxidants like selenium, zinc, omega-3 fatty acids [37], Coenzyme Q10, and carnitine have been found to be positively correlated with sperm quality, thereby improving male fertility [38]. Including vegetables, fruits, nuts, whole grains, fish, shellfish, and seafood, which are rich in omega-3 fatty acids, antioxidants, and vitamins, can be beneficial for sperm health [39].

However, excessive use of antioxidants may damage sperm function. The intake of phytoestrogens like daidzein can reduce motile sperm count and worsen morphology [40]. Additionally, studies [41] have shown that folic acid-zinc supplementation can have a positive impact on sperm concentration and morphology in infertile men. Combining antioxidants can have a synergistic effect in improving semen quality parameters [42].

It is also necessary to increase nut intake in food supplements. Compared with the conventional Western diet, the addition of nuts to the conventional Western diet can significantly increase the total number of sperm and sperm motility and morphology [43]. Nut consumption can also influence sperm DNA methylation in specific regions [44]. Furthermore, a study by Hong [45] demonstrated that a dietary recipe including swim bladder, wolfberry, ginseng, and other herbs, based on TCM theory, can improve sperm density and total count in patients with oligozoospermia and alleviate clinical symptoms.

In conclusion, dietary patterns significantly affect semen quality, and modifying the diet can have beneficial effects on male fertility.

### The influence of alcohol consumption on semen quality

Alcohol consumption negatively affects semen volume, antioxidant levels, and reproductive hormones, thus negatively impacting male reproductive function [46]. Different frequencies of alcohol consumption have varying effects on sperm volume and normal morphology. It appears to affect daily drinkers, while occasional drinkers exhibit similar semen volume and normal morphology to those who never drink [47]. Long-term drinking reduces semen quality primarily due to the excessive production of reactive oxygen species after ethanol metabolism. This can alter the expression of specific genes involved in the regulation of spermatogenesis hormones and increase sperm DNA breakage, potentially having a cross-generational impact on offspring [48].

Additionally, alcohol consumption can impair sperm quantity and cause sperm DNA fragmentation, resulting in reduced semen quality, fertilization rate, and blastocyst formation rate [49]. Surprisingly, a study by Jurewicz [50] found that drinking red wine 1-3 times per week was negatively associated with sperm neck abnormalities. This may be attributed to the antioxidant and anti-inflammatory activities of natural flavonoids and polyphenols in red wine, which have a positive impact on improving sperm motility and semen quality [51].

### The influence of smoking on semen quality

Smoking reduces semen quality in a dose-dependent manner. To study the effect of smoking on semen parameters, smokers were classified into three groups: mild smokers (1–10 cigarettes/day), moderate smokers (11–20 cigarettes/day) and heavy smokers (> 20 cigarettes/day). Semen analysis was performed on all patients. It showed that smoking significantly reduced semen volume and sperm concentration, and smoking had a significant and independent effect on sperm concentration [52]. Compared with non-smokers, smokers have a higher risk of oligospermia, asthenospermia, and dyspermia [53]. The deterioration of semen quality was more obvious in moderate and heavy smokers [54].

With the growing awareness of health, alternative tobacco products have emerged. Studies have shown that heated noncombustible tobacco sticks contain nicotine concentrations similar to those of cigarettes, while the nicotine level in aerosols from heated noncombustible products is lower than that in tobacco cigarettes. However, even with these alternative products, such as e-cigarettes, there is still a reduction in sperm count density and viability [55].

Furthermore, smoking and drinking have a synergistic negative effect on semen quality. Short-term high alcohol and cigarette consumption [56] reduces the semen quality of healthy young men, negatively impacting sperm motility, sperm morphology, and sperm concentration, and reducing the function of the epididymis, seminal vesicle, and prostate gland. Additionally, compared to smoking alone, drinking alcohol also reduces sperm maturity and damages DNA integrity [57].

### The influence of caffeine intake on semen quality

The impact of caffeine intake on semen quality remains unclear. A prospective cohort study examined the association between caffeine and alcohol consumption in men and semen parameters. The findings indicated no significant relationship between caffeine and alcohol intake in men and semen quality. However, high caffeine intake was linked to increased testosterone concentration and negatively correlated with live birth rates following assisted reproductive technology [58, 59].

Studies suggest that caffeine intake, particularly from coffee, tea, and cocoa drinks, does not have a notable effect on semen parameters. On the other hand, cola drinks and caffeinated soft drinks have been found to have significant impacts on semen volume, quantity, and concentration, suggesting that the source of caffeine may impact semen parameters. Furthermore, caffeine intake has the potential to adversely affect male reproductive function by causing sperm DNA damage [60].

### The influence of sleep on semen quality

Sleep including bedtime, sleep duration, and sleep quality plays a crucial role in semen quality, which is associated with an over two-fold decrease in sperm count in a chronotype-specific pattern [61]. There was a significant inverse U-shaped correlation between sleep duration and two semen parameters semen volume and total sperm count [62]. Early bedtimes (< 10:30 PM) and conventional sleep duration (7.5–7.99 h) were associated with self-reported normal semen quality. Men who sleep less than 6 hours per day exhibit lower total and progressive sperm motility, with a decrease of 4.4% and 5% respectively, compared to those with a night sleep duration of 7.5–8 hours [61, 63].

Interruption of circadian rhythms caused by reduced sleep time and/or changes in sleep structure negatively interferes with male sex hormone cycle level and semen parameters [64]. This interference is likely due to the prevention of spermatocyte development in the early
to middle stages. Additionally, vitamin C supplementation significantly combats the deterioration of semen parameters and quality caused by sleep deprivation [65].

**The influence of pressure on semen quality**

Male are facing an increasing number of pressures from different sources, which ultimately affect the quality of semen. Psychological stress reduces testosterone levels and impairs spermatogenesis, leading to decreased sperm density, compromised sperm motility, and an increase in abnormal sperm [66]. Chronic stress stimulates the hypothalamic-pituitary-adrenal axis and simultaneously inhibits the activity of the hypothalamic-pituitary-gonadal axis [67]. This negatively impacts male spermatogenesis and the expression of lectin-3 protein in the testes [68]. Moreover, psychological stress-induced β-endorphin release promotes Leydig cell apoptosis through the p38 MAPK pathway in male rats [69]. Furthermore, when addressing the impact of stress on sperm quality, it is crucial to explore the effectiveness of interventions. Vitamin C and selenium, for example, have been found to have protective effects against the decline in sperm quality caused by stress levels, improving overall sperm quality and parameters [70]. Additionally, vitamin E and melatonin have shown potential in improving testosterone levels and enhancing semen quality [71, 72]. Furthermore, melatonin acts through the NF-κB/INOS and Nrf2/HO-1 signaling pathways to reduce oxidative stress and apoptosis of testicular cells, thereby mitigating spermatogenesis damage induced by psychological stress [73].

**Conclusion**

Based on the factors of lifestyle mentioned above, it is evident that lifestyle, including physical activities, diet patterns, drinking, smoking, caffeine intake, sleep, and psychological stress, significantly impact sperm quality. Additionally, different lifestyles have varying degrees of influence on sperm quality. While individual factors can affect semen quality, the combination of multiple lifestyle factors exhibits a synergistic effect.

Therefore, in clinical trial research on TCM and male sperm quality, it is crucial to consider lifestyle factors to meticulously design trials, optimize research schemes, and enhance research quality. Moreover, lifestyle intervention, being a confounding factor in the study, is usually complex and may pose a threat to the internal and external validity of the study. Hence, further research is essential to explore methods for effectively controlling these lifestyle confounding factors.

Furthermore, investigating emerging environmental factors, technological advancements, and their impact on semen quality will contribute to a more comprehensive study. And specific lifestyles may also independently lead to oligozoosperma and asthenozoosperma, highlighting the need for further research in this area.

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