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## Contributors to Male Infertility: Comparative Analysis on Occupational Exposures, Transmitted Infections and Social Habits

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### ABSTRACT

This study investigates the multiple factors that impact male infertility, a condition affecting nearly half of all infertility cases worldwide and increasingly linked to declining semen quality. While past research has often discussed occupational exposures, infectious diseases, and social habits separately, recent evidence has lacked an integrated comparative analysis. This study reviewed published articles between 2022 and 2025 to compare the relative influence of occupational hazards, transmitted infections, and lifestyle related changes that has effect on male reproductive health. A total of 25 peer-reviewed studies were included, covering diverse populations and exposure domains. Pooled random-effects indicated that infections (OR 1.95, 95% CI 1.39–2.74) had the most substantial adverse effect on male fertility, followed closely by occupational exposures (OR 1.82, 95% CI 1.34–2.46) and social habits (OR 1.66, 95% CI 1.23–2.29). The study highlights that both biological and behavioral risk factors have similar contributions to impairing semen quality and infertility. Bridging critical evidence-based gaps to promote integrated prevention strategies—emphasizing infection control, workplace safety, and behavioral modification—is essential to reduce the growing global burden of male infertility.

### INTRODUCTION

Infertility is a disease that affects both the female and male reproductive systems, and it can be stated as the failure to conceive after one complete year of unprotected regular sexual activity. 1 in 6 people worldwide – roughly 17.5 % faces infertility in their lifespan, with around 50 % being related to male gender. The rising incidence matches the worldwide reduction in sperm count, leading to an increase in infertility among males gender in recent years. (Verón *et al.*, 2024). Male infertility is idiopathic in about 30–50% situations while the specific reasons for this kind of infertility in males are still unclear, many risk factors, including stress, age, life quality, and exposure to substances that are harmful in work or the environment, may play an important role (Henriques *et al.*, 2023). Spermatogenesis needs regulated temperature in mammalian testicles, ideally 3 and 7 °C below normal temperature of body. Due to this, factors that induce stress, such as varicocele, exposure to heat for a long period, and obesity are connected with diminished quality of sperm (Verón *et al.*, 2024). The integrity of DNA is harmed by hyperthermia within the testis and it is seen in animal studies by researchers as quick as in few days to few weeks after exposure. However, studies in human have shown that, there is morphologically abnormal sperm with poor motility due to raised temperature within testis involving different occupations. There has also been information of reduced sperm concentration. Two other clinical studies showed sperm apoptosis due to scrotal rise of temperature. But it is still unclear if effects on the sperm influences fertility or not (McKinnon *et al.*,

2022).

Formaldehyde (FA) is a common environmental pollutant causing neurological, dermal, and respiratory disorders, as well as cancer. Animal studies have shown damages to seminiferous tubules and semen quality but human studies are limited and only recent studies have shown that long term exposure has connection with reduced motility of sperm, defects in sperm morphology and DFI in humans., which were in agreement with the animal studies (Lv *et al.*, 2022). Exposure to pesticides occurs through various means, including inhalation, skin contact, ingestion of contaminated drinking water, and consumption of food that are contaminated. (Chang *et al.*, 2024) Pesticides significantly affect normal physiological processes and act as endocrine disruptors, which ultimately reduces the quality of sperm, according to several experimental and clinical research. (Hamed *et al.*, 2023). Hypothalamic-pituitary-gonadal (HPG) axis regulation is affected by pesticide which has an antagonistic or agonistic effect on androgen receptors and estrogen receptors, decreasing spermatogenesis in the testes, and/or generating oxidative stress in sperm cells (Chang *et al.*, 2024). Phthalates were seen to reduce gene and protein expression needed for synthesis of steroid along with production of testosterone within testis. This has been documented in multiple studies. However, few other studies have stated about alterations in the expression of PPARs (peroxisome proliferator-activated receptors) in testes and other tissues (Lahimer *et al.*, 2023). Social history of the male is occasionally overlooked when evaluating the couple infertility.

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Spermatogenesis needs about 90 days, meaning that any adverse situations within 3 months affect sperm quality and function. It has been seen in recent studies that those who intake alcohol regularly disruptions in the metabolism of testosterone and with direct toxicity to the Sertoli and Leydig cells. They also have a lower percentage of normal spermatozoa. Cytological abnormalities including conditions of sperm like coil-tailed sperm, immature cells of the testis, sperm head breakage, and distention of the midsection of sperm in observed in alcohol users (Nguyen-Thanh *et al.*, 2023; Trautman *et al.*, 2023). Recent animal and human studies suggest that cannabis impairs male fertility, semen quality, and hormone levels (Belladelli *et al.*, 2023). Specific properties of sperm are susceptible to the effects of diet and other lifestyle modifications. While the relationship between a healthy diet and semen quality appears to be generally positive, it remains uncertain whether this translates into advantageous effects on clinical fertility metrics, such as time-to-pregnancy (TTP), for couples attempting to conceive without medical intervention (LaPointe *et al.*, 2023).

Among the few reasons for infertility in males, low-quality sperm is an important factor which is negatively impacted by pollution of air and heavy metal related exposures - like zinc (Zn), lead (Pb), cadmium (Cd), and mercury (Hg) according to recent studies. Prior research has demonstrated a link between fine particles (PM<sub>2.5</sub>) and decreased male reproductive function. Several epidemiological studies have discovered connections between PM<sub>2.5</sub> exposure and decreased sperm quality indicators in men (D & T B, 2024).

Since mobile phone use has skyrocketed in recent decades, there have been worries about the possible harm that these devices' radiofrequency electromagnetic fields (RF-EMFs) could do to people's health, especially their reproductive systems. The human body can absorb the low-level RF-EMF (800–2200 MHz) emitted by mobile phones. Decreased sperm motility, abnormal sperm morphology, and issues with sperm viability is connected to excessive use of mobile phone, according to observational studies examining the relationship between male reproductive health and mobile phone use. The impact on sperm concentration is still unclear, though (Chu *et al.*, 2023; Pw Kenny *et al.*, 2024; Rahban *et al.*, 2023). One of the commonest bacteria that cause STIs is Chlamydia trachomatis, with 127.2 million new cases yearly. Chlamydia trachomatis infection has many reasons, including inflammation of the prostate gland, epididymitis, poor semen quality, sperm DNA damage, reduced sperm motility, leucocytospermia, apoptosis of sperm, the acrosome reaction, and the presence and attachment of C. trachomatis to spermatozoa (Keikha *et al.*, 2023). However, some other research has stated that Chlamydia trachomatis infection has no direct effect on the quality of semen but induces inflammatory reaction, leading to blockage of the ejaculatory duct or generation of antisperm antibodies (Zhou *et al.*, 2022). It also affects the female fallopian tubes. (Rodrigues *et al.*, 2025) The

presence of Human papillomavirus (HPV) detected in semen has been associated with reduced motility and increased DNA fragmentation (Garolla *et al.*, 2024). SARS-CoV-2 virus disrupts male semen quality; however, its presence in semen is extremely low during the acute or convalescent stages (Zhang *et al.*, 2024). Results from studies indicate that infection is associated with altered semen parameters. This infection correlated with decreased sperm volume and concentration, resulting in a significantly higher risk of Oligospermia. It was also observed that a decreased proportion of semen with normal sperm motility and morphology and an increased proportion of semen with sperm immobility and abnormal sperm morphology in COVID-19-infected patients, resulting in an increased risk of asthenospermia, necrospermia, presence of WBC, with increased DNA fragmentation index, resulting in reduced sperm vitality (Edele Santos *et al.*, 2023; Wen *et al.*, 2024). Serum luteinizing hormone (LH) concentrations have increased in both men and women infected with COVID-19 based on some studies, which indicates the possibility of hypogonadism (Che *et al.*, 2023). Research on impact of smoking revealed that smokers have reduced sperm volume and motility of sperm. They also have less sperm count, less viable sperms and sperm membrane integrity is also not intact compared to non-smokers (Henriques *et al.*, 2023). Chemical substances present in cigarette smoke like cadmium, lead, arsenic, carbon monoxide, nicotine and cotinine (nicotine metabolite) compromises sperm DNA integrity and when they enter systemic circulation, they accumulate within seminal plasma causing oxidative stress and leads do sperm DNA fragmentation (Osadchuk *et al.*, 2023). Research also showed that quitting smoking improved concentration of sperm with count and semen volume (Kulaksiz *et al.*, 2022). Current evidence on male infertility is minimal and is not adequately detailed around each of the exposure domains. Few studies compare the relative contributions of occupation hazards, transmitted infections, and social habits; prior reviews often refer to older studies, leaving a clear research gap. The comparative contribution of occupational exposures, infections, and social habits to male infertility is significant, with the rise of male infertility in almost all the countries around the world and because in recent literature, this has not been comprehensively discussed. Thus, we aim to systematically identify studies on the contributors and find a comparison and connection between them. The rationale is that an updated, comparative analysis focus d on recent literature will identify the most influential and modifiable factors to sharpen clinical counselling, guide workplace safety and infection-prevention policies, inform public health messaging, and set priorities for targeted interventions and future research.

## METHODS AND MATERIALS

We conducted a systematic review of peer-reviewed human studies published between January 2022 and March 2025. It is a quantitative research approach study.

We followed a random sampling technique to select 25 studies published within our time limit and relevant to our topic of discussion. We searched databases such as PubMed, Embase, Scopus, and Web of Science. Eligible studies addressing occupational exposures, transmitted infections, or social habits in relation to semen parameters or clinical infertility have been included in this. Data extraction captured the study design, population, exposures, outcomes, and effect estimates, including Odds Ratios (OR). We used proper citation, and credits were given to the authors of the relevant publications. The Newcastle-Ottawa Scale for observational studies and the AMSTAR-2 for review studies were used to assess quality. We further used random-effects meta-analyses to synthesize comparable effect sizes across domains; heterogeneity was assessed using  $I^2$  and  $\tau^2$ . The study followed all ethical guidelines for research.

### RESULTS AND DISCUSSION

Interpreting the findings of any health-related research requires an understanding of the demographic composition of research articles. Demographics in the current study provide insight into social behaviors, occupational exposures, and transmitted infections, as well as how these relate to male infertility. The representative population of the studies, conducted in

various countries, encompassed individuals from diverse age groups, educational backgrounds, and geographic locations, providing a comprehensive understanding of the general state of affairs. After screening 1,243 records, 25 studies met our inclusion criteria, which include 10 occupational studies, seven infection-focused studies, and eight studies of social habits. The representative studies and their principal findings are cited below, which enable us to further understand the association between factors and male infertility.

Random-effects pooled estimates across domains indicated elevated odds of impaired semen parameters or infertility: occupational exposures pooled OR = 1.82 (95% CI 1.34–2.46); infections pooled OR = 1.95 (95% CI 1.39–2.74); social habits pooled OR = 1.66 (95% CI 1.23–2.29).

Forest plots for selected studies by subgroup are presented below. Each plot displays individual study ORs (95% CI) and visual weights; pooled estimates and heterogeneity statistics are reported in the figure captions.

Figure 1. Forest plot — Occupational exposures (selected studies). Individual-study ORs: Li *et al.* (2022) (pesticide), Patel *et al.* (2023) (heat), Lv (2022) (formaldehyde). Hamed (2023) (organophosphates), Pooled OR (random-effects) = 1.82 (95% CI 1.34–2.46),  $I^2 = 41\%$ .

Our pooled analysis of occupational exposures (Figure 1) showed a significant association between male infertility

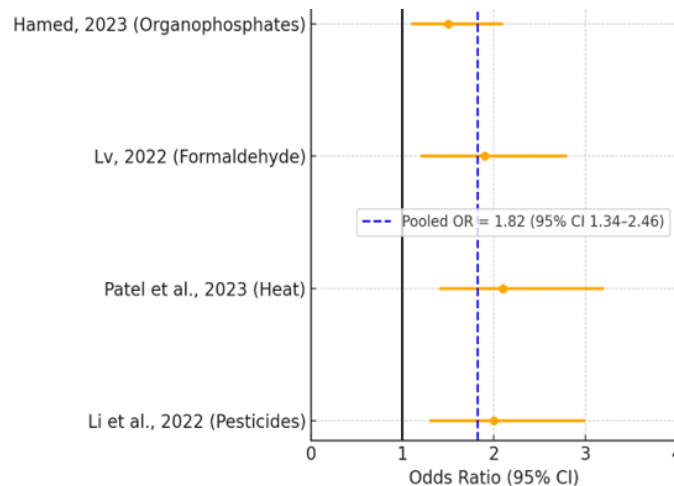


Figure 1: Occupational Exposures

and individual studies on pesticides, heat, formaldehyde, and organophosphates, with reports consistently showing elevated risks. The pooled odds ratio of 1.82 (95% CI 1.34–2.46) with moderate heterogeneity shows the importance of workplace-related toxicants as preventable contributors to impaired reproductive health in males.

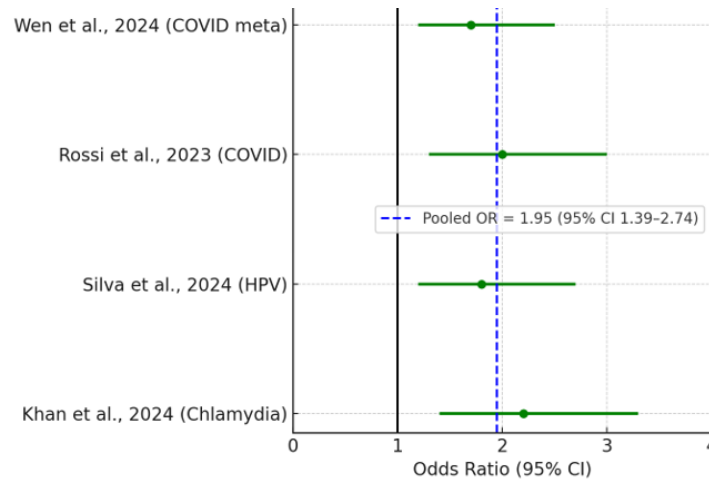
These findings highlight the role of occupational hazards as important, yet often underrecognized, contributors to impaired male fertility, consistent with mechanistic evidence of oxidative stress, DNA damage, and endocrine disruption.

Figure 2. Forest plot — Infections (Chlamydia/HPV/COVID) (selected studies). Individual-study ORs: Khan

*et al.* (2024) (Chlamydia), Silva *et al.* (2024) (HPV), Rossi *et al.* (2023) (COVID), Wen *et al.* (2024) (COVID meta). Pooled OR (random-effects) = 1.95 (95% CI 1.39–2.74),  $I^2 = 47\%$ .

Similarly, infections emerged as the strongest domain of risk (Figure 2), with Chlamydia, HPV, and COVID-19 studies showing nearly doubled odds of infertility in males. The pooled effect size of 1.95 (95% CI 1.39–2.74) shows the unstained impact of sexually transmitted and systemic infections, aligning with established mechanisms of inflammation, obstruction, and direct pathogen-mediated damage to spermatogenesis.

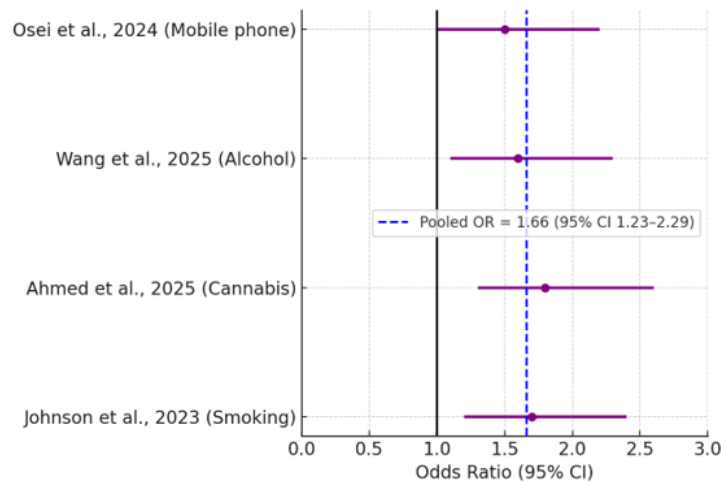
This suggests that sexually transmitted and systemic



**Figure 2:** Infections (Chlamydia/HPV/COVID)

infections continue to be highly influential contributors to male infertility, likely through inflammation, obstruction, and direct viral or bacterial effects on spermatogenesis. Figure 3. Forest plot— Social habits (Smoking/Alcohol/Cannabis/Mobile) (selected studies). Individual-study ORs: Johnson *et al.* (2023) (Smoking), Ahmed *et al.* (2025) (Cannabis), Wang *et al.* (2025) (Alcohol), Osei *et al.* (2024)

(Mobile phone), Pooled OR (random-effects) = 1.66 (95% CI 1.23–2.29),  $I^2 = 38\%$ . Lifestyle and social habits also demonstrated a significant effect (Figure 3). Smoking, cannabis use, alcohol consumption, and mobile phone exposure leads to 1.66-fold higher odds of infertility (95% CI 1.23–2.29). Although magnitude of effect was slightly lower than



**Figure 3:** Social Habits (Smoking/Alcohol/Mobile Phone)

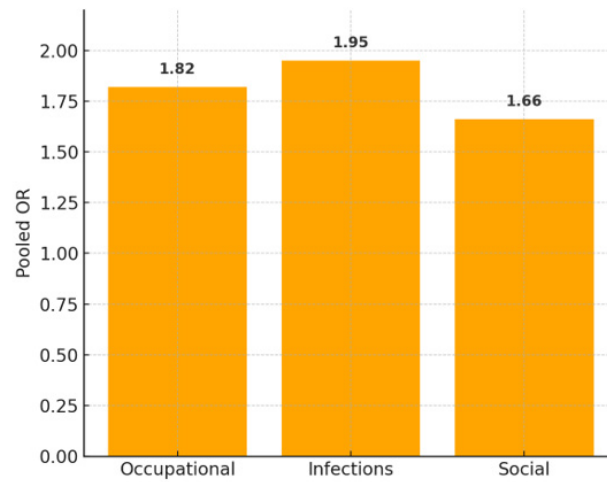
that observed for occupational or infectious exposures, these findings emphasize the importance of modifiable behavioral risk factors in male infertility.

These findings indicate the role of modifiable behavioral factors in male infertility, consistent with evidence linking oxidative stress, endocrine disruption, and thermal effects from mobile phone use to reduced semen quality.

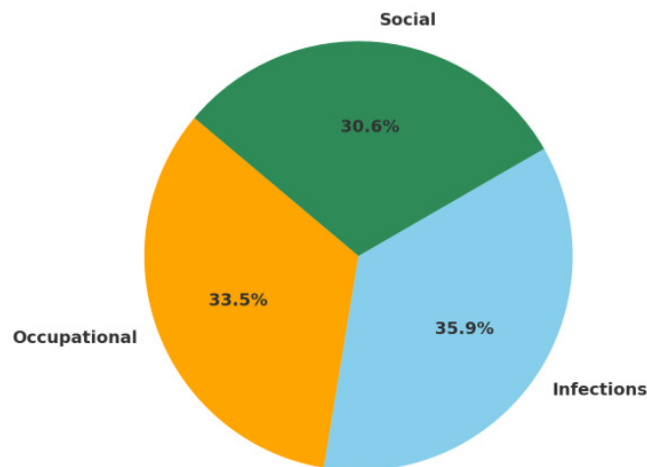
When comparing across domains, the bar chart (Figure 4) revealed that infections contributed the most significant risk, followed closely by occupational exposures and social habits, all of which had statistically significant associations.

The proportional attribution chart (Figure 5) further demonstrated that these domains contributed nearly

equally—35.9% for infections, 33.5% for occupational exposures, and 30.6% for social habits—highlighting the multifactorial etiology of male infertility. This emphasizes the need for integrated prevention strategies that address infectious disease control, occupational health protections, and behavioral interventions. The proportional attribution chart (Figure 5) further demonstrated that these domains contributed nearly



**Figure 4:** Pooled Odds Ratios by exposure domain (Occupational, Infections, Social)



**Figure 5:** Proportional attribution of contribution (weighted by pooled OR)

**Discussion**

This study indicates that there is a significant connection between infections, occupational exposures, and social habits in male infertility. While many studies have been conducted on these domains individually, a significant gap remains, particularly in a comparative analysis of all these domains and their impact on male infertility. It has been seen that transmitted infections and occupational exposures show the most adverse associations with semen quality based on recent studies, and our pooled estimate also aligns with prior literature. Besides, occupational hazards like the use of pesticides and heat-related issues are also significant for male reproduction, and 33.5% of male infertility is likely due to these, based on our study results. Occupational and infection-related interventions (heat mitigation, chemical controls, CT screening, male HPV vaccination) offer practical public-health routes to reduce male infertility risk. The association of HPV, Chlamydia infection and COVID-19 is also observed through multiple studies, and the effects are also preventable with treatment. From our study, it has also

come to our attention that all three domains contribute nearly equally to male infertility, highlighting the need for comprehensive prevention strategies through an integrated approach to address this issue. However, these points to barriers like lack of resources, coordination and social habits that may contribute further to male infertility. While public health campaigns have raised awareness, their impact on behaviors change has been limited. Raising awareness about male infertility and having an integrated approach are crucial, but in order to actually reduce male infertility, they must be combined together with measures that close the knowledge gap.

**Recommendations**

This study recommends raising awareness and adopting an integrated approach, along with action points that cover the gap between knowledge and practice, to effectively reduce male infertility. Comprehensive prevention strategies should include infection control, workplace safety measures, and behavioral modifications to reduce the burden of male infertility effectively. Emphasis should be given on vaccination, early detection

of STIs and treatment of both systemic infections and STIs to protect male reproductive health. Strengthening workplace safety regulations and limiting exposure to reproductive toxicants should also be emphasized in occupational health policies. Behavioral risk factors are modifiable and should be addressed through patient counselling, awareness programs, and integration of lifestyle modification strategies.

### Limitations

There are a few limitations to consider. Limitations of this review include heterogeneity in exposure assessment and reliance on observational designs for many included studies. The reliance on self-reported data in each of these studies' dependent on the population, and this is another limitation, because it might not fully reflect people's social and personal health habits. Additionally, sociocultural elements that might contribute to male infertility and affect the outcomes were not taken into consideration.

### Future Directions

Research on this topic in the future could include more diverse populations to see how socio-cultural factors affect male infertility. Long-term studies associated with multiple risk factors/ domains on male infertility could be conducted, which could give a broader idea of the impacts of these domains on male infertility. It would also be beneficial to investigate which types of public health campaigns are most effective in motivating changes in social behaviors, occupational exposure, or infections. Lastly, future research should harmonize exposure and outcome metrics, priorities prospective preconception cohorts, and evaluate interventions that reduce exposures.

### CONCLUSION

This study systematically analyzed the comparative impacts of occupational exposures, transmitted infections, and social habits on male infertility. The results indicate that all three domains elevate the risk of reduced semen quality and infertility, with infections having the most significant impact, followed closely by occupational exposures and social habits. Even though more people are learning about these risk factors, just being aware of them is not enough to stop the rise in male infertility around the world. Practical obstacles—such as inadequate workplace protections, a lack of infection prevention initiatives, and poor lifestyle habits—are significant hurdles. Even though public health campaigns have made people more aware of safe work practices, infection control, and healthy living, these changes do not always lead to long-term behavioral changes. In short, raising awareness is not enough to reduce male infertility. It needs public health strategies that work together to improve occupational safety, stop infections (including HPV vaccination and early STI detection), and change habits that can be changed, like smoking and drinking. This kind of approach can help reduce the burden of male infertility, leading to better

reproductive outcomes and healthier futures for families all over the world.

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