

# Essential Elements Impacting Male Fertility: A Comprehensive Review

Bhagwati Kumar Markanday<sup>1</sup>, Shalini Pandey<sup>2</sup>, Arunima Sur<sup>\*</sup>

*Amity Institute of Biotechnology, Amity University Chhattisgarh, Raipur, Chhattisgarh, India.*

-----\*\*\*-----

**ABSTRACT:** Infertility is a disorder of the reproductive system that prevents an individual from conceiving children. It affects both men and women, with reproductive dysfunction being a leading cause. Male infertility, in particular, has emerged as a growing concern in many developed countries. Over the past few decades, a noticeable decline in male reproductive health has been reported globally. This includes an alarming rise in the incidence of testicular cancer (TC) and deteriorating sperm quality. Several factors, such as lifestyle choices, environmental exposures, and substance use, contribute to this decline. The use of tobacco, excessive alcohol consumption, smoking, and certain drugs are known to have both short-term and long-term detrimental effects on sperm production and quality. The connection between lifestyle and fertility is particularly concerning, as modern habits and environmental pollutants increasingly impact male reproductive health. Various studies have shown that prolonged exposure to harmful substances, poor diet, sedentary lifestyles, and stress can negatively influence hormonal balance and sperm viability. Environmental pollutants, including endocrine-disrupting chemicals, heavy metals, and radiation, further compound these issues. In this review, we aim to highlight and analyze the significant lifestyle and environmental factors that play a crucial role in male fertility. By examining these influences, we hope to shed light on the broader impact of modern living on overall reproductive health and well-being. Recognizing these contributing factors is essential in addressing the global decline in male fertility and in developing strategies to mitigate its impact. With a better understanding of these factors, public health initiatives can promote healthier lifestyles and reduce environmental exposures that may harm male reproductive health.

**Keywords:** Male Infertility, lifestyle factors, Reproductive health, Sperm Quality, Environmental Pollutants.

## 1. Introduction:

Infertility, a condition defined as the inability to conceive after a year of unprotected sexual intercourse, has emerged as a major global health issue, affecting an estimated 48 million couples worldwide. While infertility can impact both men and women, the causes and contributing factors can vary significantly between the sexes [3]. Historically, female infertility received much of the scientific and societal attention. Women's reproductive health issues, including ovulation disorders, fallopian tube damage, and hormonal imbalances, were more extensively studied, and female infertility was often seen as the predominant factor in a couple's inability to conceive. However, recent research has increasingly highlighted male infertility as an equally critical contributor to the problem, with male factors responsible for nearly 40-50% of infertility cases [4,13].

In many ways, male infertility is a reflection of broader issues concerning male reproductive health. Over the past few decades, there has been a growing recognition of the declining quality of male reproductive health, particularly in more developed and industrialized regions [1,2]. This decline is evidenced by an alarming rise in cases of male infertility, deteriorating sperm quality, and increasing incidence rates of testicular cancer (TC), particularly in younger men. In countries where lifestyle changes, environmental pollution, and shifts in behavior have accompanied rapid industrialization and urbanization, the deterioration of male fertility has become a pressing public health concern [5,6].

This introduction explores the myriad factors influencing male infertility, including genetic, physiological, lifestyle, and environmental influences, while emphasizing the growing importance of reproductive health in modern society. It also examines how evolving societal norms, behavioral habits, and environmental challenges have contributed to a global decline in male fertility [9]. A deeper understanding of these factors can help shape both public health initiatives and clinical approaches to address this critical issue, which has significant implications for individual couples, healthcare systems, and societal demographics [7].

**Table 1. Listing Key aspects of Male Infertility**

Aspect	Description
<b>Definition</b>	The inability to conceive a child after 12 months of regular, unprotected intercourse.
<b>Common Causes</b>	<ul style="list-style-type: none"> <li>- Low sperm count (oligospermia)</li> <li>- Poor sperm motility (asthenospermia)</li> <li>- Abnormal sperm morphology (teratospermia)</li> <li>- Blockages preventing sperm delivery</li> <li>- Genetic factors (e.g., Klinefelter syndrome)</li> <li>- Hormonal imbalances (e.g., low testosterone)</li> </ul>
<b>Risk Factors</b>	<ul style="list-style-type: none"> <li>Age (increasing age reduces sperm quality)</li> <li>- Smoking and alcohol use</li> <li>- Obesity</li> <li>- Exposure to environmental toxins</li> <li>- Testicular injury or surgery</li> <li>- Chronic diseases (e.g., diabetes)</li> </ul>
<b>Diagnosis Methods</b>	<ul style="list-style-type: none"> <li>Semen analysis (sperm count, motility, morphology)</li> <li>- Hormonal testing</li> <li>- Genetic testing</li> <li>- Scrotal ultrasound</li> </ul>
<b>Treatment Options</b>	<ul style="list-style-type: none"> <li>Medications for hormonal imbalances</li> <li>- Surgery to correct blockages or varicocele</li> <li>- Assisted reproductive technologies (ART) such as IVF or ICSI</li> <li>- Lifestyle changes (improving diet, reducing stress)</li> </ul>
<b>Prevention Tips</b>	<ul style="list-style-type: none"> <li>Maintain a healthy weight</li> <li>- Avoid smoking, excessive alcohol, and drug use</li> <li>- Limit exposure to environmental toxins</li> <li>- Wear protective gear during activities that could harm the testicles</li> </ul>

## 2. Male Infertility: A Global Concern

Male infertility is no longer an isolated issue confined to specific regions or populations; rather, it has become a global concern. Over the last several decades, male infertility rates have risen in many parts of the world, particularly in industrialized countries [12]. This increase reflects a broader shift in reproductive health outcomes. What was once thought to be predominantly a female issue is now understood as a shared burden between men and women. Male infertility can arise from a wide range of factors, including genetic defects, hormonal imbalances, structural abnormalities, and problems with sperm production or function [8]. In many cases, however, male infertility is attributed to non-genetic factors, such as lifestyle choices and environmental exposures, which are becoming more prominent in today's modern world [9,10].

The causes of male infertility can be complex and multifactorial. While some men may experience genetic issues that impact sperm production or function, many others face lifestyle-related influences that compromise their fertility [15]. This includes behaviors such as smoking, excessive alcohol consumption, and drug use, all of which have been linked to poorer sperm quality and reduced fertility outcomes. Beyond lifestyle choices, environmental exposures to pollutants, toxins, and chemicals play a significant role in male reproductive health. The cumulative effects of these exposures can result in hormonal disruptions, oxidative stress, and damage to the reproductive organs, all of which contribute to male infertility [11,14].

The decline in male reproductive health has not gone unnoticed by the scientific and medical communities. Numerous studies have pointed to an overall decrease in sperm quality, with some suggesting that sperm counts have dropped by as much as 50% in recent decades [7,16]. In parallel, the incidence of testicular cancer has been rising in many countries, particularly among younger men, signaling an underlying issue with male reproductive health. These trends underscore the urgency of addressing male infertility as a critical public health issue. If left unaddressed, the consequences of declining male fertility could extend beyond individual couples to affect broader population trends and demographic shifts [3,7].

## 3. Understanding the Biology of Male Fertility

The male reproductive system is complex, and proper fertility depends on the healthy functioning of several interconnected organs and processes. At the heart of male fertility is the production of sperm, which occurs in the testes through a process called spermatogenesis [17]. This process is tightly regulated by the hypothalamic-pituitary-gonadal (HPG) axis, which coordinates the release of hormones essential for sperm production. The testes produce both sperm and testosterone, the primary male sex hormone responsible for regulating reproductive functions and secondary sexual characteristics [6,7].

Spermatogenesis is a multi-stage process that begins with the division of germ cells in the testes and ends with the production of mature sperm cells capable of fertilizing an egg. For this process to proceed smoothly, a delicate balance of hormones must be maintained [18]. The HPG axis plays a crucial role in regulating this balance by releasing gonadotropin-releasing hormone (GnRH) from the hypothalamus, which stimulates the pituitary gland to produce follicle-stimulating hormone (FSH) and luteinizing hormone (LH). FSH is essential for the development of sperm cells, while LH stimulates the production of testosterone in the Leydig cells of the testes. Any disruption in this hormonal cascade can impair spermatogenesis, leading to decreased sperm production and infertility [2,5].

The sperm cells that are produced in the testes are stored in the epididymis, where they mature and acquire the ability to swim, a process critical for their motility and fertilization capability. From the epididymis, sperm travel through the vas deferens and are eventually expelled from the body during ejaculation. Seminal fluid produced by the seminal vesicles, prostate gland, and other accessory glands mixes with the sperm to form semen, which helps nourish and protect the sperm during their journey through the female reproductive tract [19].

The health of the sperm themselves is a key determinant of male fertility. Sperm count, motility, and morphology are the three main parameters used to assess sperm health. Sperm count refers to the number of sperm present in a given volume of semen, with lower counts being associated with reduced fertility. Motility refers to the ability of the sperm to swim effectively, as sperm must be able to move through the female reproductive system to reach the egg. Morphology refers to the size and shape of the sperm, as abnormal sperm are less likely to successfully fertilize an egg. Each of these parameters can be affected by a range of factors, including genetic mutations, hormonal imbalances, lifestyle factors, and environmental exposures [8].

#### 4. The Rising Incidence of Testicular Cancer and Declining Sperm Quality

One of the most concerning trends in male reproductive health is the rising incidence of testicular cancer, particularly among younger men. Testicular cancer is the most common form of cancer in males aged 15 to 35, and its incidence has been increasing in many countries over the past several decades. While the exact causes of testicular cancer remain unclear, researchers believe that a combination of genetic, environmental, and lifestyle factors may be responsible. There is growing concern that the same factors contributing to male infertility may also be driving the rise in testicular cancer rates [9,11].

The link between testicular cancer and male infertility is not merely coincidental. Men with testicular cancer often experience compromised sperm quality, either as a result of the cancer itself or the treatments used to combat it, such as chemotherapy and radiation. Even in men without testicular cancer, declining sperm quality has become a widespread issue. Numerous studies have documented a significant decline in average sperm counts and quality over the past 40 years, with some suggesting that sperm counts have halved in this time period [15].

Poor sperm quality, characterized by low sperm counts, poor motility, and abnormal morphology, has become one of the leading causes of male infertility. This decline in sperm quality is thought to be the result of various factors, including increased exposure to environmental pollutants, poor dietary habits, and sedentary lifestyles. As sperm quality declines, men face an increased risk of infertility, as well as other reproductive complications, such as difficulty conceiving and increased rates of miscarriage in their partners [12].

#### 5. Lifestyle Factors Contributing to Male Infertility

The modern lifestyle is often characterized by a combination of behaviors and environmental exposures that can negatively impact male fertility. One of the most significant contributors to male infertility is the use of tobacco products. Smoking has long been associated with a wide range of adverse health outcomes, including an increased risk of cardiovascular disease, cancer, and respiratory disorders [6,8]. However, its effects on fertility are less widely recognized. Smoking has been shown to reduce sperm count, decrease sperm motility, and increase the rate of DNA fragmentation in sperm cells. The chemicals in tobacco smoke, including nicotine, heavy metals, and various carcinogens, can directly damage the testes and impair the process of spermatogenesis. Furthermore, smoking is associated with increased oxidative stress, which can damage sperm cells and compromise their ability to fertilize an egg [10].

Alcohol consumption is another lifestyle factor that has been linked to male infertility. While moderate alcohol consumption may not have a significant impact on fertility, excessive or chronic alcohol use can impair testicular function and alter hormone levels, particularly testosterone. Alcohol interferes with the HPG axis, reducing the production of testosterone and leading to testicular atrophy (shrinking of the testes), which in turn results in decreased sperm production. Alcohol also contributes to oxidative stress and inflammation, both of which have negative effects on sperm quality [3,8].

Obesity, a growing global health epidemic, has also been identified as a major contributor to male infertility. Excess body fat disrupts the hormonal balance necessary for proper sperm production. In particular, obesity is associated with lower testosterone levels and higher estrogen levels, as fat tissue converts testosterone into estrogen. This hormonal imbalance can lead to reduced sperm production and poor sperm quality. In addition to hormonal changes, obesity is linked to chronic inflammation, insulin resistance, and oxidative stress, all of which negatively affect sperm health. A sedentary lifestyle further exacerbates these issues, as physical inactivity is associated with lower sperm counts and reduced sperm motility. Conversely, regular physical activity has been shown to improve sperm parameters and enhance fertility outcomes [2,3].

Diet also plays a critical role in male reproductive health. A diet high in processed foods, saturated fats, and sugars can have negative effects on sperm production and quality. Conversely, diets rich in antioxidants, vitamins, and minerals, such as those found in fruits, vegetables, whole grains, and lean proteins, are associated with better sperm health. Antioxidants help to combat oxidative stress, which is one of the primary drivers of sperm damage. Several studies have shown that men who consume a diet rich in antioxidants, such as vitamins C and E, zinc, and selenium, have better sperm counts, motility, and morphology [1].

#### 6. Environmental Factors Impacting Male Fertility

Beyond lifestyle choices, environmental exposures play a significant role in male infertility. One of the most concerning groups of environmental toxins is endocrine-disrupting chemicals (EDCs), which can interfere with the body's hormonal

systems. EDCs are found in a wide range of products, including plastics (e.g., bisphenol A or BPA), pesticides, and personal care products [19]. These chemicals can mimic or block the actions of hormones, leading to disruptions in the HPG axis and impaired spermatogenesis. Numerous studies have linked EDC exposure to lower sperm counts, reduced sperm motility, and increased rates of infertility. In particular, phthalates, which are used as plasticizers in many consumer products, have been shown to negatively impact male fertility by reducing testosterone levels and impairing sperm production [11].

Heavy metals, such as lead, mercury, and cadmium, also pose a threat to male reproductive health. Occupational exposure to these metals, as well as environmental contamination from industrial processes, can result in reduced sperm counts and impaired sperm function. Heavy metals can disrupt the delicate processes of spermatogenesis by causing oxidative stress, DNA damage, and hormonal imbalances. Long-term exposure to these metals has been associated with an increased risk of infertility and reproductive disorders [14,19].

Radiation and heat exposure are additional environmental factors that can negatively impact male fertility. The testes are highly sensitive to temperature, and prolonged exposure to heat can impair sperm production. This is why the testes are located outside the body in the scrotum, where the temperature is lower than the body's core temperature. Activities that increase scrotal temperature, such as frequent use of hot tubs, saunas, or prolonged sitting, can reduce sperm production and motility. Similarly, exposure to radiation, whether from occupational sources or medical treatments, can damage sperm DNA and lead to infertility [11,13].

Air pollution is another growing concern for male reproductive health. Numerous studies have linked exposure to air pollutants, such as particulate matter (PM), nitrogen dioxide (NO<sub>2</sub>), and ozone (O<sub>3</sub>), to reduced sperm quality and increased rates of infertility. Airborne pollutants can cause oxidative stress and inflammation, both of which are detrimental to sperm health. In particular, exposure to fine particulate matter (PM<sub>2.5</sub>) has been associated with lower sperm counts and reduced motility [15, 17].

## 7. Addressing Male Infertility: Strategies and Solutions

Addressing male infertility requires a multifaceted approach that targets both lifestyle and environmental factors. For many men, lifestyle modifications can have a significant impact on fertility outcomes. Quitting smoking, reducing alcohol consumption, and adopting a healthy diet rich in antioxidants are important steps toward improving sperm health. Regular physical activity and maintaining a healthy weight can also enhance fertility by improving hormonal balance and reducing oxidative stress [16].

Reducing exposure to environmental toxins, such as EDCs and heavy metals, is another critical component of addressing male infertility. This can be achieved through public health policies that regulate the use of harmful chemicals in consumer products and industrial processes, as well as through individual efforts to avoid exposure to known toxins. For example, men can reduce their exposure to BPA and phthalates by avoiding plastic containers and choosing products that are free of these chemicals [18].

Advancements in fertility treatments, such as assisted reproductive technologies (ART), have also provided new options for men facing infertility. In cases where lifestyle modifications and environmental interventions are not sufficient, ART techniques, such as in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI), can help couples achieve pregnancy. These technologies have become increasingly sophisticated, offering hope to many couples struggling with infertility [10].

Finally, public health campaigns and educational initiatives are needed to raise awareness about the factors contributing to male infertility. Many men are unaware of the impact that lifestyle choices and environmental exposures can have on their fertility. By promoting awareness and encouraging early interventions, it may be possible to reverse some of the trends contributing to the global decline in male reproductive health [14].

## 8. Conclusion

Male infertility is a growing global health concern that is influenced by a complex interplay of genetic, physiological, lifestyle, and environmental factors. The decline in male reproductive health, as evidenced by rising rates of infertility, poor sperm quality, and increasing incidence of testicular cancer, has significant implications for individuals, couples, and societies as a whole. Addressing this issue requires a comprehensive approach that includes lifestyle modifications, environmental interventions, and advancements in fertility treatments. By understanding the factors contributing to male infertility and taking proactive steps to improve reproductive health, it is possible to mitigate the impact of this pressing

public health issue. Future research and public health initiatives must continue to focus on identifying the causes of male infertility and developing effective strategies for prevention and treatment.

## References:

1. Agarwal, A., Baskaran, S., Parekh, N., Cho, C. L., Henkel, R., Vij, S., ... & Shah, R. (2021). Male infertility. *The Lancet*, 397(10271), 319-333.
2. Agarwal, A., Mulgund, A., Hamada, A., & Chyatte, M. R. (2015). A unique view on male infertility around the globe. *Reproductive biology and endocrinology*, 13, 1-9.
3. Babakhanzadeh, E., Nazari, M., Ghasemifar, S., & Khodadadian, A. (2020). Some of the factors involved in male infertility: a prospective review. *International journal of general medicine*, 29-41.
4. Barratt, C. L., Björndahl, L., De Jonge, C. J., Lamb, D. J., Osorio Martini, F., McLachlan, R., ... & Tournaye, H. (2017). The diagnosis of male infertility: an analysis of the evidence to support the development of global WHO guidance—challenges and future research opportunities. *Human reproduction update*, 23(6), 660-680.
5. De Kretser, D. M. (1997). Male infertility. *The lancet*, 349(9054), 787-790.
6. Dissanayake, D. M. I. H., Keerthirathna, W. L. R., & Peiris, L. D. C. (2019). Male infertility problem: a contemporary review on present status and future perspective. *Gender and the Genome*, 3, 2470289719868240.
7. Dohle, G. R. (2010). Male infertility in cancer patients: review of the literature. *International journal of urology*, 17(4), 327-331.
8. Fainberg, J., & Kashanian, J. A. (2019). Recent advances in understanding and managing male infertility. *F1000Research*, 8.
9. Hanna, E., & Gough, B. (2015). Experiencing male infertility: A review of the qualitative research literature. *Sage Open*, 5(4), 2158244015610319.
10. Kolesnikova, L. I., Kolesnikov, S. I., Kurashova, N. A., & Bairova, T. A. (2015). Causes and factors of male infertility. *Annals of the Russian academy of medical sciences*, 70(5), 579-584.
11. Krausz, C., Escamilla, A. R., & Chianese, C. (2015). Genetics of male infertility: from research to clinic. *Reproduction*, 150(5), R159-R174.
12. Kumar, N., & Singh, A. K. (2015). Trends of male factor infertility, an important cause of infertility: A review of literature. *Journal of human reproductive sciences*, 8(4), 191-196.
13. O'brien, K. L. F., Varghese, A. C., & Agarwal, A. (2010). The genetic causes of male factor infertility: a review. *Fertility and sterility*, 93(1), 1-12.
14. Okonofua, F. E., Ntoimo, L. F. C., Omonkhua, A., Ayodeji, O., Olafusi, C., Unuabonah, E., & Ohenhen, V. (2022). Causes and risk factors for male infertility: a scoping review of published studies. *International Journal of General Medicine*, 5985-5997.
15. Olooto, W. E. (2012). Infertility in male; risk factors, causes and management-A review. *J Microbiol Biotechnol Res*, 2(4), 641-645.
16. Sharma, A. (2017). Male infertility; evidences, risk factors, causes, diagnosis and management in human. *Ann Clin Lab Res*, 5(3), 188.
17. Sudhakar, D. V., Shah, R., & Gajbhiye, R. K. (2021). Genetics of male infertility—present and future: a narrative review. *Journal of human reproductive sciences*, 14(3), 217-227.
18. Takeshima, T., Usui, K., Mori, K., Asai, T., Yasuda, K., Kuroda, S., & Yumura, Y. (2021). Oxidative stress and male infertility. *Reproductive Medicine and Biology*, 20(1), 41-52.
19. Turner, K. A., Rambhatla, A., Schon, S., Agarwal, A., Krawetz, S. A., Dupree, J. M., & Avidor-Reiss, T. (2020). Male infertility is a women's health issue—research and clinical evaluation of male infertility is needed. *Cells*, 9(4), 990.