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POSITIVE EFFECT OF YOGA ON REPRODUCTIVE SYSTEM WITH RESPECT TO INFERTILITY

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ABSTRACT

Infertility, a widespread medical condition affecting numerous couples globally, persists as a challenge despite advances in assisted reproductive technologies (ARTs), often burdened by financial, physical, and emotional strains. Complementary and alternative approaches, notably yoga, have garnered attention for potentially enhancing fertility outcomes. Studies reveal yoga's influence on factors contributing to infertility, including reduced oxidative stress (OS) and oxidative DNA damage (ODD). OS, linked to mutagenic base formation, higher malondialdehyde levels, abnormal methylation, and altered gene expression, can impair sperm genome integrity. Yoga's efficacy is evident in lowering OS, positively affecting signal transmission, gene expression, and physiological systems. Furthermore, yoga has a positive impact on addressing the dysregulation of apoptosis, resulting in improved processes such as spermatogenesis, sperm maturation, and motility, while also reducing DNA fragmentation. OS correlates with genome-wide hypomethylation, telomere shortening, and mitochondrial dysfunction, contributing to genome instability. Yoga and meditation significantly reduce OS and ODD, ensuring proper reactive oxygen levels and preserving physiological systems. The review explores potential mechanisms underlying yoga's positive impact on infertility, including enhanced blood flow, reduced inflammation, relaxation response, and modulation of the hypothalamic–pituitary–adrenal axis. Furthermore, a comprehensive review of the literature reveals substantial evidence supporting the positive effects of yoga on infertility factors. These include oxidative stress (OS), oxidative DNA damage (ODD), epigenetic changes, hormonal balance, ovarian function, menstrual irregularities, and stress reduction. In summary, yoga emerges as a promising adjunctive therapy for infertility, demonstrating the potential to mitigate key factors influencing reproductive success. Although preliminary evidence indicates the positive effects of yoga on infertility, further clinical research is imperative to define specific benefits, molecular mechanisms associated, optimal protocols, and long-term effects in infertility treatment plans.

KEYWORDS: Epigenetic alterations, infertility, oxidative DNA damage, oxidative stress, yoga.

INTRODUCTION

Infertility, characterized by the inability to conceive after a year of regular unprotected intercourse, affects approximately one in six people globally according to the World Health Organization.[1] Male and female infertility can cause by a variety of factors, encompassing physiological, genetic, environmental, and lifestyle-related causes. In men, infertility may stem from hormonal imbalances, structural abnormalities, genetic disorders, and sperm abnormalities.[2,3] The diagnosis often involves semen analysis, hormone testing, genetic testing, and imaging techniques to comprehensively assess the factors contributing to infertility.[4]

In contrast, female infertility may arise from factors such as ovulation disorders, tubal issues, uterine abnormalities, and hormonal imbalances. The diagnostic process typically combines elements such as medical history, physical examination, hormonal assessments, and imaging procedures.[5] Sperm DNA integrity and epigenetic health are crucial for fertility, influenced by lifestyle factors and exacerbated by the stress of infertility.[6] Yoga, known for stress reduction, emerges as a potential adjunct therapy, addressing both physiological and psychological aspects in the context of the common global issue of infertility.[7] Infertility rates vary globally, influenced by cultural norms, health-care access, and socioeconomic conditions. Recent studies show a rising trend, increasing the demand for infertility treatments and reproductive services.[8] Infertility's

impact reaches beyond individuals, affecting families, communities, and societies with far-reaching medical and psychosocial consequences. Recent advancements in infertility diagnosis and treatment aim to enhance outcomes through comprehensive assessments, including medical history, physical examinations, hormonal testing, and imaging techniques. These methods help identify underlying causes such as hormonal imbalances, anatomical abnormalities, and genetic factors.[3,9] However, diagnostic limitations exist, as some cases may remain unexplained. Treatment options range from lifestyle modifications to medical procedures and assisted reproductive technology (ART). Lifestyle changes include optimizing nutrition, managing weight, and reducing harmful habits, whereas medications address hormonal imbalances, induce ovulation, and treat infections.[10] ART procedures, such as *in vitro* fertilization (IVF) and intracytoplasmic sperm injection, offer advanced options for assisted conception, albeit with varying success rates and potential emotional, psychological, financial, and accessibility challenges.[11] Beyond the physical aspects, infertility takes a toll on the psychological well-being of individuals and couples. The impact extends to families, communities, and societies, emphasizing the need for holistic approaches to address the multifaceted challenges associated with infertility.[12]

This article explores the critical roles of DNA integrity and epigenetic modifications in sperm and their implications for fertility and offspring health. Specifically, we delve into the potential of yoga, a mind–body practice renowned for its stress-reducing effects, to optimize sperm quality and enhance oocyte health. Our aim is to examine the current evidence and knowledge gaps surrounding the impact of yoga on sperm DNA integrity and epigenetic regulation, shedding light on its potential benefits as an adjunct therapy in infertility treatment. As we explore the intricacies of infertility, our review seeks to provide a comprehensive understanding of its multifaceted landscape. This encompasses delving into the diagnostic challenges, exploring various treatment modalities, and investigating the promising role that yoga might play in optimizing reproductive outcomes.

METHODS

We conducted an extensive literature search using keywords such as “Male infertility,” “Yoga therapy,” “Lifestyle changes,” and “adjunct therapy” on databases including PubMed, Scopus, and Google Scholar. Our inclusion criteria comprised studies published between 1998 and 2023, specifically exploring male infertility, yoga therapy, lifestyle changes, and visual health. We aimed to integrate both foundational and recent research insights for a comprehensive review. Exclusion criteria were applied to filter out studies not directly aligned with our specified topics or falling outside the designated publication timeframe. This meticulous approach ensures a focused and up-to-date selection of studies contributing to the depth of our review.

Yoga and Reproductive Health

Yoga is an ancient practice originating in the Indian subcontinent, gaining global recognition for its profound impact on physical, mental, and spiritual well-being.[13] Deeply rooted in ancient Indian scriptures, notably the Rigveda, yoga encompasses diverse traditions and schools of thought, such as Hatha, Raja, Karma, and Bhakti Yoga.[14] Ancient yoga is observed the interconnection among body, mind, and spirit, developing practices to cultivate harmony within these facets of human existence.[15] Yoga encompasses physical postures (asanas), breathing techniques (pranayama), meditation, ethical principles, and self-reflection, all aimed at achieving a state of balance and inner harmony. Pranayama and yoga practices emphasize “breath-work techniques” promoting energy flow and mindfulness.[16] Yoga has gained worldwide popularity due to its numerous benefits in treating various diseases and its significant role in reducing oxidative stress (OS), maintaining nuclear and mitochondrial DNA (mtDNA) integrity, facilitating epigenetic modulation, and promoting stress reduction and mental well-being.[17] Recognized as a complementary therapy in modern health care, yoga, supported by various studies, proves effective in enhancing fertility outcomes. It positively influences crucial aspects of reproductive health, including improved sperm DNA integrity, hormonal balance, and menstrual regularity. Studies indicate benefits in women with PCOS, showing reduced testosterone and luteinizing hormone levels. In couples undergoing infertility treatment, a randomized study revealed enhanced semen parameters, such as increased sperm concentration and motility, in the yoga intervention group compared to standard care.[18] These findings collectively highlight the potential of yoga in positively impacting both male and female reproductive health.

Impact of Yoga on Both Male and Female Infertility

Yoga’s role in mitigating oxidative stress and preventing DNA damage

OS (Oxidative stress) and associated DNA damage are major factors in infertility for both male and female partners. OS occurs when the balance between reactive oxygen species (ROS) production and the body’s antioxidant defense system is disrupted, leading to cellular damage and DNA alterations. Such OS-induced DNA damage can have profound implications for overall health, including reproductive health.[19,20] In a study, yoga resulted in a notable decrease in indicators of DNA damage, such as tail moment ($P = 0.013$) and olive tail moment ($P < 0.01$). In addition, there were a significant improvement in the expression of the OGG1 protein, which is involved in DNA repair, and a decrease in the oxidative DNA damage (ODD) marker 8-OHdG ($P < 0.001$) in individuals with type 2 diabetes.[21] In a study on fathers of children with retinoblastoma (RB), significantly higher levels of ROS, sperm DNA fragmentation index (DFI), and 8-OHdG were observed. The study suggests that factors such as oxidized

mutagenic DNA, elevated malondialdehyde (MDA) levels, mutagenic accumulation, aberrant methylation patterns, and hypermutability of the sperm genome may contribute to childhood cancer. However, a 6-month yoga intervention remarkably reduced 8-OHdG ($P < 0.05$), DFI ($P < 0.05$), and ROS levels ($P < 0.05$), indicating the potential of yoga in lowering the risk of cancer.[22] It has been shown that the impact of yoga-based lifestyle intervention (YBLI) on seminal OS, DNA damage, and spermatozoal transcript levels in 30 male partners of couples experiencing recurrent pregnancy loss (RPL). Results indicated that YBLI led to upregulation of beneficial transcripts (SOX3, OGG1, and PARP1) and downregulation of others (FOXG1, RPS6, RBM9, RPS17, and RPL29). In addition, YBLI resulted in a significant reduction in OS, improved sperm motility and count, and decreased DNA fragmentation, suggesting its potential in enhancing fertility and offspring health.[18] Sperm, being a highly polarized cell, is particularly susceptible to OS due to its distinctive morphology, chromatin structure, and function. Human sperm chromatin retains 5%–15% of histones, a unique feature compared to other mammalian species.[17] In a pilot study of 10 fathers of children with nonfamilial sporadic heritable RB, practicing yoga and meditation for 3 and 6 months resulted in a significant reduction in sperm DFI at 6 months ($P < 0.05$) compared to baseline (day 0). Seminal reactive oxygen species (ROS) levels were significantly reduced after 3 months ($P < 0.05$) and 6 months ($P < 0.01$), whereas levels of the mutagenic base 8-OHdG showed a reduction after 6 months ($P < 0.05$). These findings suggest that yoga and meditation interventions can effectively lower OS and ODD, contributing to the maintenance or restoration of sperm DNA integrity in this specific population.[23] Lifestyle factors, such as fast-food consumption, sedentary habits, smoking, alcohol use, as well as experiencing stress and depression, can contribute to an overproduction of reactive oxygen species, leading to DNA damage.[24] Sperm and oocytes employ 8-oxoguanine glycosylase-1 for repairing damaged DNA; however, they lack downstream DNA repair genes.[25] The limited detection capacity of sperm may lead to substantial damage, causing the accumulation of oxidized DNA adducts in zygote cells. These mutagenic adducts can generate epimutations, leading to genomic instability and an 18-fold increase in mutation rates, including GC > TA transversions.[26] In a study of fathers with nonfamilial sporadic heritable RB, a 4-week mindfulness-based stress reduction (MBSR) intervention led to a significant reduction ($P < 0.0001$) in reactive oxygen species, DNA fragmentation, and ODD, along with an increase ($P < 0.0001$) in total antioxidant capacity.[27] The studies have shown that the yoga intervention could significantly reduce markers of OS, such as MDA levels which have been found raised in unexplained female infertility.[28,29] It also enhances antioxidant defense mechanisms, such as the activity of superoxide dismutase, glutathione peroxidase (GPx), and catalase.[30,31] While antioxidant therapy can effectively reduce reactive oxygen species (ROS) levels, its limitation lies in the inability to regulate them comprehensively. This poses a challenge in achieving a complete restoration of a healthy balance within the system. Yoga and meditation, on the other hand, regulate ROS levels, rather than merely lowering them.[32] In summary, yoga has potential as a preventive and therapeutic strategy for reducing OS and DNA damage, potentially preventing health disorders such as infertility.

Impact of yoga on genome and epigenome

Male infertility is linked to impaired sperm chromatin integrity and nuclear DNA damage, with genomic imprinting playing a crucial role. In a study after 21 days of yoga therapy, patients with idiopathic male infertility showed a significant change in the sperm parameters. Moreover, changes in the sperm epigenome of these patients are revealed by methylome analysis based on next-generation sequencing. It has been discovered that almost 400 genes have altered DNA methylation levels in relation to yoga practice; 229 of these genes were hypomethylated and 147 were hypermethylated. Among them were promoters of multiple genes associated with maintaining both genomic integrity and fertility.[33] It has been reported that mutations in the gene like DNA: It is DNA polymerase subunit gamma-1 also known as PLOG gene symbol, the only DNA polymerase known to function in human mitochondria, affect adenosine triphosphate production and fertility.[34] mtDNA damage is more severe than nuclear DNA damage. Mitochondrial dysfunction, characterized by impaired mtDNA and compromised mitochondrial function, has been implicated in male and female infertility. Studies found that mitochondrial genes are important in proper sperm growth, development, and differentiation, as well as sperm flagellar movement following ejaculation. Mutation in mitochondrial genes causes abnormal semen parameters, impaired sperm mobility, and infertility.[35] Yoga improves mitochondrial and nuclear DNA integrity, has a positive effect on sperm epigenome, and also has an impact on a variety of systems such as metabolism, epigenetics, DNA repair, aging, and reproductive health.[27,34] Previously, it has been demonstrated that post yoga practice improves mitochondrial integrity through increased membrane potential, NAD+, COX-II levels, mitochondrial copy number, and expression of genes promoting mitochondrial biogenesis.[36] Preliminary findings suggest that yoga and mindfulness interventions may positively influence mtDNA integrity and function. Exposure to mutagens such as cigarette smoke can lead to mutations in DNA repair genes and lower expression of OGG1, resulting in mutagenic lesions in sperm DNA. These lesions indicate a deficiency in DNA mismatch repair genes, which play a crucial role in meiotic recombination. Infertility in men and mice is caused by disruption of chromosomal synapsis. P53, a tumor-suppressor gene, plays a crucial role in spermatogenesis and is associated with loss-of-function mutations in P53, which can lead to ODD and testicular

cancers. P53 also upregulates antioxidant genes, such as sestrin1, nuclear factor, erythroid 2-like2, GPx1, aldehyde dehydrogenase 4, TP53-induced glycolysis regulatory phosphatase, and tumor protein p53-inducible nuclear protein 1.[37] Yoga helps to maintain and regulate the expression of such genes with key importance.

Epigenetics alterations are changes in gene expression caused by nuclear chromatin modifications, such as DNA-methyltransferase enzymes. Protamine-bound sperm DNA is inert, but its nucleosomal component contains highly acetylated histones. ODD leads to aberrant sperm DNA methylation patterns, global hypomethylation, and genomic instability. This is associated with male infertility, impaired spermatogenesis, and a higher incidence of genomic imprinting disorders in children conceived using ARTs.[38] OS-induced *de novo* epigenetic modifications, such as global hypomethylation and hypermethylation of tumor-suppressor genes, can affect embryonic development and have long-lasting implications for offspring's health. OS can affect signal transduction pathways, modulating biological processes. Free radicals (ROS) are redox sensitive, highlighting the need to maintain optimal ROS levels in men to maintain optimal sperm function.[39] Sedentary lifestyles, smoking, and excessive alcohol intake contribute to OS, leading to abnormal sperm DNA methylation.[32] A study conducted in Japan found that an MBSR program improved cognitive function and increased miR-29c expression in neuron-derived exosomes. It also decreased expression of DNA methyltransferase 3α, β and signal transducer and activator of transcription 3, suggesting that MBSR could prevent neuronal loss and cognitive decline.[40] Apart from sperm, ODD has significant implications for various biological processes, including oocyte development and function. The accumulation of ODD in oocytes can disrupt normal chromosomal structure and integrity such as chromosomal deletions, duplications, translocations, or aneuploidy that can have profound consequences on fertility and embryo development, which can increase the risk of miscarriages, implantation failure, and the birth of children with genetic abnormalities.[41] The susceptibility of oocytes to ODD is influenced by various factors, including advanced maternal age, environmental exposures, lifestyle factors (such as smoking and poor diet), and underlying medical conditions. In addition, the oocyte's limited capacity for DNA repair further contributes to its vulnerability to oxidative damage. Antioxidant supplementation, lifestyle modifications, and interventions that promote overall well-being, such as yoga, mindfulness, and exercise, have shown promise in reducing OS and protecting DNA integrity in oocytes.

Impact of yoga on apoptosis in infertility

Among the various underlying causes, apoptosis, a tightly regulated form of programmed cell death, has emerged as a critical process implicated in the pathogenesis of male infertility. It is the process by which multicellular organisms regulate cell quantity by managing cell division and cell death rates. This causes DNA breakage, cytoplasm shrinkage, and nuclear membrane blabbing while causing little harm to surrounding cells. During embryonic development, apoptosis is critical for building the spermatogonial stem cell pool in the male germline, which determines male fertility. In the testis, premeiotic spermatogonia undergo apoptosis during the first round of spermatogenesis to regulate their numbers. Deletion of genes regulating apoptosis, such as BCL-2-like protein 1 and BAX, leads to decreased germ cell apoptosis, leading to male factor infertility.[42] Apoptosis selectively removes damaged or defective germ cells from seminiferous tubules, preventing spermatogenesis and differentiation into mature spermatozoa. Factors such as unhealthy lifestyles, exposure to radiation, environmental toxins, chemotherapeutic agents, and deletions in spermatogenesis regulatory genes can induce apoptosis. These factors can promote OS, which adversely affects spermatogenesis and generates spermatozoa with poorly remodeled chromatin. The major source of DNA damage in spermatozoa is OS, which is compounded by the physical architecture of human spermatozoa. This stops nucleases from accessing the sperm nuclear DNA and fragmenting it. Spermatozoa with poorly compacted chromatin enter the apoptotic cascade, leading to male infertility.[43] The consequences of abrupt apoptosis are substantial, leading to impaired spermatogenesis, disrupted sperm maturation and motility, increased sperm DNA fragmentation, and a compromised potential for successful fertilization. Excessive ROS and OS trigger an apoptotic cascade in sperm, rendering it inert and immotile. It is critical to develop therapies to treat or prevent OS-induced apoptosis in sperm cells. Tumor necrosis factor (TNF) binding and elevated inflammatory cytokine and nuclear factor-κB levels are caused by OS-induced free radical buildup, which may explain the presence of injured sperm in the ejaculate.[44] Infertile men have higher levels of seminal OS and enhanced apoptosis compared to fertile counterparts.[25,45] Studies have proved that yoga-based lifestyle can help to reduce OS induced by these factors;[23,31] hence, yoga improves dysregulation of apoptosis in the process of spermatogenesis.

Effects of yoga on immune system regulation and inflammation

The immune system plays a crucial role in maintaining reproductive health and fertility. Dysregulation of the immune system and chronic inflammation have been associated with infertility.[46,47] Studies have suggested that yoga interventions may have immunomodulatory effects, promoting a balanced immune response and reducing chronic inflammation.[48,49] They found that the yoga group showed significant improvements in immune function, including increased natural killer cell activity and decreased pro-inflammatory cytokine levels, compared to the control group. Yoga practice has been associated with stress reduction,[50] and chronic stress has

been linked to immune dysregulation and increased inflammation.[51,52] By reducing stress levels, yoga may help restore immune system balance and attenuate inflammation. In a study by Cahn *et al*., individuals who engaged in a yoga and meditation program exhibited lower levels of pro-inflammatory cytokines and reduced gene expression related to inflammation compared to a control group.[53] In a study involving 66 rheumatoid arthritis patients, a YBLI demonstrated significant improvements, including a noteworthy decrease in DAS28-ESR ($P < 0.001$) and enhanced quality of life in physical, psychological, and social domains ($P < 0.001$). Furthermore, the study observed upregulation of transforming growth factor-β and downregulation of inflammatory cytokines (interleukin [IL]-6 and TNF-α) and CTLA4, suggesting that yoga may reduce inflammation and improve mind–body communication, positively impacting the overall quality of life. However, no studies have been reported on infertility cases.[49] Moreover, yoga's impact on the autonomic nervous system and the hypothalamic–pituitary–adrenal axis can influence immune system regulation.[54,55] The relaxation response elicited during yoga practice stimulates the parasympathetic nervous system, promoting a state of rest and repair.[56] This, in turn, can modulate immune function and decrease inflammation. It has been shown that moderate correlations were identified between yoga and psychological distress in women, with measurements of IL-6, TNF, C-reactive protein, DNA methylation, and LINE-1. The yoga group exhibited elevated IL-6 levels and reduced TNF methylation compared to the control group, but no significant differences were observed for other genes.[57] Reducing chronic inflammation is particularly relevant in the context of infertility, as excessive inflammation can disrupt reproductive processes and impair fertility.[58,59] In summary, by mitigating inflammation, yoga interventions may create a more favorable environment for reproductive health and support the success of fertility treatments. However, more research is needed to further elucidate the specific mechanisms through which yoga influences immune system regulation and inflammation in the context of infertility.

Influence of yoga on hormonal balance and enhancement of blood circulation

Studies exploring the relationship between yoga and fertility have shown promising results. Yoga practice may help regulate the endocrine system, enhance blood flow to the reproductive organs, reduce stress levels, and improve hormonal balance, all of which play a crucial role in fertility.[60] Yoga interventions have been associated with a decrease in cortisol levels, the primary stress hormone that, when elevated, can disrupt the delicate hormonal equilibrium necessary for reproductive function.[61] Polycystic ovary syndrome (PCOS) is an endocrine-metabolic illness affecting 22.5% of Indian women, yoga and herbal remedies have shown symptom relief, improved hormonal balance, and improved quality of life for women with PCOS.[62] In a study, women with polycystic ovary syndrome (PCOS) who engaged in a 2-month lifestyle modification program involving yoga and walking exercises demonstrated significant reductions in serum testosterone levels. These findings suggest a potential improvement in hormonal regulation associated with PCOS.[63,64] Circadian rhythm disruption, influenced by modern lifestyle stress, is a key factor in infertility-related conditions. Understanding the interaction between hormones, fertility, and the circadian clock could inform more effective therapeutic strategies.[65] The practicing yoga (asanas, pranayama, and yoga nidra) significantly enhances pain tolerance and reduces stress in individuals with dysmenorrhea.[66] The research evidence suggests that controlling stress through yoga is crucial for hormonal balance and decreasing dysmenorrhea. It has been shown that a 6-month yoga practice can lead to significant improvements in lipid profiles and thyroid function in female patients with hypothyroidism, including reductions in total cholesterol, low-density lipoprotein, and triglycerides, as well as enhancements in high-density lipoprotein and thyroid-stimulating hormone levels.[67] Furthermore, yoga practice has been shown to enhance blood circulation, including to the reproductive organs. Specific yoga asanas (postures) are believed to increase blood flow to the pelvic region, promoting optimal functioning of the reproductive system.[68,69] Improved blood flow can enhance the nourishment and detoxification processes within the reproductive system, thereby optimizing its functioning. In addition, increased blood circulation may help in the removal of metabolic waste products and support the transport of hormones and nutrients to the reproductive organs.[70] The mechanisms through which yoga influences hormonal balance and blood circulation are likely multifaceted. Yoga poses such as Baddha Konasana, Supported Bridge Pose, and Legs Up the Wall Pose target the reproductive system, improving function and promoting overall reproductive health. Pranayama and meditation reduce stress, lower cortisol levels, and promote balance, potentially benefiting hormonal regulation and fertility.

Impact of yoga on psychological stress and anxiety reduction in reproductive health

Psychological stress and anxiety can have a profound impact on reproductive health, affecting both women and men attempting to conceive. In recent years, there has been profound interest in the role of yoga as an effective intervention for reducing stress and anxiety, thereby promoting reproductive health.[71] The studies revealed that yoga interventions consistently led to reductions in stress levels and anxiety symptoms across different age groups and health conditions.[72] In a study, the focus was on assessing the impact of a comprehensive mind-body program, which included yoga, in alleviating psychological distress among women undergoing *in vitro* fertilization (IVF). The results showed a significant reduction in anxiety and depression scores among participants who engaged in the mind–body program compared to the control group.[73] A 12-week YBLI

program significantly improved psychological stress and overall quality of life in parents of RB patients. The intervention improved physical, psychological, social relationships and environmental domains of WHOQOL-BREF. It also increased brain-derived neurotrophic factors, dehydroepiandrosterone sulfate, and sirtuin 1 while decreasing cortisol and IL-6 levels.[74] Furthermore, the benefits of a 12-week yoga and meditation-based lifestyle intervention on major depressive disorder were linked to better systemic neuroplasticity biomarkers such as BDNF, DHEAS, and sirtuin 1. In a study examining the impact of yoga and combined aerobic and strength training (A + ST) on the quality of life of women with pituitary adenomas, the results show that both A + ST and yoga improve emotional state, sexual function, sleep, weariness, and cognitive condition. After the yoga program, FACT-Br scores increased, the A + ST program reduced Hospital Anxiety and Depression Scale levels, and both exercise programs elevated MOCA scores ($P < 0.05$).[75] Furthermore, yoga can help to reduce infertility-related stress and anxiety in men with poor semen parameters; it improves autonomic functions by triggering neurohormonal mechanisms by the suppression of sympathetic activity, along with progress in quality of life.[76] Yoga, encompassing postures, breathing exercises, and meditation, fosters relaxation, mindfulness, and inner tranquillity. The physical practice releases endorphins, promoting a sense of well-being. In essence, yoga's breathing techniques may regulate the autonomic nervous system, reducing sympathetic activation and enhancing parasympathetic response.

Yoga in Combination with Conventional Treatment

Use of yoga as an adjunct to medical interventions for infertility

Male infertility is a significant concern affecting couples worldwide, with various medical interventions available to address the underlying causes. In recent years, complementary and alternative approaches, such as yoga, have gained attention as potential adjunct therapies for male infertility. Yoga interventions have been associated with improvements in sperm quality, including sperm count, motility, morphology, and DNA integrity.[18] Studies have demonstrated that men who participated in mindfulness and yoga program exhibited a significant increase in sperm concentration and motility compared to a control group.[76] It can lead to improvements in sperm DNA integrity and reduced oxidative stress (ROS) levels in infertile men.[27,77]

Furthermore, yoga interventions have been associated with improved hormonal balance in men. Hormonal imbalances, such as low testosterone levels, can negatively affect sperm production.[78] Yoga's ability to modulate the endocrine system, including the hypothalamic–pituitary–gonadal axis, may support hormonal regulation and enhance fertility outcomes.[76] While the evidence on the use of yoga as an adjunct therapy for male infertility is promising, further research is necessary to establish standardized protocols and determine optimal practices, durations, and frequencies of yoga interventions.

Potential synergistic effects of combining yoga with assisted reproductive technologies

ARTs, including IVF and intrauterine insemination, have revolutionized the treatment of infertility. However, the success rates of ART procedures can vary, and individuals and couples are increasingly seeking complementary approaches to enhance their fertility journey.[79,80] One such approach is the integration of yoga, a mind–body practice, with ART. Several studies have investigated the impact of incorporating yoga into the treatment protocols of individuals undergoing ART procedures.[81,82] These studies have demonstrated promising results, suggesting that yoga may enhance the effectiveness of ART and improve overall reproductive outcomes. Yoga interventions have been shown to effectively reduce oxidative stress (OS) and associated DNA damage in gametes. Furthermore, these interventions contribute to a decrease in stress levels and improvement in emotional well-being, both of which are crucial factors in fertility.[83] Thus, it helps to reduce implantation failure and provide better chances to produce healthy offspring after ART. By reducing OS, yoga may create a more favorable environment for conception and support the success of ART procedures.[83,84] Furthermore, yoga practice has been associated with improved ovarian function and uterine receptivity, which are crucial for successful implantation and pregnancy.[85,86] A study showed that women who participated in a yoga program during their IVF cycles had significantly higher implantation rates and pregnancy rates compared to the control group.[87] In a randomized controlled trial with 128 women undergoing infertility therapy and IVF, a 6-week yoga program significantly reduced stress and anxiety, as indicated by the Copenhagen Multi-center Psychosocial Infertility. This suggests that yoga may positively impact the treatment course and outcomes for infertile women.[72] In addition, studies have reported that women who underwent a mind/body program before their first IVF cycle exhibited higher pregnancy rates compared to control subjects. Therefore, mind/ body intervention is associated with improved pregnancy outcomes.[88] The integration of yoga with ART may also help individuals and couples cope with the emotional and psychological challenges associated with infertility and fertility treatments.[81] These findings suggest that yoga may positively influence the physiological aspects of the reproductive system, enhancing the chances of successful ART outcomes. It was shown that yoga intervention effectively reduces stress, anxiety, and depression linked to infertility, serving as a potential adjuvant therapy, especially during IVF treatment.[89] In addition, there is evidence indicating a positive impact of yoga on pregnancy outcome.[71] In summary, yoga's mindfulness supports emotional well-being in fertility, and combining

it with ART shows promise for enhanced outcomes, though further research is needed for optimization.

Future Perspective and Conclusion

OS has been identified as a contributing factor to infertility, particularly in the context of male infertility. However, the impact of OS on spermatozoa remains insufficiently explored. Promisingly, yoga and mindfulness interventions offer noninvasive and holistic approaches that have the potential to enhance oxidative defense mechanisms, maintain nuclear and mtDNA integrity, and improve overall sperm function. These interventions may play a significant role in addressing both male and female fertility challenges. By mitigating OS and promoting general well-being, yoga practices emerge as a novel and adjunctive therapeutic strategy for individuals grappling with infertility. Despite these promising indications, further research is necessary to elucidate the specific mechanisms underlying the effects of yoga and mindfulness on mtDNA. In addition, determining optimal intervention protocols is crucial for maximizing the potential benefits. Existing studies exploring the relationship between yoga and infertility face noteworthy limitations that demand careful consideration. Heterogeneity across research designs, sample sizes, and yoga interventions poses challenges to establishing consistent findings. The reliance on self-reported data introduces a potential source of bias, and the lack of long-term follow-up hinders our understanding of the enduring impacts of yoga on fertility outcomes. Furthermore, there is a critical gap in the literature, with a predominant focus on the female perspective, leaving the effects of yoga on male fertility underexplored. Henceforth, future investigations should adopt more rigorous methodologies, including randomized controlled trials, larger and more diverse participant cohorts, and standardized yoga interventions. Addressing potential confounding variables, such as lifestyle factors and underlying health conditions, is crucial for refining the precision of outcomes. Comprehensive assessments of both male and female reproductive parameters are imperative to provide a holistic understanding of yoga's impact on fertility. Specific areas of research could include elucidating the underlying molecular, anatomical, and immune mechanisms through which yoga influences reproductive health, exploring optimal frequency and duration of yoga practice, and investigating potential synergies between yoga and conventional fertility treatments. A more meticulous and standardized approach will enhance the reliability and generalizability of findings, paving the way for a well-informed integration of yoga as a complementary intervention in fertility treatments. Integrating yoga and mindfulness interventions into fertility care may open new avenues for improving reproductive health and fertility outcomes.

In conclusion, our research highlights the promising role of yoga and mindfulness interventions in mitigating OS and improving fertility outcomes. Despite acknowledging study limitations such as diverse methodologies and the absence of long-term follow-up, we emphasize the importance of future research adopting rigorous methodologies, larger participant cohorts, and standardized interventions. A critical focus on understanding the impact of yoga on male fertility is imperative to fill existing knowledge gaps. Through these refinements, we aspire to solidify yoga's position as a holistic and evidence-based approach in addressing fertility challenges, contributing to the advancement of this field.

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