



The Impact of Yoga Based Interventions in Infertility, Cancer and Alzheimer's disease: A Brief Review

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ABSTRACT

Yoga is a profound science involving a set of practices consisting of a combination of physical postures (asanas), breathing techniques (pranayamas), and meditation (dhyana). The therapeutic effects of yoga on some of the complex lifestyle diseases are now well established. Our previous studies have consistently revealed that yoga influences the expression of genes involved in stress response, inflammation, and oxidative damage. Yoga up regulates the expression of anti-inflammatory and antioxidant genes and down regulates pro-inflammatory pathways. Yoga has demonstrated promising benefits for infertile couples. The integrative approach of yoga practice helps an individual to connect body with mind thereby fostering a sense of control and empowerment which is extremely essential in couples undergoing fertility treatment and to deal with the emotional turmoil. Regular practice of yoga maintains and restores sperm DNA integrity and thus can reduce the occurrence of childhood cancers and complex neuropsychiatric disorders in offspring. Yoga also helps to cope up with the medical therapy induced adverse effects in cancer survivors. The addition of yoga with the conventional treatment regime has demonstrated to expand the treatment horizon by better modulation of disease activity and inducing clinical remission in rheumatoid arthritis patients. A better cognitive and immunological effect of yoga has been observed compared to memory training in elderly women at risk for Alzheimer's disease. Most of the chronic lifestyle diseases are associated with decreased quality of life, but the psychosocial impact of the medical condition is less often addressed. Yoga can act as adjunct therapy in conjunction with the standard treatment modalities to alleviate the stress, anxiety and depression in these complex diseases and can promote health and prevent these diseases if practiced regularly.

Keywords: yoga, infertility, DNA damage, cancer, alzheimer's disease, quality of life

INTRODUCTION

Yoga is a profound science of mind-body practice which originated in ancient India. It incorporates a combination of techniques involving physical postures (*asanas*), breathing techniques (*pranayama*), and meditation (*dhyana*) to foster balance between the body, mind, and spirit. The current knowledge provide enough evidence that regular practice of yoga helps to alleviates the symptoms of many chronic and complex diseases like autoimmune rheumatoid arthritis (RA), diabetes mellitus, infertility, depression, cancers and Alzheimer's disease (AD) etc. (Gautam et al., 2018; Tolahunase et al., 2018). In particular, the combined effect of yoga and meditation based lifestyle is best observed in cases of chronic complex disease like infertility (Rooney and Domar, 2018). In recent times integrated treatment approaches like yoga based lifestyle interventions (YBLI) or yoga based mind body interventions (YB-MBIs) are gaining wide popularity. Yoga has been earmarked as a potentially beneficial arena serving not merely as an therapeutic intervention but as a way of life in dealing with complex lifestyle diseases including infertility (Khalsa, 2004). The molecular mechanisms by which yoga practice maintains the integrity of genomic and mitochondrial DNA and positively influences the epigenome are now deciphered. In this brief review the physiological and psychological impacts of yoga on such complex lifestyle diseases is discussed in the backdrop of existing evidence and our own research experiences.

I. Yoga and Infertility

Infertility is a complex lifestyle disease affecting a huge proportion of couples in the reproductive age group globally. There are considerable emotional, physical and economic issues associated with the condition (Rooney and Domar, 2018; Gdanska et al., 2017). Often the conventional treatment modalities like drug therapy and assisted reproductive techniques (ARTs) including in vitro fertilization (IVF) techniques dominated the conversation. The problems associated with infertility are multifaceted encompassing physical, emotional and psychological burdens (Rooney and Domar, 2018). Yoga acts through various bio-molecular mechanisms such as the anti-inflammatory effect, improved mitochondrial function, hormonal regulation etc. Improved mitochondrial function enhances the energy production in sperm cells thereby promoting enhanced motility and fertilization potential

(Tolahunase et al., 2017; Gautam et al., 2021). The most important underlying factor in cases of idiopathic and unexplained male factor infertility is oxidative stress (OS). OS causes sperm DNA damage, which along with hormonal dysfunction and hostile environmental factors results in decline of semen quality. A subject with poor semen quality is not a good candidate for infertility treatment by assisted reproductive techniques (Bisht et al., 2017; Yadav et al., 2024). Yoga helps to balance key hormones like testosterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH) which have a major role in the molecular regulation of reproductive pathways. By increased telomerase activity and regulating the OS in sperm, yoga maintains optimum telomere length that is considered crucial for the proper development of the blastocyst. It delays oocyte senescence which may improve reproductive potential and decrease incidence of premature ovarian insufficiency (POI). Yoga promotes and smoothens the journey of an implanted blastocyst to a fully developed embryo by maintaining physiological homeostasis.

The delicate interplay between the fetus and the mother determines the pregnancy outcome. Early pregnancy loss (EPL) that occurs in many women is a psychologically distressing condition and needs mental support and counselling. It also has a significant impact on subsequent pregnancies. In fact, the impact of yoga in addressing the psychological and emotional aspect in an infertile couple is very wide in dimension. Different body postures adopted in yoga called '*asanas*' and meditation sequences when practiced regularly provide emotional stability and resilience during the difficult period of journey of infertility. It also helps relieve tension and anxiety. There are special '*asanas*' for the reproductive organs and their proper hormonal regulation such as '*Baddha Konasana*' (bound angle pose), '*Bhujangasana*' (cobra pose) and '*Sarvangasana*' (shoulder stand). The overall vitality is promoted through '*Pranayama*' techniques. Yoga collectively helps developing a positive attitude and rejuvenates the body and mind of an infertile individual.

Male factor infertility accounts for approximately 40–50% cases of infertility. One of the important contributing factors is OS which results in sperm DNA fragmentation (DFI) and oxidative DNA damage in sperm and build up of mutagenic adducts. These mutagenic adducts induce

denovo germ line mutations and epimutations and thus increase the genetic and epigenetic diseases burden in the offspring (Tolahunase et al., 2021; Dhawan et al., 2024). OS is often due to imbalance between the reactive oxygen species (ROS) and the body's scavenging potential to deal with the OS. Conventional antioxidants improve sperm membrane integrity and sperm motility but have minimal effect on the crystalline sperm toroid. Yoga enhances expression of genes coding for antioxidants and also improves mitochondrial integrity. This results in reduced free radical production and increased ATP production. Decrease in ROS results in improved sperm DNA integrity and better reproductive outcomes. Unhealthy lifestyle, diet, and social habits, smoking, drinking, exposure to micronanoplastics, psychological stress are factors which adversely impact sperm genetic integrity. The conventional treatment of male factor infertility consists of various medications like antioxidants to improve the semen quality, and many couples opt for assisted conception. However, these therapeutic methods often do not work successfully in an individual with poor Sperm DNA quality. Decrease in the ROS was observed after adopting YBLI even after a brief period 21 days and it took 6 months for significant improvement in DNA integrity (Bisht et al., 2017; Dada et al., 2015). Yoga has been found to significantly change the expression of base excision repair (BER) genes, whose optimum functioning is essential for prevention of any DNA damage occurring in germ cells. Yoga also helps in the epigenetic modification by histone protein and changes in DNA methylation pattern. Yoga has been found to be associated with methylation changes in approximately 400 genes including several genes related to optimum fertility and genomic integrity. Therefore, it is associated with epigenetic change by altering the DNA methylation status, which in turn directly impacts gene expression levels (Bisht et al., 2020). Up regulation of expression of BER genes OGG1 and PARP-1 have been found after 21 days of YBLI (Dhawan et al., 2018). Overall, improvements in the sperm motility, concentration, and morphology were observed in the participants who underwent regular YB-MBIs (Yadav et al., 2021). Infertile men have higher risk of developing cancer and our studies on effect of yoga primed serum on cancer cell lines have shown enhanced apoptosis, reduced viability and reduced migration of cancer cells. Thus yoga a mind body intervention improves

both mitochondrial and nuclear DNA integrity and this has transgenerational effects.

Physiological role of yoga in infertile couples

Endocrine support: For optimal gonadal activity, proper functioning of the hypothalamic-pituitary-gonadal (HPG) axis is a prerequisite. Stress induced disruption of the axis can lead to irregular ovarian cycles and may predispose to infertility. Chronic stress adversely affects the hypothalamic-pituitary-gonadal (HPG) axis, leading to hormonal imbalances that impair spermatogenesis (Tolahunase et al., 2021). Yoga can ameliorate the stress induced disruption in the HPG axis in infertile females (Domar et al., 2011; Cramer et al., 2018). Yoga also improves sleep quality and restores sleep hygiene and regulated the circadian rhythm which also helps to maintain hormonal homeostasis.

Improved circulation: Certain yoga postures like '*Baddha Konasana*' (bound angle pose) and '*Supta Baddha Konasana*' (reclining bound angle pose), are believed to increase pelvic blood flow. Adequate circulation and nutrient delivery may support healthier gamete production and subsequent successful implantation (Gdanska et al., 2017; de Manincor et al., 2016). Yoga practice increases parasympathetic dominance and increases nitric oxide production and thus blood flow to pelvic viscera and also has been to be useful in maintaining erection in erectile dysfunction cases.

Hormonal regulation: Improved menstrual regularity has been observed in women practicing yoga in women with polycystic ovarian syndrome (PCOS). Regular yoga practice can effectively regularize the ovarian cycles and reduce hyperandrogenism which is a critical factor contributing to infertility (Darbandi et al., 2018; Kundarti et al., 2023). Yoga asanas such as '*Sarvangasana*' (shoulder stand) have been demonstrated to positively influence and enhance thyroid function, indirectly promoting hormonal equilibrium (Khalsa, 2004; Nery et al., 2019). Studies from our lab have shown that regular Yoga practice increases SHBG levels reduces levels of free Testosterone, decreases AMH, normalises LH/FSH ratio, regulates carbohydrate and lipid metabolism, normalises menstrual cycle and increases insulin sensitivity. It also reduces stress and anxiety and comorbid depression in women with PCOS.

Psychological Benefits:

The psychological stress in an infertile couple can negatively impact the reproductive outcome. Yoga and mindfulness based programs reduce the cortisol level, activates the parasympathetic system and counteracts the detrimental effects of stress. Yoga also addresses the anxiety and depression in an individual and fosters emotional resilience in infertile couples. Couples practicing yoga reported significant emotional wellbeing even after attending and practicing yoga sessions for 8 weeks (Sharma, 2021). Yoga has been shown to promote neuroplasticity and build emotional resilience.

Yoga has the multipronged potential to bring about a favourable outcome in infertility management. At the same time it also mitigates the emotional ups and downs and reduces psychological stress which has a negative impact on the reproductive functions as a whole. Yoga thus can thus improve reproductive health in both men and women.

II. Therapeutic potential of yoga in cancer:

Cancer is a rising non-communicable disease (NCDs) with significant morbidity and mortality. A recent study suggested that yoga could decrease the burden of NCDs including cancer and promote preventive health strategies in the general population (Malik et al., 2024). In the meta analysis of functional assessment of cancer therapy, yoga was found to be one of the preferred modality of exercise chosen by the breast cancer patients who had undergone surgery (Lin-Xi, 2023). It is often observed that prolonged physical and psychological symptoms prevail in cancer survivors. Similarly fatigue, sleep disturbances, stress are other concerning issues, in those patients which may be effectively addressed by yoga (Giridharan et al., 2024). Cancer and its treatment are often associated with adverse physical and psychosocial symptoms including increased risk of anxiety and depression, all of which reduces the overall quality of life (QOL). The greater role of various spiritual and religious practices were found to be associated with improved QOL, less distress, enhanced coping, and a better treatment results. A phenomenological study in Turkey investigated the perspective and attitude of cancer patients towards the use of complementary and alternative treatments to cope with the challenges experienced during chemotherapy. The patients reported significant psychological, physical,

and social challenges due to the primary disease i.e. cancer but with the use of alternative therapeutic methods such as yoga they could effectively manage their chemotherapy induced adverse effects and symptoms (Özmaya and Uzum, 2025). The surgical interventions for the treatment of breast cancer often have adverse psychological effects in the form of mental stress, negative body image, diminished self-esteem etc. Yoga and mindfulness-based therapy for approximately 90 minutes per day for 8 weeks was found to effectively alleviate the stress, enhancing self-esteem, in women undergoing radical mastectomy. The physical and emotional QOL was significantly better in those patients who had undertaken yoga practice. The study advocated initiation of the yoga based therapy in the preoperative period itself to maximally obtain the benefit of yoga therapy (Pehlivan and Eyi, 2024). During the surgical treatment in breast cancer patients, lymphoedema is another notable adverse effect in the postoperative period. Yoga has been found to reduce tissue induration of limbs, and greater strength in shoulder abduction post surgery (Freguia et al., 2024). This further advocates integration of yoga in patient care by healthcare workers (Nagy et al., 2024). A meta analysis revealed that yoga enhances the QOL among the survivors of oral cancer (Deepthi et al., 2024). A very interesting fact observed about cancer treatment is the occurrence of body balance problems. Therapeutic yoga thrice daily per week for 16 weeks proved to be of tremendous benefit to the cancer survivors to deal with the problem of body balance (Giridharan et al., 2024).

III. Therapeutic potential of yoga for Alzheimer's disease:

Alzheimer's disease (AD) is a progressive neurodegenerative disease characterized by cognitive decline, behavioural changes and impaired daily living activities (Morgad et al., 2024; Kamatham et al., 2024). The global magnitude of the problem due to AD is huge. It is estimated that around 50 million people struggled globally with dementia in 2023, and the number is expected to rise to up to 74.7 million by 2030 and 131.5 million by 2050 (Yang et al., 2020). Complex interplay between various genetic, environmental, and several age-related factors are implicated in the etiopathogenesis of AD. AD severely affects the QOL of the elderly patients and their caregiver. Generally speaking, psychological and mental health problems along with cognitive decline are

notable problems in the geriatric population, but have been under-treated on most occasions. Early and accurate diagnosis of AD is crucial for effective treatment and prognosis. Biomarkers are biological indicators of any disease process. The role of biomarkers in AD has been increasingly emphasized in order to detect the condition early and to provide therapeutic interventions in a timely manner, monitor disease progression and for prognosis. The mechanism of the biomarkers modulating the pathophysiology of AD is however complex and not fully understood yet. A number of biomarkers have been identified which are linked with the pathophysiology of AD such as the accumulation of β -amyloid plaques and neurofibrillary tau tangles (Gao et al., 2023; Tao et al., 2023). One important hallmark of AD is accumulation of A β peptides in the brain. The accumulations of A β peptides form plaques which subsequently disrupt neuronal function. The commonly employed methods to detect these plaques are positron emission tomography (PET) imaging and cerebrospinal fluid (CSF) analysis. Senile plaques composed of amyloid-beta (A β) peptides and neurofibrillary tangles formed by tau proteins are implicated in the pathogenesis of AD and these also serve as diagnostic and prognostic biomarkers (Klyucherev et al., 2022). Studies have shown that oxidative stress, A β oligomer accumulation and tau pathology are definitely linked with the cognitive deficits and neuronal death associated with AD (Slanzi et al., 2020).

Hyperphosphorylated tau proteins aggregate to form neurofibrillary tangles and cause neuronal dysfunction. It serves as an important biomarker because the evidence for the presence of tau tangles can be obtained a decade before they appear on brain scans. Genetic factors like APOE ϵ 4 allele has been linked with increased risk for the development of AD (Sharari et al., 2023). Increased risk of occurrences of AD has been observed in individuals carrying one or two copies of this allele. Therefore, genetic testing for APOE ϵ 4 may aid in the assessment of susceptibility for the disease. Similarly, elevated serum levels of neurofilament light chain (NF-L), a structural protein of neuronal origin, suggests neurodegeneration. Hence, increased NF-L in AD patients correlates well with disease severity and progression.

That means these biomarkers are reliable and can be utilized for early detection of individuals with mild

cognitive impairment (MCI), and are at risk of progressing to full-blown dementia. Some of the blood based biomarkers with potential for utilization for early detection of AD are plasma A β 1-42, A β 1-40 levels, phosphorylated tau (p-tau), particularly p-tau181 and p-tau217 (Gao et al., 2023; Klafki et al., 2022; Coley et al., 2024; Tropea et al., 2023; Giacomucci et al., 2023; Ashton et al., 2024). Recent studies suggested that p-tau could serve as a dynamic biomarker to understand the disease pathophysiology and monitor disease progression and to distinguish AD from other neurodegenerative conditions. Nevertheless, the precise mechanisms and interaction between genetic and environmental factors leading to the development of AD is poorly understood. 8-hydroxy-2'-deoxyguanosine' (8-OHdG) is an OS biomarker which helps in assessing cellular damage in AD (Peña-Bautista et al., 2019). The neurodegenerative process in AD can also be assessed with biomarkers such as brain-derived neurotrophic factor (BDNF) and interleukins like IL-37 and IL-38 (Ng et al., 2021; Lonnemann et al., 2022; Li et al., 2022). Inflammatory cytokines such as IL-15, a proinflammatory cytokine, which has been linked with the neuroinflammation in AD pathology may prove to be a very useful biomarker (Mahdavi et al., 2021). This is further supported from the fact that cognitive decline in AD patients has been seen associated with altered BDNF levels.

AD though incurable, the cognitive decline and other predominant symptoms affecting the patient's QOL can be targeted via pharmacologic and non pharmacologic therapeutic interventions. YB-MBIs have been shown to reduce OS, neuroinflammation, and amyloid-beta production, while promoting A β clearance. The YB-MBIs can be effectively incorporated along with the pharmacologic treatments to help alleviate predominant AD symptoms by reducing stress, improving emotional well-being, balance, and sleep. Because yoga poses are gentle and slow they are suited to be administered to patients with cognitive impairments (Madhu, 2021). Our preliminary studies on the impact of yoga on clinical, neuropsychological, and biomarker profiles in AD patients revealed significant improvement in cognitive function, mood and AD biomarkers. Regular YB-MBIs help reduce OS, neuroinflammation, and amyloid plaque formation, simultaneously promoting A β degradation and clearance. Yoga also improves visuospatial functioning along with

stress reduction, further supporting its role in cognitive enhancement (Kilpatrick et al., 2023; Grzenda et al., 2024). There is a higher prevalence of AD in females because of relatively longer life expectancy (Rahman et al., 2019). The co-morbidities like hypertension, depression, and diabetes have been found to exacerbate AD symptoms which is probably related with the physical attributes like height and weight (Ruthirakuhan et al., 2024). Existing evidence including evidence from our ongoing studies further suggests that YB-MBIs may support neuroplasticity and memory consolidation, which are key mechanisms in the therapeutic modulation of AD (Gothe et al., 2015). Overall, it is observed that the YB-MBIs have promising effects on the modulation of key AD biomarkers. Previous studies have shown a significant reduction in A β 40 levels suggesting reduction in the process of amyloid plaque accumulation which probably counteracts neurodegeneration. There is evidence of increase in A β 42 levels suggesting a more balanced amyloid profile, which may slow down disease progression (Manafikhi et al., 2021; Innes et al., 2018; Xiong et al., 2024).

Many studies including systematic reviews have attempted to assess the effectiveness of yoga on cognitive and psychological health and have found profound benefits for cognitive functions (Chobe et al., 2020). Whereas pharmacological therapies proved to offer not much benefit, yoga therapy has been proven to be successful in addressing the various psychological issues in AD. The benefits of yoga for AD patients are multipronged. It positively influences physical function, improves cognition, optimizes inflammatory markers, offers neuro protection and brings about an overall positive attitude in these patients. There is growing evidence that chronic musculoskeletal pain occurring in AD patients has an impact on the progression of dementia. A randomized controlled trial found that Kundalini yoga (KY) training for 60-minutes per day for 12 weeks could be an effective way for enhancement of cognitive functions in elderly females. At the follow-up examination at 12th and 24th weeks, the females in the KY group demonstrated stable *chemokine eotaxin-1*, which is an aging marker suggesting further clinical and biological benefits (Grzenda et al., 2024). Considering the potential of yoga therapy to ameliorate chronic pain, it can be a safe and convenient non pharmacologic mode of therapy in AD

patients. But administering physical yoga is a real difficult challenge in AD patients. Some authorities advocated the administration of tele-yoga. A recent study has shown preliminary evidence of feasibility of tele-yoga for AD patients and their caregivers (Allende et al., 2024). Establishing the long-term effects of yoga on AD progression might require more concrete evidence, but several workers suggested that yoga may be an ideal early intervention strategic model for individuals with modifiable risk factors for development of AD (Brown et al., 2024). In a recent experimental study, it was observed that the left anterior hippocampal sub-region in females practicing KY had greater increases in resting state connectivity as compared to females undergoing therapeutic memory enhancement training (MET). The increased connectivity has been associated with less frequency of forgetfulness (Kilpatrick et al., 2023). Another recent systematic review examining the health effects of yoga in individuals with mild cognitive impairment and associated dementia revealed that yoga is a safe and beneficial intervention to maintain the wellbeing of people with cognitive impairment and dementia (Lima et al., 2023; Karamacoska et al., 2023).

The female gender, existing cardiovascular disease are known risk factors for development of AD. Studies have shown that yoga prevents decline in the volume of grey matter in women at risk of developing AD. In those with known risk factors, yoga may offer substantial neuro protective effects as compared to conventional MET alone and significantly decrease the neurodegenerative process (Beatrix et al., 2023). In another trial, KY administered to 11 healthy meditation-naïve older adults showed significant increase in hippocampal volume which further testify neuro protective capability of KY (Ibrahim et al., 2022). As the health of the general population is improving day by day, the global population is ageing, and so is the prevalence of dementia. It is now widely agreed that a huge proportion of the causes of dementia can be prevented with appropriate modalities of treatment and strategies adopted in a timely manner. Such intervention strategies may be effectively implemented in a cost effective manner to deal with AD as a preventive measure in public health set up (Farhang et al., 2022). Owing to the lack of efficacy of the commonly used drug therapies, a new interest has been developed towards the use of various non pharmacologic strategies to combat these

issues. Yoga naturally exerts its health benefits on a broad range of chronic diseases. The effect of yoga on cognition improvement has been observed and understood now and therefore, now this modality of alternative therapy is increasingly utilized as a safe therapeutic tool for cognition improvement. It is to be noted however, that once dementia advances, the patients may not be able to undergo yoga practice on their own. Therefore, those patients should be screened at the mild dementia stage to offer maximum benefit of the yoga. Though the evidence in favour of the yoga practice to deal with the symptoms of dementia is not concrete and also conflicting at times, the preliminary reports from the existing evidence still suggests it to be an excellent cost effective and harmless therapeutic intervention for elderly people with dementia. It is definitely going to be incorporated into public mental health programmes to reach a wider section of the population (Bougea, 2022).

IV. Our experiences with yoga in complexes diseases:

Infertility management:

Our research in the past has consistently demonstrated the beneficial effect of yoga practice in the management of infertility (Tolahunase et al., 2017; Bisht et al., 2017; Giacomucci et al., 2023). Yoga practice when incorporated with the standard treatment protocol demonstrated significant improvement in the sperm DNA integrity and reduction in OS in infertile men. The effect of yoga on infertility is of special significance in cases of unexplained infertility where a favourable outcome through ARTs is possible.

Recurrent pregnancy loss:

In our study involving the male partners of women with recurrent pregnancy loss (RPL) and recurrent implantation failure (RIF), 6 weeks of supervised YBLI proved to be of tremendous benefit to infertile couples. A significant improvement in the semen parameters were noted with concomitant decrease in the ROS and DFI. There was also a relative increase in the telomere length at the end of 6 weeks of yoga practice. All these results suggested the beneficial role of yoga in the male partners of the infertile couples. The couples also had reduced stress and anxiety and improved QOL (Ashton et al., 2024). Better outcomes in ARTs have also been observed

in the subjects who underwent YB-MBIs (Dhawan et al., 2024).

Rheumatoid arthritis:

The previous studies have provided compelling evidence to support the incorporation of YB-MBIs in the management of complex diseases like infertility and rheumatoid arthritis (RA). The multifaceted benefits of yoga include inflammation reduction, immune system modulation, and enhancement of mental health. Results of the controlled trial of structured 8-weeks of YB-MBIs on systemic inflammatory markers and co-morbid depression in RA patients revealed significant reductions in the markers of disease severity. It was evidenced by decline of systemic inflammatory markers and improved disease activity scores (DAS). Remarkable decline in the symptoms of depression were observed as reported by the RA patients. This further highlights the impact of yoga on depression and its potential to address the psychosomatic aspect of an individual (Gautam et al., 2018; 2021). These improvements were attributed to be due to the modulation of immune parameters by YB-MBIs. Overall findings of these studies strongly suggest that yoga can be utilized as an adjunct therapy to deal with the complexities of complex lifestyle diseases like RA (Peña-Bautista et al., 2019). Yoga can dramatically improve the psycho-somatic symptoms, pain perception, disability quotient, joint flexibility, range of motion, posture, muscle strength, coordination, and disease activity and thus can be effectively utilized as a conjunctive treatment to aid in improving the QOL of these patients (Gautam et al., 2021). Co-morbid depression also adversely affects the therapeutic outcome in RA. The conventional medical therapies are not sufficient enough to deal with the condition alone. In our clinical trial it was observed that after 8 weeks of YB-MBIs, there was a significant decrease in the severity of RA evidenced by reduction in the levels of systemic inflammatory markers. Concomitantly, the patients of the yoga group experienced a statistically significant time dependent stepwise decline in depression symptoms as compared to the control group. Greater reduction in the scores of Beck Depression Inventory II scale (BDI-II) was observed among the yoga group in regression analysis. Thus integration of this simple mind-body intervention could achieve immunological tolerance by aiding remission at molecular and cellular level along

with significant reduction in depression ((Gautam et al., 2018; Peña-Bautista et al., 2019).

Immune modulation:

Yoga also has a role as immunomodulator apart from decreasing oxidative DNA damage (Ng et al., 2021). Our previous research explored the cellular mechanisms underlying yoga's benefits and found that regular yoga practice helps maintain a balanced state between pro-inflammatory and regulatory T cells (Th17/Treg cell homeostasis). This aspect of immunomodulatory effect explains the slowing down of the disease process in complex diseases like RA by restoring immune tolerance (Gautam et al., 2021)(8). This suggests that yoga can effectively restore immune tolerance and thereby reducing the disease severity (Gautam et al., 2021; Yadav et al., 2024).

Mitochondrial health:

Yoga improves mitochondrial health through up regulation of expression of mtDNA, mitochondrial activity markers and transcripts that maintain mitochondrial integrity. These are brought about by improving COX-II activity, regulation of circadian rhythm, and increase in level of melatonin. Melatonin is a potent antioxidant and a key molecule which maintains homeostasis and circadian rhythm and increases expression levels of transcripts that maintain mitochondrial integrity. COX-II is an important component of complex IV, and increased COX-II levels by yoga stabilize the cytochrome C oxidase super-complex.

Impact on cellular aging:

It is now known chronic stress and inflammation is a major factor contributing to accelerated cellular aging. Yoga has been seen to affect telomere length and telomerase activity, which are important markers of cellular aging. Cellular longevity is enhanced by the practice of regular yoga through enhancement of telomerase activity and by means of reducing OS. The potential of yoga practice to mitigate the stress induced cellular damage is well recognised in the management of autoimmune diseases like RA (Giacomucci et al., 2023; Peña-Bautista et al., 2019).

Mental health and stress reduction:

The outcome of chronic diseases like infertility and RA is interconnected and dependent on the management of

coexisting mental health conditions. For example, an infertile couple undergoing ARTs are more stressed and the prevalence of anxiety, depression is much more as compared to normal couples. Yoga practice regulates cortisol level, improves the overall emotional resilience and thus promotes to lead a life with less stress and anxiety. Yoga benefits both the mind and the body by decreasing stress and improving QOL.

Epigenetic regulation:

Another groundbreaking aspect of regular yoga practice is that it induces positive changes in the epigenome and it up regulates expression of genes related to inflammation, stress response, and immune regulation (Giacomucci et al., 2023). These molecular changes bring about fruitful changes in the individual practicing yoga beyond the symptomatic relief and promotes overall good health and well being. It also affects signal transduction and gene transcription by causing genome wide hypo-methylation and thus causes changes in the epigenome. We found up-regulation in the expression of MTHFR gene with significant reduction of seminal free radical levels after 3 weeks of yoga practice (Lonnemann et al., 2022). Yoga also causes significant increase in NAD⁺ levels. NAD⁺ acts as a central metabolic cofactor having an important role in biological processes including energy homeostasis, DNA repair, gene expression and calcium-dependent second messenger signalling. YBLI causes decline in reduced expression levels of pro-inflammatory genes like TNF- α , nuclear factor kappa B subunit 1 (NFKB1), IL-6 and upregulation in anti-inflammatory genes (LI et al., 2022). Regular yoga practice also has the potential of significantly reducing the transmission of heritable mutation and epimutations in the developing embryo thus improving the health of the offspring (Dhawan et al., 2024).

Stress and Depression:

It is now widely accepted that major depressive disorder (MDD) is a mind-body disorder whose pathogenesis is largely dependent on cellular aging. The condition is often characterized by altered molecular markers of stress, immune and homeostasis response. The pathogenesis of MDD is complex and manifest with a wide range of clinical features. It is also seen associated with other complex diseases like diabetes, hypertension, cardiovascular diseases, cancers, infertility etc. Such a disease with complex etiopathogenic mechanisms are not good

responders to pharmacological therapy alone. Hence the current recommendation is for a holistic approach by adopting alternative therapy such as yoga. YB-MBIs can thus be adopted for prevention of MDD in complex lifestyle disorders (Tolahunase et al., 2021).

CONCLUSION

The impact of yoga can be much broader and even beyond simple management of chronic disease. It addresses the root causes of many chronic diseases in a holistic and natural way in conjunction with the conventional standard therapeutic methods. The increasing acceptance and implementation of yoga based therapy is definitely going to have a great impact on the global healthcare landscape. As it is a natural solution to keep an individual healthy, it can thus be incorporated into the public health strategies to manage chronic diseases in an efficient manner. Yoga has proved to be a useful adjunct harmless therapeutic strategy in the clinical management of several chronic diseases. However, in spite of having substantial compelling evidence of yoga's benefits, there is still a need for larger, multicentre studies that can validate its usefulness in a clinical setting. Several standardized protocols designed to co administer yoga based therapy with standard of care therapy in modern medicine have already come up and many more will follow. Nevertheless, the practice of yoga in an otherwise healthy individual is also encouraged in order to maintain health and well being.

Abbreviations used:

AD: Alzheimer's disease
ARTs: assisted reproductive techniques
ARTs: assisted reproductive techniques
BER: base excision repair
DAS: disease activity scores
DFI: DNA fragmentation
EPL: early pregnancy loss
FSH: follicle-stimulating hormone
IVF: in vitro fertilization
KY: kundalini yoga
LH: luteinizing hormone
MDD: major depressive disorder
MET: memory enhancement training
NCDs: non-communicable disease
NFKB1: nuclear factor kappa B subunit 1

OGG1: 8-oxoguanine glycosylase
OS: oxidative stress
PARP-1: Poly (ADP-ribose) polymerase 1
PCOS: polycystic ovarian syndrome
POI: premature ovarian insufficiency
QOL: quality of life
RA: rheumatoid arthritis
ROS: reactive oxygen species
RPL: recurrent pregnancy loss
YBLI: yoga-based lifestyle interventions
YB-MBIs: yoga-based mind body interventions

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