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ROLE OF YOGIC INTERVENTION IN OCCUPATIONAL STRESS INDUCED ALTERATION IN PARENTAL DNA WITH SPECIAL REFERENCE TO CARDIO-METABOLIC HEALTH: AN OVERVIEW

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ABSTRACT
The present era of 'Always On' generation has seen a notable shift in the working hour expectations and also have recognized the escalation of occupational stress. Job Burnout in several cases leads to disturbed circadian rhythm which further triggers Hypothalamic-Pituitary-Adrenal (HPA) axis. Elevated oxidative stress contributes to the pathogenesis of cardio-metabolic diseases. Further, cardio-metabolic diseases results in pervasive chronic inflammation causing degradation of sperm quality, hormonal imbalance and in several cases it also leads to erectile dysfunction. The Parental Origins of Health and Disease (POHaD) paradigm, an extension of the Developmental Origins of Healthcare and Disease framework, highlights about the role of a father's health, lifestyle and environment before the conception shape the health of their offspring. This paper explains the underlying mechanism and connection between the Oxidative Stress, Epigenetics and DNA damage and how Yoga as an intervention works on a parental lifestyle and overall wellbeing. Yoga solely improves quality of life, calm mind and work well on cardio-metabolic disease. It improves mitochondrial function and reduces DNA damage working as the best adjunctive therapy to improve Quality of Life of a person.

KEYWORDS: Cardio-metabolic, HPA axis, Oxidative stress, Stress, Yoga

INTRODUCTION
The 21st century, an era defined by the rise of computers, globalisation, artificial intelligence and major shifts in work cultures. The last two decades have seen a drastic shift in professional atmosphere with integration of technology and further blurring the boundaries leading to higher working hour expectations. From 40 hour workweek in 1900s shifted to informal working hours in 2000s.[1] This shift is associated with perpetual availability leading to driving up the occupational stress all over the world with around 40-50%[2] of the workers report having burnout whereas in India this prevalence is around 70-80% accelerated due to 48-60hours work/week[3] in different sectors such as health care, IT, manufacturing, in gig and platform workers[1]. Recent surveys indicate that 46% of the employees agree that the root cause of their stress is workload, 77% says that job pressure negatively affects their physical health with 68% of Gen Z and 73% of Millennials claiming burnout.[4] Depression and anxiety due to work exertion leads to loss of 12 billion days per year costing around $ 1 trillion in yield.[5]
With this Always On work culture still prevalent in 2026 is associated with expectations for perpetual presence due to visibility bias, availability heuristics and defensive promotion practices[6] relating late night availability with prolificacy and productivity.

Stress and its mechanism
Stress is a complex physiological mechanism involving the Sympathetic-adreno-medullar (SAM) axis and the Hypothalamus-pituitary-adrenal (HPA) axis, which release major stress related hormones such as noradrenaline, norepinephrine and glucocorticoids. These hormonal changes prepare the body to handle stress through compensatory mechanism but excess production can lead to long-term health consequences.[7] All sensory systems can detect stress-related stimuli and relay this information to the brainstem, which regulates activation of the autonomic nervous system (ANS) and the HPA axis.[8] Stress signals from the hippocampus, prefrontal cortex and amygdala activate the paraventricular nucleus of the hypothalamus, leading to release of corticotropin-releasing hormone (CRH) from the pituitary gland and subsequent glucocorticoid secretion from the adrenal glands.[7, 8] ANS activate sympathetic preganglionic neurons in the spinal cord that immediately increase the release of catecholamines. Sympathetic activation is classical fight & flight response that increase heart rate, blood pressure, vasoconstriction, stimulation of sweat glands, energy mobilization etc.[9]

Occupational stress and Circadian Rhythm

Physiological parameters, biological processes and behaviour elucidate circadian variations in humans, which influences nearly every function ranging from the gene expression to overt behaviour. The circadian system works on a 24-hr genetic feedback loop (Transcription-Translation Feedback Loop (TTFL) with the activators (CLOCK and BMAL1) and the repressors (PER and CRY) genes. This intrinsic molecular clock works within almost every cell controlled by suprachiasmatic nucleus (SCN) in the brain. The SCN uses the light information captured by the retina to reset its timings daily and thus also synchronizing the peripheral clocks of the body. The TTFP loop ensures the alignment of the day and night cycle with biological and behavioural processes.[10] Occupational stress leads to the dysregulation of the HPA axis. Job burnout and disturbed circadian rhythm possibly triggers the release of cortisol via HPA axis.[11] Cortisol production is stabilized using a self-regulating negative feedback loop. The brain release CRH and ACTH (adrenocorticotropic hormone) to signal the adrenal glands to release cortisol, once the production is high enough this loop effectively supresses the release of CRH and ACTH preventing hypercortisolemia.[12] The SCN functions as the principal circadian pacemaker which sends signals to HPA axis to regulate according to the environmental photic stimuli (light-dark cycles).[13] Cortisol levels slowly rise during the day time and steadily drops in the night hours.

Cortisol binds with the glucocorticoid receptors virtually influencing all organ systems of the body. It plays a key role as a regulator of metabolism,[14] immune system, inflammatory processes[15] and blood pressures.[16] Chronic instability in the process of allostasis leads to an increased risk of diseases.[17] A marked difference in the circadian rhythm plays a key role in the pathogenesis of health issues such as depression[13], cardio-metabolicand cardiovascular diseases.[18]

Cardio-metabolic Activity and their Circadian Regulation

Cardio-metabolic disease is a cluster of interrelated condition that share common root cause like hypertension, obesity, diabetes mellitus, dyslipidaemia, that further increase the risk of chronic disease like heart stroke, chronic kidney disease, non- alcoholic fatty liver disease etc. Light and food are two dominant stimuli that affects daily life. Circadian system regulates gene expression, glucose availability, body temperature maintenance, heart rate regulation, hormone production, sleep, mood and higher cognitive functions.[8] Turek et. al found that mutated clock gene disrupts the SCN and CNS that cause loss of rhythmic control over hunger hormones like ghrelin and orexin, which triggers metabolic instabilities like obesity and glucose irregularities.[19] Clock genes can regulate circadian rhythmicity as well as peripheral tissues, through medio basal hypothalamus, liver, muscle and pancreas; indicates that circadian and metabolic processes are linked at multiple levels.[20,21,22,23] Diet-induced obesity disrupts temporal control of metabolism through constant activation, persistent inhibition or improper timing of key liver pathways such as gluconeogenesis for blood sugar production, fatty acid synthesis for energy storage, cholesterol and bile acid synthesis for lipid handling and the pentose phosphate pathway for cellular fuel and antioxidants.[12]

Many epidemiological researches consistently shows that sleep deficit and shift work culture correlate with higher incidence of metabolic diseases in humans such as obesity, diabetes mellitus, hypertension etc.[24,25]

Cardio-metabolic Activity and Oxidative stress

Production in substantial amount of reactive oxygen species (ROS) leads to oxidative stress, saturating the antioxidant defences, causing damage in DNA, proteins and lipids. The cellular oxidation stress leads to insulin resistance, dyslipidemia, hypertension, etc. in cases of cardio-metabolicdisorders like Metabolic Syndrome (MetS), Type 2 diabetes (T2D), Obesity and Cardiovascular disease (CVD)[26, 27] in a bidirectional loop.[28] The ongoing oxidative stress plays a significant role in disease progression, particularly among shift workers with circadian-HPA axis dysregulation, where flattened cortisol rhythms further worsen the effects.

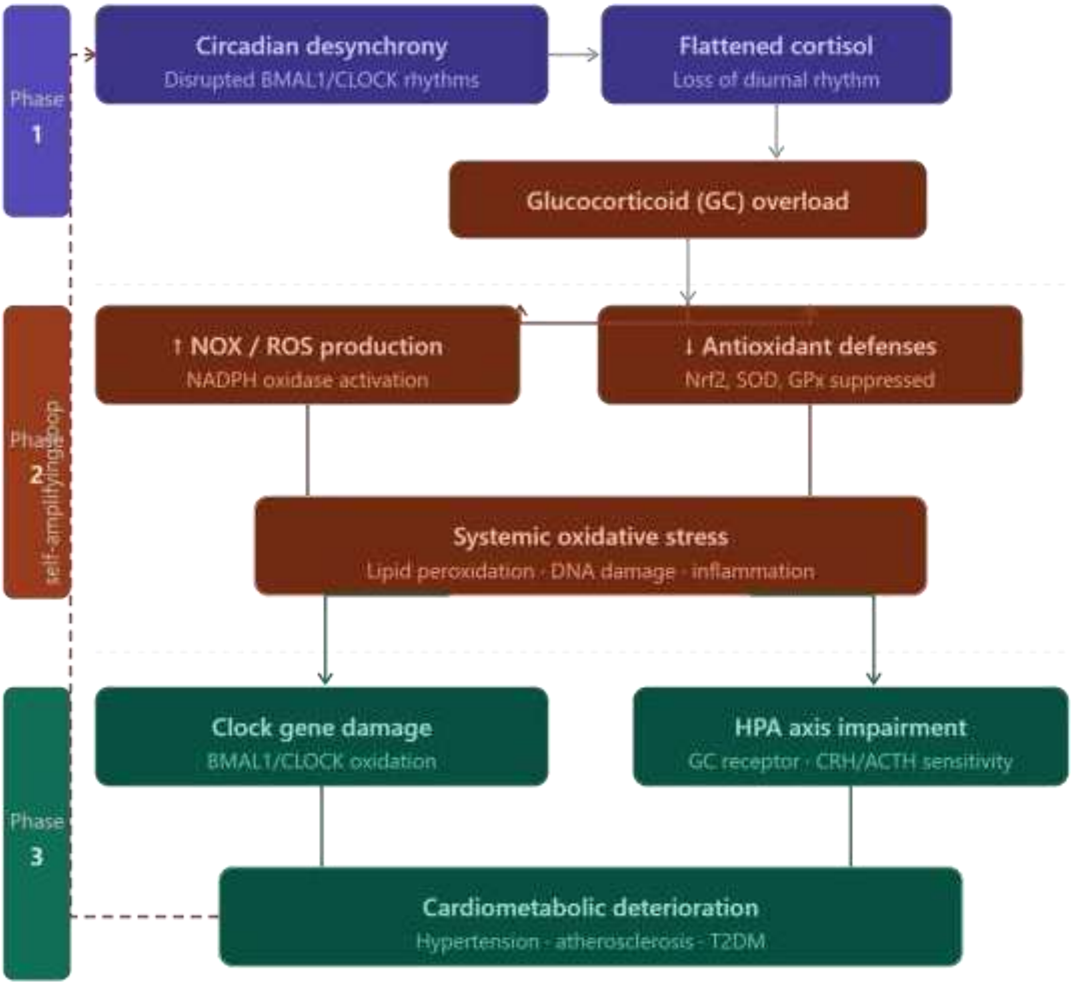

Fig 1: A self-reinforcing three phase biological loop linking circadian disruption to cardiovascular and metabolic disorders.[29]

Oxidative Stress and Epigenetics

Traditionally, neonatal health outcomes have been viewed almost exclusively through the lens of maternal health. However, accumulating evidence supports the "Paternal Origins of Health and Disease" (POHaD) paradigm. This framework suggests that a father's physiological state, specifically driven by occupational stress and cardio-metabolicdysfunction, can influence fetal development and neonatal phenotypes. The transmission of this paternal environment to the offspring occurs primarily through two interconnected pathways: Oxidative Stress-induced DNA damage and Epigenetic Reprogramming of the sperm.

Epigenetic Reprogramming- Epigenetic reprogramming refers to the dynamic changes in epigenetic marks that influence gene expression without altering the underlying DNA sequence.[30] During the formation of gametes and early development in mammals, the genome undergoes major and continuous changes. This process plays a crucial role in various biological contexts, including development, differentiation, and the response to environmental factors. These modifications include DNA methylation, histone modifications, and the influence of non-coding RNAs (ncRNAs) that together regulate gene expression without altering the DNA sequence itself. [31, 32]

In the context of sperm, abnormal DNA methylation patterns are frequently linked to male infertility and may disrupt normal embryonic development.[33, 34] Research has indicated that --ROS can interfere with DNA methylation processes, resulting in compromised sperm quality and subsequent reproductive success.[34,35]

In male germ cells, these modifications are crucial for proper spermatogenesis, changes in the expression of lncRNAs due to oxidative stress can lead to abnormal gene expression patterns, potentially contributing to fertility issues and developmental disorders in offspring.[35] miRNAs can also modulate the expression of genes linked to metabolic health and cardio-metabolicdiseases, indicating a complex interplay between epigenetic reprogramming and health outcomes.[32,36]

Oxidative Stress – DNA Damage

Oxidative Stress (OS) harms sperm DNA and overall function through three main processes: DNA fragmentation, lipid peroxidation, and protein oxidation. This damage happens when the levels of ROS become higher than what the sperm's limited antioxidant system can handle, which further leads to cellular and genetic damage.[31]

DNA Fragmentation - Sperm DNA is tightly packaged, but it is highly vulnerable to oxidative damage because spermatozoa possess very limited DNA repair mechanisms. Spermatozoa carrying fragmented DNA exhibit a reduced capacity to successfully deliver the paternal genome to the oocyte.[37] If fertilisation does occur, this DNA damage is strongly correlated with poor reproductive outcomes, including failed implantation, recurrent pregnancy loss and a higher risk of congenital abnormalities in the offspring.[31]

Lipid peroxidation - When ROS levels increase, they attack these fatty acids, leading to damage of the membrane structure.[38] In this process, the toxic byproducts further spread and damage inside the cell by affecting proteins, DNA, etc, ultimately reducing sperm function and viability. It also harms the acrosomal membrane which deteriorates the sperm's fertilising ability.

Protein Oxidation - ROS can interact with specific amino acids to oxidise proteins that alter the protein's natural structure and function. This oxidative modification impairs multiple facets of sperm function, [31] like, weakening the framework of the sperm tail resulting in abnormal sperm shape and reduced motility, it also leads to decreased ATP generation and thereby reducing energy levels in the sperm[39, 40] ; which further affects both the surface proteins that help the sperm recognise the oocyte and the enzymes within the acrosome that are essential for breaking through the egg's outer layers[41, 42]

Paternal DNA and Perinatal

High levels of OS and associated DNA damage in paternal sperm can enhance the risk of cardio-metabolicproblems in the perinatal period and also increases the risk of various health and developmental problems in the offspring.

DNA damage of sperm may lead to birth defects (heart defects, cleft palate, etc.) due to chromosomal or genetic errors, [31, 43] neurodevelopmental and cognitive problems (Autism Spectrum Disorder, ADHD, etc.), growth and developmental delays. [44]

High oxidative stress in sperm can cause change in sperm DNA and small RNA molecules, which are linked with the child's metabolism, as they grow it further gets associated with higher risk of obesity, insulin resistance, metabolic syndrome and future heart disease. [45, 46]

Yoga and Neonatal Outcome

Lifestyle is the key factor for the genesis of variety of disorders in the body. In today's era there has been a significant increase in the sedentary lifestyle, which make human body prone to cardio-metabolic disorder and reproductive disorders. Yoga is a very profound ancient practice describes by great Indian sages that does not only calm the body but also rejuvenate thought, enhance emotional resilience and metacognition.

Sleep is very integral part of human life and quality & quality of sleep affects human body and mind. Various studies prove that by integrating yoga in the combination of asana (physical posture), pranayama (control breathing), mudra (gesture), meditation (dhyana) and relaxation etc improve various systemic health issues like improve circadian rhythm pattern, increase fertility rate prevent neonatal and perinatal from the major worst outcomes that induce from low quality sperm.[47]

Yama- Niyama

Yama are the five commandments, which are "non-violence (Ahimsa), truth (satya), honesty (asteya), continence (brahmacharya), and Non-possessiveness (aprigraha)." Niyama are the five self-purification, which are purity of body and mind (shauch), contentment (santosh), self-discipline(tapa), study of literature (swadhyaya),and resignation to God (ishwar-pranidhan)"[48] A review of Marie et. al show bidirectional relationship between sleep and emotion. They suggest that lack of sleep or disturb circadian rhythm enhance negative emotion reactivity and suppressed positive emotion and that further disconnect prefrontal cortex and amygdala connection.[49] Xu et. al study suggests that by adopting this ethical discipline in daily life stable physiological energy, enhance cognitive ability, improve quality of life and improved regulation of emotion.[50]

Asana

Asana is the physical part of yoga therapy to achieve physical stability and steadiness. Physical activity and sleep have a bidirectional relationship because poor sleep hamper daily activity and lack of physical activity create tension in muscles that generate negative stress.[51] Asana increases the blood flow in the pelvic region, release tension and provide strengthen to body, calm mind, regulate hormonal secretion, optimizing testicular function, sperm maturation, stabilize sexual energy, stimulate digestion, increase gastric fire, and some asana like gomukhasana, vajrasana, veerasana may imparts heels touch the gluteal region that affects vajra nadi, which are very beneficial for reproductive system.[49,52] Asana like bakasana, veerbhadrasana, surya namaskar, dandasana increase body endurance power, create balance between body and mind and also strengthen core muscle and lead to muscle hypertrophy. Muscle hypertrophy improves adenosine triphosphate (ATP) and enzyme efficiency thus increase muscle cell size and volume. Although hypertrophy boosts strength and power, it also impacts on oxygen use and mitochondrial performance. It also enhances myoglobin storage, which is essential for oxygen delivery within muscles.[53] Asana improve blood circulation the body, improves quality of life, cardiac function, heart rate, blood pressure, cardiac autonomic function, reduce oxidative stress and daily practice of asana also promote good quality of sleep.[54]

Pranayama

Pranayama is the process of inhalation and exhalation of gaseous exchange of CO_2 and O_2. It activates menoreceptors and chemoreceptors of circulatory system and send information to pons and medulla to adjust chemoreceptors activity. Practice of pranayama weakened chemoreceptors activity and increase baroreflex sensitivity by involving both efferent and efferent vagal nerve activity.[55] Practice of pranayama strengthen respiratory system functioning and this automatically improve circulatory system, expel toxins from body, purify body, mind and intellectual.[49] Majumdar et. al study shows that daily practice of pranayama improves sleep quality, decreased episode of disturbed sleep, take less time to fall asleep in night, increased sound sleep.[56] Respiration helps to regulate HPA Axis by reducing cortisol level and stimulate parasympathetic nervous system. It also reduced perceived stress, stimulate vagus nerve, lowering anxiety and stress levels which are major contributor to sleep fragmentation.[57] Recently a cross-sectional study shows that regular practice of pranayama improve oxidant- antioxidant defence system, lower free radical related damage, lower plasmas malondialdehyde level, which is key marker to access oxidative stress in the body.[58] When oxidative stress is high, it automatically increases the ROS level that further leads to peroxidation of sperm membrane, impairing sperm motility and viability.[48] Agarwal study show that pranayama practice reduces oxidative stress as well as improve antioxidant status in the body. [59] By reducing oxidative stress from pranayama one can protect sperm quality and DNA sequencing of neonatal and prevent them from childhood malignancies.[60]

Mudra & Bandha

Paternal genital health is very important for healthy progeny in which pelvic musculature play a major role. Rathore et. al study shows that the practice of Ashwini Mudra, Moola Bandha, and Vajroli Mudra strengthening the pelvic floor function. These practices involve controlled contraction and relaxation of different components of the pelvic floor muscle, particularly the levator ani muscle group and associated sphincters.[61] Mishra et. al found that moola bandha, Goraksasana and uddiyana bandha these three practices worked as best posture for the muscles of pelvic region especially levator ani and anal sphincters and they also found that Viparitakarni helped in venous return against gravity.[62] Moola bandha strengthen puboperinealis muscle whose fibre attach to the perianal body.[64] Ashwini Mudra, Vajroli mudra and Moola Bandha they all follow the same neurological process. They activate sacral nerves that communicate with brain and promote relaxation by enhancing parasympathetic nervous system activity in which body shift from stress to calm state.[63]

Meditation

Meditation is the process of one pointedness and a state of continuous dynamic consciousness without any obstruction. It also affects cognitive, emotional, and behavioural aspects. Black et. al study show that mindfulness meditation is a community accessible technique that improve quality of sleep after immediate practice of meditation in among older adults and it also reduces sleep related day time impairment like fatigue, disturbed mood, depressive symptoms and quality of life.[64] Study also reported that meditation practices enhance the amplitude of gamma synchrony, strengthen the thalamocortical and cortico-cortical interactions.[65] Meditation practices help to bring about sympatho-vagal balance by decreasing sympathetic nervous system activity and increase parasympathetic nervous system activity like decrease heart rate, reduce blood pressure, reduce eye movement during REM.[66] Meditation practices are linked to increased frontal midline theta activity, which arises from the anterior cingulate cortex and plays a key role in regulating parasympathetic function. Vipassana meditation stimulate this brain region during practice that further influence and enhance parasympathetic activity especially during sleep.[67,68,69] Meditation increase melatonin level by either reducing its breakdown in the liver or enhancing its production in the pineal gland. Melatonin act as an antioxidant and immunomodulator and it is the precursor of serotonin which play primary role in sleep quality.[70]

DISCUSSION

Women infertility is a well-documented topic comparitively male infertility is a less explored area. 15% of the globe couple are suffering from infertility in which approx 50% is because of men.[71,72] In male infertility, sperm DNA fragmentation is a critical determinant, which is associated with reduced fertility, impaired embryo development and an increased risk of miscarriages. Additionally it also leads to higher incidence of autosomal dominant diseases, congenital malformations, childhood cancers and neuropsychiatric disorders.[73,74] Semen abnormalities, such as oligospermia, asthenozoospermia, teratozoospermia and azoospermia, impair sperm quality and fertilisation potential.[75] Yadav et al. study show that regular yoga practice improve sperm motility, enhance sperm functioning and density, decreased semen pH level and show significant reduction in seminal ROS level.[48] This study also reveal that yoga increase total sperm count, stimulate spermatogenesis, improved testicular function, reduce 8-OHdG levels which is primary biomarker for oxidative DNA damage and can help in prevention of genomic integrity, global hypomethylation and epimutations. Yoga reduces OS which affects sperm DNA, proteins and prevent lipid per-oxidation. Yoga practice enhance mitochondrial integrity, improves mitochondrial function and reduces DNA damage.[48] Yoga increases the expression of genes that support mitochondrial biogenesis and preserve mitochondrial integrity (AMPK, IGF1R, PRC-1, TFAM, SIRT-1, TIMP-1, and KLOTHO), as well as the levels of nicotinamide adenine dinucleotide (NAD+), cytochrome c oxidase (COX-II), and mitochondrial copy number.[76] Yoga practice increases the levels of melatonin in body and regulates sleep wake cycle in better way. That increase level of melatonin play a crucial in minimization of oxidative damage to mitochondrial DNA and moreover it reduces mitochondrial mutations.[77] Yama – Niyama give power to control thought and help to manage social interaction with people. When the asana purifies the body physically, then the practice of pranayama purify body on pranic level. Mudra and Bandha strengthen pelvic function and integrity whereas mediation practice calm the mind and enhance sleep quality.

CONCLUSION

Yoga has the power to solely improve quality of life and act as co-therapeutic tools in some life threating clinical conditions. It works as the best adjunct with modern medicine. It promotes good sleep, regulating circadian rhythm. Yoga improve resilience and self-efficacy on both physical and emotional level, promotes relaxation, reduces inflammation and oxidative stress. Regular practice of yoga is linked to decrease size of amygdala and increased grey matter in the hippocampus and prefrontal cortex, which are linked to better memory, mindfulness, cognition and also fosters neuroplasticity, which promote better resilience and thus affecting the overall well-being.

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