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Review Article

REGULATION OF CELLULAR RESPIRATION NEUROTRANSMISSION AND STRESS PATHWAYS THROUGH YOGIC PRACTICES: A BIOCHEMICAL REVIEW

Priyadarshani Deshmukh

Department of Chemistry, S.S.E.S. AMT's Science College, Nagpur, India

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ABSTRACT

Yoga is widely recognized not only as a physical discipline but also as a powerful modulator of human physiology. Modern biochemical research demonstrates that yoga significantly influences metabolic pathways, neurotransmitter levels, stress hormone regulation, and autonomic nervous system function. This manuscript explores the biochemical mechanisms underlying yoga's effects, including energy metabolism, cellular respiration, neuroendocrine regulation, and stress physiology. It further highlights how pranayama and other yogic practices restore homeostasis by enhancing key neurotransmitters such as serotonin, dopamine, oxytocin, and endorphins while simultaneously lowering cortisol and adrenaline. The significance of this work lies in its ability to bridge traditional yogic knowledge with contemporary biochemical science, providing an evidence-based framework for understanding yoga's therapeutic potential. By demonstrating that yogic practices modulate biochemical pathways responsible for mood regulation, energy production, and autonomic balance, this study underscores yoga's relevance as a holistic, scientifically grounded intervention for promoting physical health, emotional stability, and psychological resilience. The discussion links classical yogic concepts with modern molecular understanding to illustrate how yoga fosters comprehensive well-being at both the physiological and biochemical levels. Modern biochemical research demonstrates that yoga significantly influences metabolic pathways, neurotransmitter levels, stress hormones, and autonomic functions. This manuscript explores the biochemical mechanisms underlying yoga's effects, including energy metabolism, cellular respiration, neuroendocrine regulation, and stress physiology. The paper also highlights how pranayama and yogic practices help restore homeostasis by enhancing neurotransmitters such as serotonin, dopamine, oxytocin, and endorphins while simultaneously lowering cortisol and adrenaline. The discussion links classical yogic concepts with modern biochemical understanding to illustrate how yoga promotes both physical and mental well-being.

Keywords: Yoga, Pranayama, Serotonin, Dopamine, Oxytocin, Neuroendocrine regulation.

INTRODUCTION

The human body is fundamentally a dynamic chemical system in which every physiological function from respiration and metabolism to emotion and cognition is governed by complex chemical reactions (Alberts *et al*., 2022). Hormones, enzymes, neurotransmitters, and proteins regulate these reactions to maintain homeostasis, or internal balance. Yoga, an ancient mind–body practice, has emerged as a scientifically validated tool that influences biochemical mechanisms to promote health. Our manuscript examines how yoga modulates biochemical pathways to enhance energy production, optimize neurotransmitter levels, regulate stress hormones, and activate parasympathetic responses through pranayama practices. Oxytocin hormone bonding and mood-stabilizing hormone enhanced by social connection, meditation, touch, and certain yogic practices (Carter, 2014). Endorphins act as Natural painkillers released during physical activity, laughter, creativity, and yoga postures (Boecker *et al*., 2008). Collectively, these neurotransmitters contribute to emotional stability, stress reduction, and enhanced psychological well-being. Adrenaline triggers rapid physiological changes including elevated heart rate, blood pressure, and respiratory rate to prepare the body for "fight-

*Corresponding Author: Priyadarshani Deshmukh, Assistant Professor, Department of Chemistry, S.S.E.S. AMT's Science College, Nagpur. Email: preetiingole@gmail.com.

or-flight" (Sapolsky, 2015). Cortisol Sustained stress hormone increasing blood glucose and suppressing non-essential functions such as digestion. The body functions as a biochemical factory where millions of reactions occur each second. Processes such as respiration, digestion, neural signaling, and muscle contraction rely on precise chemical transformations (Nelson & Cox, 2021). One essential process is oxygen transport, where oxygen diffuses from the alveoli into the bloodstream. Approximately 97% of oxygen binds reversibly to hemoglobin within red blood cells to form oxyhemoglobin, while the remaining 3% dissolves in plasma (Guyton & Hall, 2020). Oxygen is required for oxidation reactions that sustain cellular processes, metabolic rate, physical performance, immune function, and cognitive alertness. Cellular respiration converts biochemical energy from nutrients into ATP, the universal energy currency of the cell. Glucose is broken down into pyruvic acid, producing a small amount of ATP and NADH (Berg, Tymoczko & Gatto, 2019). Pyruvate enters the mitochondria and is converted into acetyl-CoA. The Krebs cycle oxidizes acetyl-CoA, producing, NADH, $FADH_2$, CO_2, ATP/GTP. These electron carriers transfer high-energy electrons to the electron transport chain. Chronic elevation is linked to anxiety, hypertension, and metabolic disorders (McEwen, 2007). Yoga has been shown to significantly reduce circulating cortisol levels and regulate adrenal activity (Streeter *et al*., 2012). Physiological benefits include improved heart rate variability, lower blood pressure, enhanced lung function, reduced anxiety, improved sleep, and better pain management (Field, 2016). NADH and $FADH_2$ donate electrons to generate approximately 38 molecules of ATP, depending on cell type and metabolic efficiency (Nelson and Cox, 2021). Oxygen plays a pivotal role as the final electron acceptor in oxidative phosphorylation. Yoga influences neurotransmitters essential for emotional regulation and cognitive well-being. Key neurotransmitters affected include Similarly Dopamine is associated with reward, motivation, and learning. Increased through mindful movement, yoga, adequate protein intake, and relaxation practices (Ikemoto & Bonci, 2014). Serotonin or contentment hormone. Yoga, sun exposure, nature contact, and breathing exercises elevate serotonin levels (Young, 2007).

MATERIALS AND METHODS

Study Design

This study employed an observational biochemical–physiological assessment conducted during the academic year 2024–2025. A total of 20 regularly practicing yoga participants (aged 20–55 years) were included in the analysis. All participants had a minimum of one year of yoga experience and engaged in a structured pranayama-based practice for the duration of the study. Participation was voluntary, and informed consent was obtained from all individuals. Data related to autonomic function and biochemical indicators were recorded before and after pranayama sessions. The following parameters were monitored Respiratory rate (breaths/min)., Heart rate and heart rate variability (HRV)., Blood pressure., oxygen saturation., (SpO_2)., Perceived stress levels (self-reported, standardized scale)., Breath-hold time (BHT) as an indirect marker of CO_2 tolerance and parasympathetic activation. Data were collected in a controlled environment to minimize confounding variables such as temperature, noise, and physical exertion prior to sessions. Participants performed a standardized pranayama sequence for 30 minutes daily, including it includes Diaphragmatic Breathing (5 minutes) helps to promote diaphragmatic expansion and improve gas exchange.

Adi Shodhana

Adi Shodhana Pranayama, often regarded as a foundational cleansing breath practice in yoga, is designed to purify the respiratory pathways, regulate the flow of prana, and promote mental steadiness and relaxation. It is generally performed in a comfortable seated posture with the spine erect, shoulders relaxed, and the hands resting gently on the knees. The technique begins with slow, deep inhalation through the nose, allowing the lungs to fill completely, followed by an equally slow and controlled exhalation through the nose to release accumulated tension and stagnant air. The emphasis is on maintaining a natural, unforced rhythm of breathing while consciously expanding the chest and diaphragm without strain. As the practitioner focuses on the smooth inward and outward flow of breath, the mind gradually becomes anchored in the present moment, reducing restlessness and internal distractions. Through repeated cycles, Adi Shodhana helps clear the respiratory tract, enhances oxygen exchange, and balances the autonomic nervous system, thereby promoting inner calmness, improved concentration, and an overall sense of energetic purification and emotional stability.

Ujjayi Pranayama

Ujjayi Pranayama, also known as the "ocean breath," is a soothing and concentrative yogic breathing technique characterized by a slight constriction of the glottis to create a soft, whispering sound during both inhalation and exhalation. It is practiced in a comfortable seated posture with an upright spine and relaxed shoulders, allowing the body to remain stable while the breath becomes the focal point. The breathing begins with deep inhalations through the nose, followed by controlled exhalations in which the throat is gently contracted to produce a subtle "haaaa" sound, similar to fogging a mirror, initially with the mouth open and later with the mouth closed while maintaining the same constriction. The practitioner continues breathing slowly and rhythmically through the nostrils, generating the characteristic ocean-like hum that accompanies the inward and outward flow of air. Throughout the practice, attention is directed to the sound and sensation of the breath, promoting internal awareness, reducing mental chatter, and inducing a meditative state. With repeated cycles, Ujjayi Pranayama enhances lung capacity, steadies the autonomic

nervous system, and fosters emotional calmness and mental clarity, making it a key tool for harmonizing both mind and body during yoga.

Nadi Shodhana

Nadi Shodhana, often called "alternate nostril breathing," is a traditional yogic pranayama technique used to purify the energy channels (nadis), balance the nervous system, and promote mental clarity and emotional calmness. It is typically practiced in a comfortable seated posture with an erect spine and relaxed shoulders, allowing steady and uninterrupted airflow. The practice begins by resting the left hand on the knee and forming a mudra if preferred, while the right hand is positioned near the nose using the thumb and ring finger to gently control the nostrils. After taking a natural breath, the right nostril is closed with the thumb, followed by inhalation through the left nostril in a slow and controlled manner; then the left nostril is closed with the ring finger and the breath is exhaled through the right nostril. This is followed by inhaling through the right nostril and exhaling through the left, completing one full cycle of alternate nostril breathing. The breath remains deep, smooth, and rhythmic throughout, free of strain, force, or sound. By directing awareness to the steady alternation of airflow, the mind becomes anchored, reducing distractions and nervous tension. Through repeated cycles, Nadi Shodhana supports physiological balance by harmonizing sympathetic and parasympathetic responses, fostering a calm and centered state of mind while improving focus, emotional stability, and internal equilibrium.

Bhramari Pranayama

Bhramari Pranayama, often referred to as the "humming bee breath," is a deeply calming yogic breathing technique that uses gentle humming vibrations to soothe the mind, relax the nervous system, and induce a meditative state. The practice begins in a stable seated posture with the spine erect and the shoulders relaxed, with the hands resting on the knees or positioned in Shanmukhi Mudra by lightly closing the ears and placing the fingers over the eyes and face to minimize external sensory input. After taking a slow, deep inhalation through the nose, the practitioner exhales steadily while producing a soft humming sound from the throat, resembling the continuous buzz of a bee. The vibration naturally extends the duration of exhalation and resonates throughout the head and chest, creating a subtle internal massage effect while channeling awareness inward. The breath remains smooth, unforced, and rhythmic, and attention is focused on the auditory and vibrational sensations that flow from the humming. Repeated rounds promote rapid mental relaxation by reducing autonomic arousal, quieting intrusive thoughts, and regulating stress-related responses. With regular practice, Bhramari Pranayama enhances emotional stability, improves concentration, promotes sound sleep, and supports the overall balance of the mind and nervous system. Comparative percentage change was calculated for key parameters such as respiratory rate, HRV, and stress levels. Findings were interpreted in the context of established biochemical mechanisms of autonomic regulation, vagal activation, and respiratory physiology. It Lowers heart rate and induces calm through vibrational stimulation of vagus nerve pathways. Scientific studies show pranayama improves blood pressure, respiratory efficiency, and emotional regulation (Brown and Gerbarg, 2005).

RESULTS AND DISCUSSION

Analysis of data from the 20 yoga practitioners demonstrated measurable improvements in autonomic balance following regular pranayama practice. Our results indicate Reduction in respiratory rate by 12–20%, indicating enhanced parasympathetic activity and improved respiratory efficiency. Increase in heart rate variability (HRV) in 75% of participants, reflecting improved vagal tone and reduced sympathetic arousal. Decrease in systolic and diastolic blood pressure in participants with elevated baseline values. Improved oxygen saturation (SpO_2) and more stable oxygen–carbon dioxide balance, suggesting enhanced gas exchange efficiency. Increase in breath-hold time (BHT) by 15–30%, signifying increased CO_2 tolerance and parasympathetic dominance. Reduction in perceived stress levels across participants, aligning with lowered sympathetic output and reduced cortisol activity. The outcomes align with existing scientific literature demonstrating that pranayama Slows respiratory rate and reduces metabolic oxygen demand., Enhances vagal activity and parasympathetic dominance suppresses sympathetic arousal. Stablizes CO_2-O_2 homeostasis., Promotes emotional regulation through improved autonomic balance. These findings support previous studies (Brown and Gerbarg, 2005) showing that pranayama improves blood pressure regulation, respiratory efficiency, and neurochemical balance. Pranayama, the yogic discipline of controlled breathing, directly influences the autonomic nervous system. Significantly it slower down respiratory rate, increases vagal tone, activates parasympathetic rest and digest tone response, reduces sympathetic arousal and also enhances oxygen carbon dioxide balance.

CONCLUSION

Yoga and biochemistry are closely interconnected. By influencing neurotransmitters, hormones, and autonomic responses, yoga promotes homeostasis and holistic well-being. Yogic practices such as asana, pranayama, and meditation modulate biochemical pathways that shape energy metabolism, stress response, and emotional balance. Understanding the chemistry of yoga provides a scientific foundation for integrating yoga into physical, mental, and therapeutic health practices.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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