

Yog, Stress and Systemic Regulation: A Narrative Review

Ketaki Milind Manthalkar^{1*}, Sheetal Ruikar²

ABSTRACT

Stress-related disorders, both physical and mental, are rising globally and call for integrative models of care. Rooted in Indian philosophy, yog has long been recognized as a path to balance and well-being, yet modern research often reduces it to a relaxation technique. This review takes a broader perspective by examining yog-based breath practices through the lens of vagal modulation—a central mechanism connecting the autonomic, endocrine, and immune systems. Drawing on psychology, physiology, and psychoneuroimmunology, it highlights three measurable outcomes of vagal regulation: heart rate variability (HRV), cortisol, and inflammation markers. Evidence indicates that breath practices enhance HRV, restore adaptive cortisol rhythms, and reduce inflammatory activity via pathways such as the cholinergic anti-inflammatory reflex. These findings support yog as a systemic intervention promoting homeostasis and balance. For scholars of yog, this clarifies how ancient practices regulate stress through biological pathways and for scientists, it underscores yog's relevance as a biologically grounded, low-cost, and accessible healthcare tool. The review concludes with the concept of *samatvam (equanimity)* - balance amidst stress/chaos from the Bhagavad Gita, presenting yog as both a philosophical ideal and a physiological reality.

Keywords: *Yog, Vagus Nerve*

The last decade has witnessed a sharp rise in both physical and mental health concerns. Non-communicable diseases such as cardiovascular illness, diabetes, and autoimmune disorders now account for more than 60% of global mortality, with stress consistently identified as a contributing factor (WHO, 2021). At the same time, mental health conditions—particularly anxiety and depression have doubled in prevalence over the last 30 years, affecting nearly one in eight people worldwide (UNICEF, 2021). Against this backdrop, originating from Eastern philosophy, yog has increasingly gained empirical attention across the globe. Systematic reviews conducted over the past two decades have highlighted yog's therapeutic potential in managing stress-related conditions, cardiovascular risk, and mental health disorders. For example, Cramer et al. (2017) conducted a comprehensive review of yog interventions and found consistent evidence for improvements in depression, anxiety, and quality of life. Similarly, Pascoe and Bauer (2015) concluded that yog and meditation can reduce cortisol and improve autonomic balance.

¹PhD scholar, School of Humanities and Social Sciences, DES Pune University

²Associate Professor and Head, School of Humanities and Social Sciences, DES Pune University

*Corresponding Author

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Although the philosophy of yog has caught attention predominantly for its physical postures called *asana*, the entire philosophy in itself is an integrative system consisting of meditative practices, breathing exercises, *mudras*, moral adherences etc. (Iyengar, 1966; Woodyard, 2011). Research often highlights yog's calming effect and capacity to facilitate emotional regulation, attentional control, and body-based awareness.

Despite growing interest in yog-based interventions for mental and physical health, several limitations remain in the current literature. Existing studies are fragmented, focusing on either physical or psychological outcomes, with little effort to examine yog's influence across interconnected systems such as the autonomic, endocrine, and immune pathways (Saoji et al., 2019; Pascoe & Bauer, 2015). Intervention methods also vary widely in terms of duration, frequency, and type of practice, which makes it difficult to draw consistent conclusions or establish standardized recommendations (Cramer et al., 2017; Woodyard, 2011).

A key gap in the literature is the narrow framing of stress itself. While frequently treated as an unambiguous threat, stress is adaptive when acute, mobilizing the hypothalamic-pituitary-adrenal (HPA) axis and cortisol release to meet challenges or to remain in a state of alertness. Problems arise when stress is prolonged i.e., takes a chronicle form and the body cannot recalibrate, producing dysregulation across multiple systems (McEwen, 1998; Schneiderman, Ironson, & Siegel, 2005). In other words, the real challenge lies not in the presence of stress itself, but in the body's inability to restore balance after exposure. To move the field forward, research needs to link psychological changes with physiological markers rather than reporting them in isolation (Pascoe & Bauer, 2015; Cramer et al., 2017). Yog offers a unique strength in this context: its inherently integrative approach provides a framework to study stress not only as a psychological burden but also as a disruption of systemic regulation (Saoji et al., 2019). Addressing this gap is essential to reposition yog research from fragmented symptom relief toward a deeper exploration of systemic regulation and resilience.

Building upon these identified gaps, this review proposes a model that studies the effect of yog on an autonomic-balance regulating system called the Vagus Nerve. The vagus nerve is the 10th cranial nerve originating from the brain stem and is known as the longest nerve. A key component of the parasympathetic nervous system, the vagus nerve plays a central role in regulating heart rate, digestion and stress recovery (Breit et al., 2018). Its extensive reach across the body makes it a promising pathway through which breath-based yog practices may influence systemic regulation (Streeter et al., 2012).

Taking this understanding ahead, the present review utilizes the concept of *vagal modulation*- the way vagal activity adjusts physiological responses across different systems. In this model, vagal activity is studied through measurable variables: heart rate variability (HRV) as a proxy for vagal tone (Shaffer & Ginsberg, 2017), cortisol as a marker of HPA axis function, and inflammatory markers as indicators of immune balance. Together, these outcomes provide an entry point for understanding how yog-based breath practices may support homeostasis.

In the Indian philosophical tradition, Yog has long been viewed as a comprehensive system for cultivating balance between body, mind, and consciousness (Feuerstein, 2001; Saraswati, 2009). Classical texts such as the *Upanishads* and the *Yog Sutras* of Patanjali describe Yog not only as a spiritual path but also as a science of mental discipline and bodily regulation.

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While these traditions have been extensively explored from philosophical standpoints, their physiological underpinnings remain comparatively under examined in contemporary research. This review therefore seeks to bridge Indian knowledge systems with contemporary science, situating yog as both a philosophical ideal and a biologically grounded intervention.

For scholars of yog, this offers a purposive way of understanding how ancient techniques that are already present in practice, can regulate stress and restore balance not only experientially but also through measurable biological pathways; for scientists, it demonstrates that yog is not merely a cultural or spiritual construct, but also a biologically grounded intervention capable of influencing regulatory systems such as the vagus nerve and markers like HRV and cortisol.

METHODOLOGY

This review followed a narrative synthesis approach to integrate findings from diverse disciplines, including psychology, neuroscience, physiology, and integrative medicine, on the relationship between yog-based breath practices and physiological regulation.

Databases Searched

PubMed, PMC, Scopus, ScienceDirect, and ResearchGate.

Keywords Used

Yoga/yog, Pranayama, Breathwork, HRV, Cortisol, Inflammation, Vagus Nerve, Vagal one. Autonomic Nervous System, Allostatic Load, Psychoneuroimmunology, Mind-Body Connection.

Inclusion Criteria

- Peer-reviewed experimental and review studies
- Papers published between 2005 and 2024
- Papers that evaluate physiological measures related to autonomic, endocrine, or immune function in response to breath-based or yog-based intervention

Study Selection Process

The initial search yielded a broad pool of literature, from which duplicates were removed. Titles and abstracts were screened for relevance, followed by full-text reviews to confirm eligibility. Selected studies were then thematically analyzed based on their focus on HRV, cortisol regulation, inflammation, or vagal function.

Data Extraction and Synthesis

Key details from each study such as authors, year of publication, sample size, design, measures, and major insights were extracted and summarized into a comparative table. Findings were synthesized narratively to highlight convergences and divergences across studies and to identify gaps in the literature.

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Table No. 1 Summary of key studies on yog, vagal modulation, and stress-related outcomes

Author, Year	Sample	Design	Intervention	Outcome Measures	Findings	Relevance (to this review)	Insights
Chiarpenello et al., 2024	NA (review)	Review	NA	HPA dysregulation, cytokines (IL-6, TNF), depressive symptoms	Links HPA axis & inflammation to depressive symptoms (directly links to mental health)	Justifies cortisol/inflammation markers in mental health context	Useful to show psychiatric relevance
Maniaci et al., 2024	Healthy Adults, n=44	Pilot Randomized Control Trial	Neofunctional Deep Breathing (NDB) vs. Attention control	HRV, salivary cortisol, cytokines (IL-6, TNF- α , IL-1 β , IL-10) anxiety (STAI), perceived stress (SUDS), allostatic load index	NDB group showed \uparrow HRV, \downarrow salivary cortisol, \downarrow pro-inflammatory cytokines, and reduced allostatic load compared to control	Demonstrates that breathwork can simultaneously affect autonomic, endocrine, and immune markers. Validates the connection between the three physiological levels.	Supports diaphragmatic breathing as a non-invasive vagus nerve stimulator
Palanimugan et al., 2024	1 patient with IBS	Case study	Yoga + naturopathy tailored program	HRV, psychological scales (eg. anxiety/depression inventories), and IBS symptoms (IBS-SSS)	Improvements in HRV, reduced psychological comorbidity, reduced IBS symptoms	Adds anecdotal clinical evidence linking yoga with autonomic and gut function	Very limited generalizability (n=1), but useful as preliminary support in the Indian context
Kavitha et al., 2023	Medical students (India), n=100	Cross-sectional	Self-reported practice of Yog and meditation	Serum Cortisol	Practitioners showed lower morning cortisol levels than non-practitioners	Supports role of yog in endocrine modulation	Highlights cumulative effect of consistent practice
Jensen et al. 2022	Rheumatoid Arthritis & SLE patients + healthy controls (Europe), n=50	Randomized Control Trial	Deep breathing vs. transcutaneous vagus nerve stimulation	HRV, Inflammation markers	Both interventions improved HRV; some reduction in IL-6 observed (inflammatory marker)	Direct evidence of breath-based stimulation of vagal tone supports use of DB as intervention in chronic stress/inflammatory populations	Strengthens case for yog as low-cost vagus nerve modulator
Estevão, 2022	Multiple populations (systematic)	Systematic review	Various yoga protocols	CRP, IL-6, TNF- α (inflammation markers), cortisol	Converging evidence of yoga reducing cortisol/inflammation markers;	Evidence synthesized across studies	Supports triad of HRV-cortisol-inflammation as key

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Author, Year	Sample	Design	Intervention	Outcome Measures	Findings	Relevance (to this review)	Insights
	review)				heterogeneity noted		outcome set
Gautam et al., 2022	Patients with Rheumatoid Arthritis, n=66	Randomized Control Trial	8-week yoga based lifestyle program vs. control	CRP, IL-6, disease activity score, QoL	Reduced CRP/IL-6 and improved QoL & disease activity in yoga group	Clinical evidence linking yoga → reduced inflammation	Demonstrates immune changes alongside symptom improvement
Nugent et al., 2019/2021	Adults with major depression	Randomized controlled trial	Adjunctive Hatha yoga	IL-6, depression scores	IL-6 reductions in yoga vs. control	Direct RCT evidence of yoga's anti-inflammatory effect	Supports inclusion of inflammatory markers in yoga research
Kuppusamy et al., 2020	Healthy adolescents, n=520	RCT (6 months)	Bhramari Pranayama, 5 days/week	HRV (time-domain: RMSSD, SDNN; frequency-domain: LF, HF, LF/HF ratio)	Significant increases in parasympathetic HRV indices (RMSSD, HF power) and decreases in LF/HF ratio compared to controls, indicating improved vagal tone	Provides strong empirical evidence in a young, healthy cohort that breath-based yogic practice enhances vagal regulation	Serves as a model for preventive/early interventions and informs design parameters (frequency, duration)
Bonaz et al. 2018	NA (review)	Review	NA	Vagal afferent pathways, immune signaling, gut markers	Details vagal afferent/immune cross-connection & implications for systemic health	Key mechanistic reference linking vagus → immune/inflammation	Explains theoretically cholinergic anti-inflammatory pathway
Breit et al., 2018	NA (review)	Review	NA	HRV, inflammatory cascade	Summarizes vagal modulation of autonomic & immune systems	Mechanistic support for vagus as central thread	
Nivethitha et al., 2016	Healthy Adults, n=90	Experimental, within-subjects (before vs after pranayama)	Pranayama techniques (slow and fast)	HRV indices, heart rate, blood pressure, respiratory rate	Slow pranayama techniques typically enhance autonomic balance (favoring parasympathetic dominance); fast pranayama increased sympathetic drive; cardiovascular effects varied with breathing type	Offers a broad contextual foundation for understanding how different breath techniques impact autonomic function and sets the stage for comparing experimental findings	Demonstrates that breathing rate and type are critical parameters when designing yoga-based vagal modulation interventions
Kox et al.,	Healthy	Experimental	Wim Hof	Autonomic	Increased	evidence that	Supports

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Author, Year	Sample	Design	Intervention	Outcome Measures	Findings	Relevance (to this review)	Insights
2014	trained volunteers n=24	ental	breathing + meditation + cold exposure	activation, immunity	epinephrine, blunted pro-inflammatory cytokines	voluntary autonomic control affects inflammation	vagal/inflammatory hypothesis for yoga-based breath interventions
Streeter et al., 2012	Epilepsy, depression, PTSD (conceptual + clinical links)	Theoretical synthesis	Yoga (postures + breath)	Autonomic function, GABA, stress symptoms	Yoga proposed to increase vagal activity, enhance GABA, restore allostatic balance	Provides integrative neurobiological model while underscoring the importance of homeostasis and balance	Bridges yoga, vagus, and GABA tone within stress/allostasis framework
Telles et al. 2008	Healthy adults, n=30	Experimental	Nostril-specific breathing	HRV, EEG	Left nostril breathing increased parasympathetic activity; right nostril breathing showed sympathetic arousal	Demonstrates the capacity of yogic breathing exercise to fine-tune autonomic responses thus indicating impact on stress levels	Suggests tailored pranayama could regulate ANS balance

FINDINGS

Relevance of the studying from a Physiological lens

Relevance of the study of Yog from a Physiological lens

In India, yog traditionally finds its earliest references in the oldest scriptures of *Vedas* and *Upanishads*, where it was described as a spiritual discipline aimed at attaining inner peace and liberation (Feuerstein, 2001). In the Vedic period, contemplative and meditative practices were emphasized as pathways to transcendence and balance. Over time, as social and individual needs evolved, yogic philosophy expanded to address the practical challenges of human life. This led to the codification of **Ashtanga Yog** by Patanjali in the *Yog Sutras* (2nd century BCE-4th century CE), which outlined an eightfold path integrating moral disciplines (yamas and niyamas), physical postures (asanas), breath regulation (pranayama), and meditative practices to achieve holistic wellbeing (Iyengar, 1993). Later traditions such as **Hatha Yog** (emerging around the 11th-13th century CE) placed greater emphasis on bodily techniques-postures, breath control, and purification practices-as preparatory tools for meditation and higher states of consciousness (Mallinson & Singleton, 2017). This historical trajectory highlights yog's inherently integrative nature, combining physical, mental, and spiritual practices.

In contemporary contexts, yog's integrative model has drawn increasing scientific interest for its potential to regulate stress-related physiological systems. Unlike conventional treatments that address isolated symptoms, yog practices engage multiple pathways simultaneously, supporting both psychological resilience and physiological balance (Streeter et al., 2012; Telles et al., 2020). What remains less understood, however, is *how* these effects occur at a systemic level. Clarifying this "how" is central to the present review: understanding the pathways of vagal modulation allows us to explain why practices like breath regulation influence markers such as HRV, cortisol, and inflammation. This mechanistic focus does more than validate ancient practices through modern science; it

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provides a framework for developing more precise and adaptable interventions. At its core, the inquiry is about balance- how the body returns to stability after stress, a principle deeply valued in both psychoneuroimmunology and yogic philosophy.

Figure 1 presents a conceptual framework derived from the reviewed literature, visually mapping how chronic stress and yog-based breath practices interact through vagal modulation to influence systemic homeostasis.

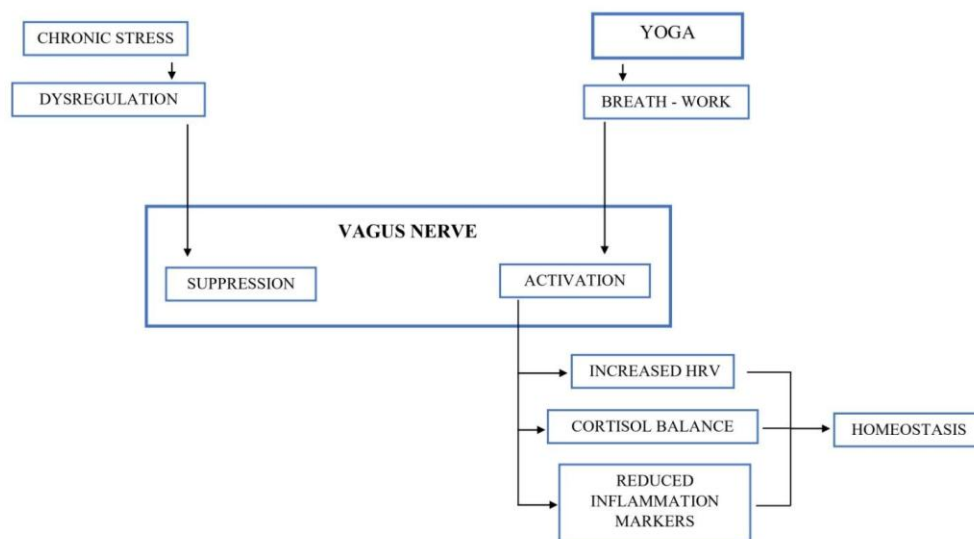


Figure 1. Conceptual model/framework proposed for the relationship between chronic stress, yog and its impact on homeostasis through vagus nerve activation.

Breath and Vagus Nerve

Emerging literature identifies the vagus nerve as a central modulator for maintaining autonomic balance across multiple organ systems. Through its widespread innervation, the vagus influences cardiovascular function, hormonal secretion, digestion, and inflammatory signaling (Breit et al., 2018). When stimulated, it promotes parasympathetic dominance, supporting recovery and restoration. Higher vagal tone is consistently linked with improved physiological and psychological states of rest (Porges, 2007).

Breath-based yog practices, particularly those involving slow and paced breathing, have been shown to stimulate vagal pathways and increase parasympathetic dominance (Gerritsen & Band, 2018; Lehrer & Gevirtz, 2014). This vagal stimulation appears to extend downstream, influencing major stress-regulating systems such as the hypothalamic–pituitary–adrenal (HPA) axis, which controls cortisol release (Streeter et al., 2012). Evidence also points to vagal signaling in modulating immune responses via the cholinergic anti-inflammatory pathway- a pathway first described by Tracey, thereby reducing chronic inflammation (Tracey, 2002; Jerath et al., 2018).

Taken together, these findings suggest that breathing practices may function as integrative interventions whose systemic effects can be assessed through key physiological markers: HRV as an indicator of autonomic tone, cortisol as a measure of neuroendocrine balance, and inflammatory markers as signals of immune regulation.

Physiological markers

The following sections explore how each of these variables, though tied to different physiological systems, converge to illustrate how breath-based practices may support homeostasis through the common thread of vagal modulation.

- a. **Heart Rate Variability (HRV)** : HRV is widely recognized as a reliable marker of vagal tone and autonomic adaptability (Shaffer & Ginsberg, 2017). It is a measure of the variation in time intervals between consecutive heartbeats. It reflects the interplay between the sympathetic and parasympathetic nervous systems. Higher HRV is associated with emotional regulation, stress resilience, and reduced risk of chronic illness, while lower HRV is linked to inflammation and maladaptive stress responses (Olivieri et al., 2024). Evidence from yog-based interventions shows improvements in HRV parameters such as RMSSD and SDNN with slow breathing (Telles et al., 2013). Comparisons with other interventions, such as biofeedback and aerobic exercise, suggest that yog offers unique benefits by integrating physical, mental, and respiratory regulation (Lehrer et al., 2020). However, Indian studies remain limited by inconsistent protocols regarding practice duration and frequency, underscoring the need for standardized approaches that examine HRV alongside other physiological and subjective indicators.
- b. **Cortisol and HPA axis** : Cortisol, a glucocorticoid hormone produced by the adrenal glands, is regulated by the hypothalamic-pituitary-adrenal (HPA) axis and plays a critical role in maintaining alertness, mobilizing energy, and adapting to daily stressors (Sapolsky, Romero, & Munck, 2000). While acute cortisol release is protective, chronic activation of the HPA axis—whether through prolonged psychological stress or illness, leads to dysregulation that is seen as either persistently elevated or blunted responses (Miller, Chen, & Zhou, 2007). Both patterns are associated with metabolic imbalance, mood disorders, and immune dysfunction (Miller et al., 2007). Breath-based yog practices have been shown to restore adaptive cortisol rhythms by calming HPA hyperactivity and supporting diurnal balance (Khajuria et al., 2024; Streeter et al., 2012). This suggests that the therapeutic value of yog lies not in simply lowering cortisol, but in re-establishing its natural rhythmicity, which is critical for homeostasis.
- c. **Inflammation Markers**: Chronic low-grade inflammation is now understood as a common pathway linking stress with a range of physical and mental health conditions, including cardiovascular disease, depression, autoimmune disorders, and metabolic syndromes (Slavich, 2020). Psychoneuroimmunology research shows that long-term immune dysregulation often arises from prolonged HPA activation and failure to return to baseline cortisol levels (Kiecolt-Glaser et al., 2015). The vagus nerve helps counter this process through the cholinergic anti-inflammatory pathway, which suppresses pro-inflammatory cytokine production (Tracey, 2002). Yog-based interventions support this view: Jerath et al. (2018) describe how slow, deep breathing activates vagal anti-inflammatory signaling, while a randomized trial by Gautam et al. (2022) reported significant reductions in CRP levels among rheumatoid arthritis patients following an 8-week yog program. Together, these findings highlight inflammation as a key marker of yog's systemic effects, linking symptom management with immune resilience.

Although HRV, cortisol, and inflammation may appear as distinct variables, they represent interconnected dimensions of the body's stress-response system. Current evidence suggests that the vagus nerve serves as the common pathway linking these systems, coordinating autonomic, endocrine, and immune responses to maintain homeostasis (Gerritsen & Band,

2018). Breath-based yog practices appear to influence these vagal pathways, facilitating cross-talk between immediate autonomic shifts, hormonal regulation, and long-term immune balance. This interconnectedness highlights that yog's impact extends beyond relaxation; it enhances the body's capacity to recalibrate and return to baseline after stress, a process central to resilience and health. By grounding research in HRV, cortisol, and inflammation, yog-based breath practices can be studied as systemic interventions with the potential to restore balance across multiple physiological pathways (Bhasin et al., 2013).

CONCLUSION

This review seeks to broaden the understanding of yog's role in health beyond its frequent portrayal as a relaxation technique. While relaxation is one aspect, growing evidence suggests that yog breath-based breath practices engage with deeper physiological mechanisms that regulate stress and resilience. Stress is not inherently harmful to the body; acute activation of the hypothalamic-pituitary-adrenal (HPA) axis and the release of cortisol are adaptive, preparing the body to meet challenges. The concern arises when stress becomes persistent/ chronic and the body is unable to return to homeostasis, resulting in dysregulation across multiple systems.

In this context, heart rate variability (HRV), cortisol regulation, and inflammatory processes emerge as interconnected markers of stress regulation. HRV reflects autonomic flexibility and vagal tone, cortisol indicates HPA axis functioning, and inflammation reflects the immune system's sensitivity to chronic stress. Although much of the existing literature examines these variables in isolation, evidence suggests that they are part of a coordinated network. Breath-based yog practices, via vagal modulation, may influence all three pathways simultaneously, pointing to their potential as integrative tools for maintaining systemic balance (Tracey, 2002; Bhasin et al., 2013). Future research should adopt standardized protocols and measure multiple outcomes- HRV, cortisol, inflammation and subjective well-being to capture the full scope of yog's effects. Well- designed randomized designs with clear intervention parameters (duration, frequency, and type of breath practice) and longer follow-ups would provide evidence on both short- and long-term benefits. Such work would help identify effective, evidence based breathing interventions. If any empirical support is found it will be of great value in establishing not just the relationship between yog, autonomic, endocrine, and immune systems but it will pave the way for yog-based interventions which is a low-cost, accessible, and holistic means of supporting homeostasis. The broader implications of the finding extend beyond symptom relief; they point to improved physical and mental health and invite a rethinking of how healthcare approaches resilience and integrative care.

Finally, this review interestingly resonates with the philosophical insights from Bhagavad Gita, where yog is defined as "*samatvam yog ucyate*" which translates to equanimity (BhG 2.48). The Gita looks upon yog itself as equanimity in action; a steady and balanced state amidst life's changing phases and fluctuations. Translating this ancient insight into the language of modern science; equanimity appears as homeostasis and vagal balance in our bodies, where resilience arises not from absence of stress but from ability to recover and calibrate. Situating equanimity as both a spiritual ideal and a physiological reality offers a powerful bridge between the Indian Knowledge System and contemporary ways of science, underscoring the integrative potential of yog as a pathway to holistic well-being.

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Conflict of Interest

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