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NEUROENDOCRINE AND IMMUNE PATHWAYS LINKING YOGA TO GUT–BRAIN AXIS MODULATION: A NARRATIVE REVIEW

DR. MAHENDRA K M MD (Clinical Yoga) Scholar
Guide: DR. SHIVAPRASAD SHETTY, Dean & Professor
DR. PRASHANTH SHETTY, Principal,
SDM College of Naturopathy and Yogic Sciences,
Ujire, Dakshina Kannada, Karnataka – 574240
Mobile number: 9036869615, Email id: drmahishetty29@gmail.com

ABSTRACT

The gut–brain axis (GBA) is a bidirectional network linking the central nervous system, gastrointestinal tract, immune system, endocrine signalling, and gut microbiota. Imbalance in this network contributes to gastrointestinal conditions like irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and stress-related psychological disorders. Yoga, a holistic mind–body practice combining physical postures (asana), breathing (pranayama), meditation, and relaxation, modulates the GBA by enhancing vagal tone, regulating hypothalamic–pituitary–adrenal (HPA) axis activity, reducing inflammation, and supporting emotional well-being. Emerging evidence suggests yoga also alters gut microbiome composition and function, adding a novel therapeutic dimension.

Yoga's influence on the GBA occurs through five main pathways: autonomic regulation, HPA-axis modulation, immune-inflammatory control, microbiome interactions, and behavioural factors. This narrative review synthesizes current neuroendocrine, immune, and microbiome research elucidating yoga's modulatory role, discusses clinical implications for functional gastrointestinal disorders, and outlines methodological challenges. Future research should prioritize rigorously designed randomized controlled trials incorporating standardized yoga protocols, biological outcome measures, active control comparators, and systematic adverse event monitoring. Establishing yoga as an evidence-based adjunctive therapy for GBA-related illnesses will require addressing these gaps. By integrating ancient yogic wisdom with contemporary scientific insights, yoga holds promise for holistic management of gut-brain disorders, improving both physical and psychological health.

Keywords: Yoga; Gut–brain axis; Vagus nerve; Microbiome; Irritable bowel syndrome; Inflammatory bowel disease.

Introduction

The gut–brain axis (GBA) represents a complex, bidirectional communication system linking the gastrointestinal (GI) tract with the central nervous system (CNS). This communication occurs through multiple overlapping pathways: the autonomic nervous system (particularly vagal efferent and afferents), the hypothalamic–pituitary–adrenal (HPA) axis, immune and inflammatory mediators, enteroendocrine signalling, and gut microbiota-derived metabolites. Together, these pathways regulate GI motility, secretion, permeability, immune surveillance, and visceral sensation, while also influencing mood, cognition, and stress reactivity.[1–3]

Disruptions of this axis are increasingly recognized in functional gastrointestinal disorders (FGIDs) such as irritable bowel syndrome (IBS), which affects up to 10–15% of the global population and is strongly associated with psychological distress.[4] Similarly, the GBA plays a role in inflammatory bowel disease (IBD), where stress and altered autonomic tone exacerbate disease flares and impair quality of life.[5] Psychiatric disorders including anxiety and depression are also closely linked to GBA dysfunction, mediated in part by microbial dysbiosis and altered vagal signalling.[6]

In recent years, the gut microbiome has emerged as a key regulator within the GBA. Microbial metabolites such as short-chain fatty acids (SCFAs), tryptophan catabolites, and bile acids directly affect neural signalling and immune responses. Dysbiosis has been implicated in both GI disorders and extraintestinal conditions including metabolic syndrome and neuropsychiatric diseases.[7,8] Therefore, interventions capable of modulating stress physiology, autonomic balance, inflammation, and potentially the gut microbiome are of high clinical relevance. Through its integrative influence on neural, endocrine, and immune networks, yoga can be viewed as a practical model of psychoneuroimmunology—modulating the gut–brain axis via simultaneous regulation of mind, autonomic function, and immune signalling.

Yoga, an ancient Indian discipline integrating asanas (postures), pranayama (breathing practices), meditation, and relaxation, is increasingly investigated as a complementary and integrative health approach. Yoga has demonstrated efficacy in reducing stress, improving heart rate variability (HRV), lowering cortisol, and decreasing inflammatory markers.[9–11] These effects map directly onto key nodes of the GBA, providing a mechanistic rationale for yoga as an intervention in gut–brain disorders. For example, pranayama enhances vagal tone, meditation reduces HPA-axis hyperactivity, and combined practices may alter microbial composition by reducing stress-induced dysbiosis.[12,13]

Clinical evidence, though preliminary, supports yoga's role in GI conditions. Systematic reviews report improvements in IBS symptoms and quality of life.[14,15] Pilot studies in IBD suggest yoga can reduce stress and improve well-being.[16] Furthermore, early microbiome-focused interventions indicate that intensive yoga and meditation programs may enrich beneficial microbial taxa.[17] However, existing studies are limited by heterogeneity in protocols, small sample sizes, and lack of standardized outcomes.

METHODS: -This structured narrative review incorporated systematic search elements to enhance transparency and reproducibility. Search strategy and selection included PubMed/MEDLINE, Scopus, and Web of Science databases were searched for articles published from January 1, 2010 to March 31, 2025. The search combined controlled vocabulary (MeSH) and free-text terms using Boolean operators. The search strategy included combinations of the following keywords: ("yoga" OR "pranayama" OR "mind-body" OR "meditation") AND ("gut-brain axis" OR "vagus nerve" OR "HPA axis" OR "microbiome" OR "irritable bowel syndrome" OR "inflammatory bowel disease"). Articles were selected based on relevance to yoga interventions examining neuroendocrine, immune, and microbial aspects of the gut–brain axis in humans. Both mechanistic and clinical studies were included. Study selection and data extraction were performed iteratively to capture key findings related to yoga's effects on autonomic regulation, HPA-axis activity, inflammatory markers, gut microbiome composition, and clinical outcomes in functional gastrointestinal disorders. A qualitative synthesis approach was employed due to heterogeneity in intervention types and outcome measures.

Mechanistic Pathways Linking Yoga to Gut–Brain Axis Modulation

1. Autonomic modulation and vagal tone

The autonomic nervous system, particularly the vagus nerve, forms the physiological backbone of gut–brain communication, and yoga practices enhance parasympathetic regulation through breath and posture-based modulation. The **autonomic nervous system (ANS)** serves as a primary channel in gut–brain communication, with the **vagus nerve** acting as the central parasympathetic pathway that regulates motility, secretion, and visceral sensitivity. Specific **pranayama techniques**- notably **Nadi Sodhana (alternate-nostril breathing), Bhramari (humming breath),** and **slow diaphragmatic breathing-**have been repeatedly shown to **enhance heart rate variability (HRV),** a reliable marker of vagal tone [12,18,19]. These breathing practices promote slow, rhythmic respiration that entrains cardiovascular

oscillations, thereby increasing **baroreflex sensitivity** and **parasympathetic activation** while downregulating sympathetic drive.

The resulting rise in **vagal efferent output** contributes to smoother gastrointestinal motility, reduced visceral pain perception, and activation of the **cholinergic anti-inflammatory pathway,** whereby acetylcholine suppresses macrophage-derived pro-inflammatory cytokines such as TNF-α and IL-6 [20]. In addition to breathing, gentle **asana-based practices** such as **Supta Baddha Konasana (Reclined Bound Angle Pose), Viparita Karani (Legs-Up-the-Wall Pose),** and **Shavasana (Corpse Pose),** when combined with deep breathing, further facilitate parasympathetic predominance. These restorative postures elicit measurable decreases in heart rate and blood pressure and reinforce vagal activation [21]. Together, such integrative practices correct autonomic dysregulation-a hallmark of stress-related gut disorders like **IBS** and **functional dyspepsia**-and help restore gut–brain equilibrium.

2. HPA-axis regulation and stress response

The hypothalamic–pituitary–adrenal (HPA) axis is the body's central stress-regulation network, and yoga harmonizes this system by reducing cortisol output and restoring neuroendocrine balance. The **hypothalamic–pituitary–adrenal (HPA) axis** orchestrates the body's neuroendocrine response to stress. Chronic activation of this system elevates **corticotropin-releasing hormone (CRH)** and **cortisol**, impairing intestinal barrier integrity and promoting dysbiosis [22].

Structured **Hatha yoga programs**, typically comprising **asanas (e.g., Surya Namaskar, Trikonasana, Bhujangasana), pranayama (e.g., Anulom Vilom, Ujjayi breathing),** and **mindfulness-based meditation,** have consistently demonstrated reductions in **salivary cortisol** and improvements in **stress resilience.** For instance, daily Hatha yoga practice for 8–12 weeks produces sustained decreases in resting heart rate, blood pressure, and cortisol, indicating a recalibrated HPA-axis response. [9]. Functional neuroimaging studies further show that **meditation practice such as Yoga Nidra** reduce amygdala hyperactivity while strengthening prefrontal regulation of stress perception, reflecting a neural mechanism underlying emotional balance [23]. By attenuating HPA-axis hyperactivity, these practices preserve **intestinal tight junction integrity**, reduce **stress-induced gut permeability**, and mitigate microbial disturbances associated with chronic psychological stress.

3. Immune and inflammatory modulation

Inflammation acts as a shared biological thread linking gut dysfunction and mood disorders, and yoga mitigates this process by dampening pro-inflammatory signalling and enhancing vagally mediated immune control. Chronic, low-grade inflammation is common in gut–brain disorders. People with IBS and IBD often have high levels of IL-6, TNF-α, and CRP, which heighten visceral sensitivity and mood symptoms [24]. Studies show that yoga can reduce these inflammatory markers. In a 12-week Hatha yoga program, participants practicing Surya Namaskar, Trikonasana, Tadasana, and Shavasana had significantly lower IL-6 and TNF-α, likely due to reduced sympathetic tone and HPA-axis activity [25]. Similarly, an integrated yoga and meditation protocol with gentle Asanas, Bhramari, Nadi Śodhana, and mindfulness practice decreased IL-6 and CRP, while increasing IL-10, indicating improved vagal tone and lower cortisol [26].

Breathing practices like Bhramari and Nadi Śodhana activate vagal afferents that trigger the cholinergic anti-inflammatory reflex, reducing cytokine release [20]. Slow, rhythmic breathing also increases the high-frequency component of HRV, showing stronger parasympathetic control [19]. Yoga and meditation downregulate NF-κB activity and related gene expression [27], while mindfulness enhance parasympathetic dominance and reduce cortisol-driven immune activation [9].Together, these findings suggest that Hatha yoga, Pranayama, and meditative relaxation work in harmony to lower inflammation

by aligning autonomic, endocrine, and immune responses—relieving gut and brain inflammation, and improving overall well-being.

4. Gut microbiome interactions

The gut microbiome serves as a critical intermediary of gut–brain signalling, and emerging evidence suggests yoga and meditation can reshape microbial ecology through stress reduction and improved physiological homeostasis. The **gut microbiome** acts as a key intermediary of gut–brain signalling, influencing neural, immune, and endocrine processes through microbial metabolites such as **short-chain fatty acids (SCFAs), tryptophan derivatives,** and **bile acids** [28]. Altered microbial composition has been implicated in disorders ranging from **IBS and IBD** to **anxiety and depression** [7]. Emerging studies suggest that specific yogic regimens can beneficially influence microbial ecology. A **pilot study during an Arhatic Yoga retreat,** which combined **daily meditation, pranayama, gentle asana, and a vegetarian sattvic diet**, demonstrated enrichment of beneficial microbes like Faecalibacterium prausnitzii and elevated SCFA production within nine days [13].

Similar results were observed in integrative lifestyle interventions involving **yoga-based stress reduction, mindful eating, and moderate physical activity**, which collectively enhanced microbial diversity and metabolic balance [17]. Mechanistically, yoga may favor microbial stability indirectly by reducing stress hormones that alter gut permeability, increasing vagal tone that regulates intestinal motility, and improving sleep and dietary rhythms that sustain microbial homeostasis. Although causality remains to be clarified, these findings underscore the potential of yoga-especially when integrated with mindful nutrition—to promote **a gut environment conducive to symbiotic microbial health.**

5. Behavioural and psychosocial pathways

Beyond its physiological impact, yoga cultivates behavioural and psychosocial resilience—transforming stress perception, emotional regulation, and lifestyle habits that collectively sustain gut–brain health. Beyond physiological regulation, yoga profoundly reshapes **behavioural and psychological patterns** that influence the gut–brain axis. Regular engagement in **Hatha yoga, Yoga Nidra,** and **mindfulness-oriented yoga programs** has been linked to **reduced anxiety and depressive symptoms, improved sleep quality,** and **enhanced emotion regulation** [29,30]. These benefits stem from a combination of self-awareness, breath control, and focused attention that collectively strengthen cognitive–emotional integration. Furthermore, yogic philosophy encourages **mindful eating, self-compassion**, and **moderation**, which contribute to improved dietary habits and reduced reliance on stimulants such as caffeine, alcohol, or nicotine. Such behavioural refinement not only supports gastrointestinal health but also stabilizes circadian and metabolic rhythms, thereby enhancing microbial and neuroendocrine balance.

The **community and spiritual aspects of yoga**, including satsang (group practice) and introspection, further foster **social connection and resilience,** reducing the psychological burden of chronic gut symptoms [31]. Thus, yoga's behavioural dimension complements its physiological effects—creating a comprehensive biopsychosocial framework for healing along the gut–brain continuum.

Clinical Evidence of Yoga in Gut–Brain Axis Disorders

Efficacy in Irritable Bowel Syndrome (IBS)

Previous studies indicate yoga can reduce IBS symptom severity, improve quality of life, and alleviate psychological comorbidities such as anxiety and depression.[14] Trials employing standardized protocols reported improvements in bowel habits and reductions in visceral pain.[15] However, sample sizes remain modest and control conditions vary widely, limiting generalizability.

Impact on Inflammatory Bowel Disease (IBD)

Preliminary studies in IBD patients demonstrate yoga's potential to reduce disease activity and enhance psychological well-being. Studies combining yoga with conventional therapy suggest reductions in inflammatory biomarkers, though randomized controlled trials remain sparse. Rigorous investigation with validated endpoints is required to confirm efficacy and mechanistic pathways. [16] (Table-1)

Safety and Adverse Events

Yoga interventions are generally considered safe with low incidence of serious adverse events in gastrointestinal populations. Mild musculoskeletal discomfort, transient exacerbation of symptoms, or fatigue have been occasionally reported, emphasizing the importance of instructor expertise and patient-tailored modifications. Systematic adverse event reporting remains sparse in the literature, underscoring the need for explicit monitoring and documentation in clinical trials to establish safety profiles. Inclusion of adverse event data is pivotal for integrating yoga into conventional treatment paradigms to enhance clinician and patient confidence. [32,33]

FUTURE DIRECTIONS:- Although research on yoga and the gut–brain axis is growing, most studies are still small and use varied yoga practices, making it hard to draw firm conclusions. Future research should use well-defined yoga protocols that combine postures, breathing, and meditation, with clear details on duration and frequency. Including measurable markers—like heart rate variability, cortisol, inflammation levels, and gut microbiome changes—can help explain how yoga works at a biological level. Larger and longer-term trials comparing yoga with other lifestyle or relaxation practices are also needed to confirm its unique benefits. Finally, exploring online or community-based yoga programs could make these mind–body practices more accessible for people with gut and stress-related conditions.

CONCLUSION

Yoga modulates the gut–brain axis through five converging mechanisms: (1) enhancing vagal tone, (2) regulating HPA-axis activity, (3) reducing systemic inflammation, (4) promoting beneficial microbiota, and (5) improving psychosocial resilience. These integrated effects translate into symptomatic relief in IBS, stress reduction in IBD, and overall quality-of-life improvement. While preliminary evidence is encouraging, larger and mechanistically rigorous randomized controlled trials are needed — incorporating HRV, cortisol, cytokines, and microbiome sequencing. Standardized yoga protocols, active comparators, and attention to diet/behavioural confounders will help establish causality and optimize clinical translation.

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Conflicts of interest

None declared.

Table 1. Clinical Studies of Yoga and Gut–Brain Axis Disorders

Author (Year)	Condition	Design & Sample	Intervention	Outcomes	Key Findings
Schumann et al. (2016) (14)	IBS	Systematic review, 6 RCTs	Yoga 6–12 weeks	Symptom severity, QoL	Improved IBS symptoms; small samples
Saab et al.	IBS	Systematic	Yoga vs control	Pain, Anxiety,	Reduced IBS

(2022) (15)		review, 12 RCTs		QoL	severity; heterogeneity noted
Sharma et al. (2020) (16)	IBD	Pilot RCT, n=60	Yoga 12 weeks	Stress, disease activity	Improved stress, QoL; no biomarker change
Swarup et al. (2025) (17)	Healthy	Pilot, n=40	Arhatic Yoga retreat	Microbiome	Enrichment of beneficial taxa

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