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Review Article

Yoga and neuroplasticity: an integrative narrative review of molecular, structural, and functional evidence

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ABSTRACT

Yoga is a traditional mind-body practice that integrates physical postures (asanas), regulated breathing (pranayama), and meditation (dhyana). This narrative review synthesizes empirical evidence regarding the potential effect of Yoga practice on Neuroplasticity related changes. We reviewed neuroimaging (structural and functional), molecular biology, and clinical research studies investigating Yoga's impact on brain structure, function, and biochemical markers. Structural neuroimaging studies have reported associations between long-term Yoga practice and differences in grey matter volume, grey matter density, and cortical thickness in regions including the hippocampus, prefrontal cortex, and insula. However, findings remain heterogeneous and are largely derived from small observational or cross-sectional studies. Molecular studies suggest that Yoga may influence peripheral neurotrophic and stress-related biomarkers, including BDNF, although the relationship between circulating BDNF and central neuroplastic mechanisms remains uncertain. The evidence is constrained by methodological shortcomings, including small cross-sectional samples, heterogeneous intervention protocols, and a lack of active-controlled longitudinal randomized trials. Yoga demonstrates promise as a holistic, multicomponent intervention influencing macroscopic brain structure, regional function, and network-level organization. However, it should be viewed as an emerging neuroplastic stimulus requiring rigorous, scaled replication rather than a definitively established therapy. This review establishes a multidimensional framework for future research on Yoga's therapeutic potential for long-term brain health and cognitive longevity.

Keywords: Yoga, Neuroplasticity, Asana, Pranayama, Dhyana, Hippocampus, Prefrontal cortex, Functional connectivity, Brain health

INTRODUCTION

Yoga is an ancient Indian mind-body discipline that integrates physical, respiratory, and meditative practices. The Sanskrit term Yoga is derived from the root "Yuj", signifying union, integration, or connection.[1] Yoga is described as a systematic discipline aimed at the regulation and stabilization of mental activity.

Patanjali describes Yoga in the Yoga Sutras as "Yogas Citta-vritti-nirodhah" (Yoga is the cessation of the fluctuations of the mind), emphasizing the regulation of mental activity. The eight-limbed (Ashtanga) approach consists of Yama (ethical restraints), Niyama (observances), Asana (postures), Pranayama (breath control), Pratyahara (sense withdrawal), Dharana (concentration), Dhyana (meditation), and Samadhi (absorption).[2] Contemporary research has particularly focused on investigating the physiological and neurocognitive effects of asana, pranayama, and meditation.[2] In Hatha Yoga, Asana is described first.[3]

According to a textbook of Svasthavritta by Dr. Mangalagowri V. Rao, Yoga is considered an important component of health-promoting lifestyle practices and is discussed in relation to physical and mental well-being.

The text also describes the traditional foundations and development of Yoga.[1]

Yoga and Ayurveda share the broader objective of maintaining health and promoting higher states of well-being. Both systems conceptualize health as a dynamic equilibrium of physiological, psychological, and spiritual factors, providing a holistic framework that complements reductionist neuroscientific approaches. Although their theoretical frameworks differ from contemporary neuroscience, both traditions emphasize regulation of the mind, sensory processes, behaviour, and physiological functions.

Modern neuroscience has provided increasing evidence that the nervous system is capable of modifying its activity through reorganization of structure, functions, or connections in response to intrinsic or extrinsic stimuli. This phenomenon is termed neuroplasticity.[4]

NEUROPLASTICITY

Neuroplasticity, also termed neural or brain plasticity, refers to the ability of the nervous system to modify its activity by reorganizing its structure, function, or connections in response to intrinsic or extrinsic stimuli [4]. These changes may involve synaptic strength, neuronal connections, cortical organization, and functional network activity.[4]

Neuroplasticity contributes to learning, memory, development, adaptation, and recovery following neurological injury.[4] Neuroplasticity encompasses both positive adaptations (learning, recovery) and maladaptive changes (chronic pain, addiction), highlighting the importance of understanding how Yoga might specifically promote beneficial plasticity. At the cellular level, synaptic plasticity includes long-lasting alterations in synaptic transmission. One of the best-known experimental examples is long-term potentiation (LTP), which was demonstrated in the dentate region by Bliss and Lømo in 1973.[5]

For the purpose of this review, neuroplasticity can be considered across the following interconnected levels.

The following classification system provides a framework for understanding the different levels at which neuroplastic changes can occur.

Structural plasticity

Changes in grey matter volume, cortical thickness, dendritic architecture, synaptic organization, and other anatomical features.[4,20,21]

Functional plasticity

Changes in patterns of neuronal activation and functional recruitment.[4,20]

Functional connectivity plasticity

Changes in the strength or organization of communication between brain regions and networks.[4,21]

Synaptic plasticity

Activity-dependent modification of synaptic efficacy, including long-term potentiation (LTP) and long-term depression (LTD).[4,5]

Neurochemical/molecular plasticity

Alterations in neurotrophic factors, neurotransmitter systems, and other molecular pathways.[4,20,21]

Factors influencing neuroplasticity

A range of intrinsic and extrinsic factors can influence neuroplastic processes. These include:

Exercise

Physical activity has long been established as a positive modulator of brain health, supporting neuroplastic alterations through the upregulation of neurotrophic factors.[4,20]

Learning

Acquisition of new skills and knowledge drives experience-dependent changes in neural circuits.[4]

Environmental stimulation

Exposure to enriched or novel environments promotes structural and functional reorganization of neural networks.[4,20]

Neuromodulatory systems

Dopaminergic, serotonergic, and other neurotransmitter systems regulate the conditions under which plasticity occurs.[4,21]

Yoga as a potential neuroplastic stimulus

Yoga combines physical movement, controlled breathing, attentional regulation, and meditation. Therefore, unlike exercise involving only physical activity, Yoga may simultaneously influence a wide range of neurobehavioral domains, including: Sensorimotor processing and interoception, autonomic regulation and stress-response systems, attention and working memory, emotional regulation, cognitive control and executive function, brain network connectivity, and neurotrophic and molecular signalling pathways.[6,7,9,11-13,16,17] A systematic review by Gothe et al identified 11 studies investigating the effects of Yoga on brain structure, function, and cerebral blood flow

using MRI, fMRI, and SPECT. Collectively, these studies reported findings involving the hippocampus, amygdala, prefrontal cortex, cingulate cortex, and default mode network (DMN). However, the authors emphasized that the evidence was still preliminary and that larger longitudinal and randomized studies were required.[6]

Similarly, van Aalst et al reviewed 34 neuroimaging studies of Yoga using MRI, PET, and SPECT. They reported relatively consistent findings involving the hippocampus and insula structurally, as well as frontal executive regions and functional connectivity networks. They also emphasized considerable heterogeneity in Yoga styles, study designs, and sample sizes.[7]

Aim

Aim was to evaluate structural, functional, and molecular effects of Yoga on human brain and Neuroplasticity.

Objectives

Objectives were to synthesize evidence on Yoga-associated neuroplastic changes in brain structure, function, functional connectivity, and molecular mechanisms and to examine the association between Yoga-related neuroplastic changes and cognitive outcomes, including memory, attention, and executive function.

REVIEW OF LITERATURE

Review design

This study was conducted as a narrative review integrating classical Yoga literature with contemporary scientific literature related to Yoga, neuroplasticity, brain structure, brain function, and brain health.

Data sources and search strategy

Relevant classical and contemporary literature was considered. Classical sources included the Patanjali Yoga Sutra, Hatha Yoga Pradipika. A Textbook of Svasthavritta by Dr. Mangalagowri V. Rao, and relevant Ayurvedic literature. Contemporary scientific literature was identified from major electronic databases, including PubMed, Google Scholar, Scopus. The scientific literature was searched from database inception to the final search date, without restriction on publication year. The final database search was conducted on August 2026. Classical Yoga and Ayurvedic texts were examined without restriction on publication period.

Search keywords

The following MeSH terms, where applicable, and free-text keywords were used individually and in combination using Boolean operators (AND/OR/NOT):

Yoga, Ayurveda, Svasthavritta, Brain plasticity, Neuroplasticity, Synaptic plasticity, Long-term potentiation, LTP, Hippocampus, Brain health, Brain function, Neuroimaging, MRI, PET, SPECT, Grey matter, Brain structure, Working memory, Cortical thickness, Prefrontal cortex, Insula, Yoga meditation, fMRI, Emotion, Cognition, Functional connectivity, DMN, Memory, Neural connectivity, Cerebral blood flow, BDNF, Neurotrophic factor, Cortisol, Stress, GABA, Neurotransmitter Learning.

Literature identification and screening process used for the narrative review

Following the database searches, retrieved records were screened for relevance to the objectives of the review. Duplicate records identified across databases were removed before screening. Titles and abstracts were initially examined to identify potentially relevant publications addressing Yoga or related yogic practices in relation to neuroplasticity, brain structure and function, functional connectivity, cerebral blood flow, cognition, or molecular and neurochemical mechanisms. Publications considered potentially relevant were subsequently assessed through full-text review for their relevance to the predefined inclusion and exclusion criteria.

Studies were considered eligible when they involved human participants and investigated Yoga, asana, pranayama, meditation, or related yogic practices and reported relevant structural, functional, connectivity, cognitive, molecular, or neurochemical outcomes. Animal studies, *in-vitro* or cell-culture studies, studies involving exercise without a Yoga component, publications without relevant neurological, cognitive, or molecular outcomes, non-English publications, and articles for which the full text was unavailable were excluded.

As this study was designed as an integrative narrative review, literature selection was guided primarily by relevance to the predefined objectives, methodological contribution, and relevance to the thematic synthesis rather than by a formal systematic-review or meta-analytic selection procedure. Relevant classical Yoga and Ayurvedic literature, together with foundational neuroscience references, were considered separately to provide conceptual, historical, and theoretical context.

The selected literature was synthesized thematically across the major domains of neuroplasticity, including structural neuroplasticity, functional neuroplasticity, functional connectivity, cognitive and emotional effects, cerebral blood flow, and molecular/neurochemical mechanisms. Particular attention was given to study design, sample characteristics, type and duration of Yoga practice, methodological approaches, principal findings, and major limitations when interpreting the available evidence, a total 26 Studies has been added to this review.

Database and literature searching→PubMed, Google Scholar and Scopus→Title and abstract screening for relevance→Full-text assessment of potentially relevant articles→Selection according to predefined inclusion and exclusion criteria→Thematic synthesis of relevant literature.

Inclusion criteria

Human studies investigating Yoga, including asana, pranayama, meditation, or integrated yogic practices. Studies reporting structural, functional, functional-connectivity, molecular/neurochemical, cognitive, or psychological outcomes relevant to neuroplasticity or brain health. Neuroimaging, clinical, observational, cross-sectional, longitudinal, and intervention studies. English-language, full-text publications were included.

Exclusion criteria

Animal, *in-vitro*, or cell-culture studies. Studies involving physical exercise without a Yoga or yogic-practice component. Studies without relevant neurological, neuroplasticity-related, cognitive, psychological, molecular, neurochemical, or brain-imaging outcomes. Non-English publications. Publications for which the full text was unavailable. Duplicate publications or reports containing substantially overlapping data, where applicable were excluded.

REVIEWS OF YOGA AND BRAIN HEALTH

Gothe et al

Gothe et al conducted a systematic review of the existing literature investigating Yoga and brain health. Eleven studies involving brain structure, function, and cerebral blood flow were reviewed. Evidence suggested associations between Yoga practice and structural or functional differences involving the hippocampus, prefrontal cortex, amygdala, cingulate cortex, and DMN. The authors concluded that Yoga may have potential for supporting brain health, while emphasizing the need for randomized controlled trials and longitudinal studies.[6]

Van Aalst et al

van Aalst et al critically reviewed neuroimaging studies of Yoga, including MRI, PET, and SPECT investigations. Their review suggested that Yoga may influence brain areas involved in interoception, executive function, attention, and emotional regulation.

Structural findings were particularly reported in the hippocampus and insular cortex, while functional studies frequently involved prefrontal regions and functional connectivity networks. Importantly, the review emphasized the limited number and heterogeneity of available studies.[7]

STRUCTURAL NEUROPLASTICITY

Structural neuroplasticity refers to changes in measurable brain anatomy, including grey matter volume, grey matter density, and cortical thickness.[4,20,21]

Hippocampus

The hippocampus is critically involved in learning, memory, spatial processing, and emotional regulation. Because hippocampal structure and function are vulnerable to aging and chronic stress, it has become an important region of interest in Yoga research.

Hariprasad et al

Hariprasad et al conducted a small intervention study involving seven healthy elderly participants. MRI scans were obtained before and after six months of Yoga intervention. Voxel-based morphometry demonstrated increased hippocampal grey matter volume and density after the intervention. However, the study had a very small sample and no control group, so the findings should be interpreted as preliminary and cannot establish that Yoga alone caused the observed changes.[8]

Gothe et al

Gothe et al investigated 26 healthy adults, including 13 experienced Yoga practitioners and 13 matched controls. The Yoga practitioners had more than three years of regular Yoga experience. Structural MRI demonstrated greater grey matter volume in the left hippocampus among Yoga practitioners. During a working memory task, the Yoga group also demonstrated lower activation of the dorsolateral prefrontal cortex during encoding. These findings suggest an association between long-term Yoga practice and structural and functional differences in brain regions involved in memory and cognitive processing.[9]

Prefrontal cortex and cortical thickness

The prefrontal cortex contributes to executive function, attentional control, working memory, decision-making, and emotional regulation.

Afonso et al

Afonso et al conducted a cross-sectional MRI study involving 42 older women: 21 long-term Hatha Yoga practitioners and 21 matched controls. The Yoga group had practiced Hatha Yoga for at least eight years.

Yoga practitioners demonstrated significantly greater cortical thickness in a left prefrontal cluster, including portions of the lateral middle frontal gyrus and anterior and dorsal superior frontal gyri. These areas are associated with attention and executive functions. Because this was a cross-sectional study, the finding demonstrates an

association rather than proof that Yoga caused the increased cortical thickness.[10]

Insula and other brain regions

The insular cortex plays important roles in interoception, bodily awareness, emotional processing, and integration of internal physiological signals.

Villemure et al

Villemure et al investigated structural brain differences in experienced Yoga practitioners using MRI-based voxel-based morphometry. The study examined the relationship between Yoga experience, frequency of practice, and grey matter volume.

Years of Yoga practice were associated with grey matter volume in several regions, including the left mid-insula, left frontal operculum, left orbitofrontal cortex, and right middle temporal gyrus. Weekly practice duration was also associated with grey matter volume in several regions, including the left hippocampus, precuneus/posterior cingulate cortex, superior parietal regions, and primary sensory areas.[11]

These findings suggest a possible dose-related association between Yoga practice and regional brain structure, but the cross-sectional design prevents determination of causality.

FUNCTIONAL NEUROPLASTICITY

Functional neuroplasticity refers to changes in how brain regions are recruited during cognitive, emotional, or behavioural tasks.[4,20]

Neural efficiency

Gothe et al found that experienced Yoga practitioners showed lower dorsolateral prefrontal cortex activation during the encoding phase of a working memory task compared with controls. This may be compatible with altered neural efficiency, although reduced activation alone does not prove greater efficiency and may reflect differences in cognitive strategy or task processing.[9]

YOGA MEDITATION AND EMOTIONAL REGULATION

Froeliger et al

Froeliger et al investigated neurocognitive correlates of Yoga meditation practice using fMRI. The study examined emotional processing and cognitive control in Yoga practitioners compared with non-practitioners.

Yoga practitioners demonstrated differences in prefrontal activation during emotional and cognitive-control tasks, including altered responses within the dorsolateral and ventrolateral prefrontal cortex. The findings suggested differences in the neural processing of emotional information and cognitive control among experienced practitioners.[12]

These results are relevant to functional neuroplasticity but should be interpreted cautiously because the study was small and cross-sectional.

FUNCTIONAL CONNECTIVITY AND THE DEFAULT MODE NETWORK

Functional connectivity plasticity refers to changes in the strength or organization of communication between brain regions and networks.[4,21] Neuroplasticity is not restricted to individual brain regions. Changes may also occur in the functional communication between distributed neural networks.

Santaella et al

Santaella et al. investigated 40 older women, comprising 20 experienced Hatha Yoga practitioners and 20 controls. Participants underwent resting-state fMRI.

The Yoga group demonstrated significantly greater functional connectivity between the medial prefrontal cortex and right angular gyrus, two regions associated with the anterior and posterior components of the default mode network. The authors suggested that enhanced anteroposterior DMN connectivity may be relevant to neural correlates of healthy cognitive aging.[13]

However, because the study was cross-sectional, it cannot establish that Yoga practice produced the connectivity differences.

YOGA, MEDITATION AND COGNITIVE FUNCTION

Eyre et al

Eyre et al investigated a mind-body intervention involving yogic meditation in older adults with mild cognitive impairment. Participants were randomized to a yogic meditation intervention or memory enhancement training.

Functional neuroimaging demonstrated relationships between changes in verbal memory and functional connectivity involving regions of the default mode and related cognitive networks.

These findings provide preliminary evidence that mind-body practices may influence functional brain networks associated with memory.[14]

Importantly, because the intervention involved Kirtan Kriya/Kundalini Yoga and meditation rather than isolated asana practice, these findings should not be generalized to physical Yoga postures alone.

YOGA AND HIPPOCAMPAL CHANGES IN AGING

The hippocampus is especially relevant to neuroplasticity because it participates in learning and memory and remains capable of experience-dependent structural modification.

The combination of findings from Hariprasad et al, Gothe et al and the broader neuroimaging reviews suggests that the hippocampus is one of the most consistently reported structural targets in Yoga-related neuroimaging research. Nevertheless, the available studies vary considerably in sample size, Yoga style, duration, and methodological design.[6-9]

Therefore, the evidence supports the statement that Yoga practice is associated with hippocampal structural differences, but stronger longitudinal evidence is required before concluding that Yoga directly induces hippocampal neuroplasticity.

CEREBRAL BLOOD FLOW AND FUNCTIONAL BRAIN ACTIVITY

Cohen et al

Cohen et al conducted a preliminary study involving four participants to examine the effects of Yoga training on cerebral blood flow using SPECT.

Changes in regional cerebral blood flow were observed following *Yoga* training and during meditation. The findings suggested that Yoga and meditation may influence cerebral perfusion and regional brain activity. However, because the study included only four participants, the results are highly preliminary.[15]

MOLECULAR AND NEUROTROPHIC MECHANISMS

Neurochemical/molecular plasticity refers to alterations in neurotrophic factors, neurotransmitter systems, and other molecular pathways.[4,20,21] Structural and functional brain changes require molecular mechanisms capable of modifying neuronal function and synaptic organization.

BRAIN-DERIVED NEUROTROPHIC FACTOR

Brain-derived neurotrophic factor (BDNF) is an important neurotrophin involved in neuronal survival, synaptic plasticity, learning, memory, and adaptive responses to experience.

Emerging studies have investigated whether Yoga may influence circulating BDNF and other metabolic or neurotrophic markers. For instance, Pal et al demonstrated that yogic practice was associated with age-related preservation of cardiovascular function and BDNF levels in healthy active males.[16] Similarly, Naveen et al reported that Yoga intervention in patients with major depression was associated with changes in serum cortisol and BDNF levels.[17]

However, circulating BDNF should not be automatically interpreted as a direct measurement of BDNF activity within the human brain. It is important to note that peripheral BDNF levels- typically measured in serum or plasma- do not necessarily reflect central BDNF activity in the brain.

The relationship between peripheral and central BDNF is complex, and peripheral measurements may be influenced by platelet storage, circadian variation, and other factors. Therefore, while circulating BDNF represents a valuable proxy measure, it should not be equated with direct measurement of brain BDNF bioavailability.

Therefore, the current evidence supports BDNF as a plausible molecular pathway associated with Yoga-related neuroplasticity, but further controlled studies are required to establish the precise relationship between Yoga, BDNF signalling, and structural brain changes.

YOGA AND NEUROTRANSMITTER SYSTEMS

Yoga and meditation may influence neurotransmitter systems involved in mood, stress regulation, cognition, and arousal.

Particular interest has been directed toward:

GABA

Inhibitory neurotransmission and regulation of neuronal excitability. Streeter et al reported that a single Yoga session increased brain GABA levels, and a randomized controlled trial found greater GABA increases following Yoga compared with walking.[18,19]

Dopamine

Motivation, reward, attention, and motor function.

Serotonin

Mood and emotional regulation.

Glutamate

Excitatory neurotransmission, learning, and synaptic plasticity.

However, evidence directly demonstrating that routine Yoga practice produces persistent clinically significant changes in these neurotransmitter systems remains limited.

Therefore, neurotransmitter modulation should currently be presented as a potential mechanism, rather than an established direct pathway.

YOGA, STRESS REGULATION AND NEUROPLASTICITY

Chronic psychological stress can influence neural systems involved in cognition and emotional regulation. Yoga incorporates controlled breathing, physical activity, relaxation, and attentional regulation, which may collectively influence autonomic and stress-response systems.

Potential pathways include:

Yoga practice → autonomic regulation → reduced physiological stress → altered neuroendocrine signalling → improved conditions for adaptive neural plasticity.

This provides a plausible link between behavioural regulation and neuroplasticity. Nevertheless, the relationship is multifactorial, and direct causal pathways in humans require further investigation.

INTEGRATED NEUROPLASTIC MECHANISM OF YOGA: A CONCEPTUAL MODEL

The available evidence can be conceptually organized into interconnected levels:

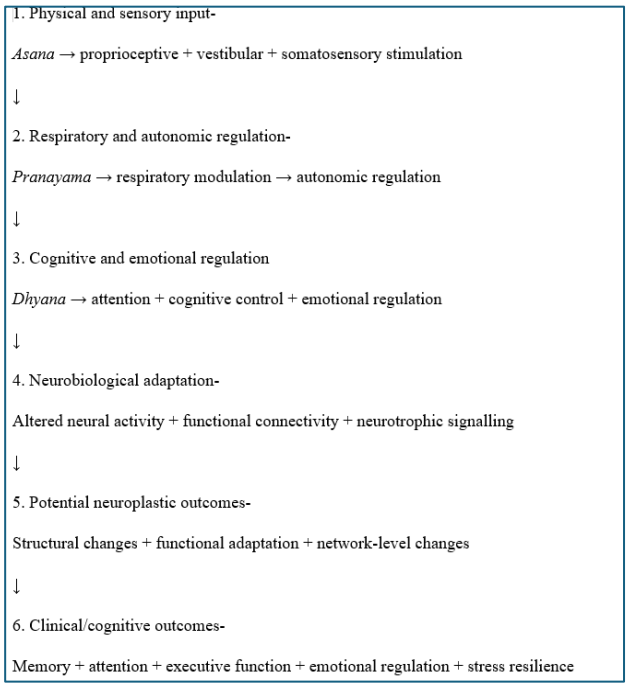


Figure 1: Conceptual model illustrating the proposed integrated pathways through which Yoga may influence neuroplasticity.

This framework represents a conceptual model based on converging evidence and should be interpreted as an interactive, bidirectional system rather than a simple linear cascade. Neuroplastic changes likely emerge from the simultaneous, synergistic interaction of multiple components, with feedback loops between levels (e.g., improved emotional regulation → reduced stress → enhanced neuroplastic conditions → further cognitive improvements).

CRITICAL APPRAISAL

Although the literature provides promising evidence, several limitations must be considered.

Small sample sizes

Many neuroimaging studies included relatively small numbers of participants. For example, the Hariprasad study included only seven participants, while the Cohen study included four.[8,15]

Cross-sectional designs

Several important studies, including Villemure, Afonso, Gothe, and Santaella, compared experienced Yoga practitioners with non-practitioners. Such designs demonstrate associations but cannot establish whether Yoga caused the observed differences.

Heterogeneity of Yoga interventions

Yoga interventions differ in: asana selection, intensity, duration, pranayama, meditation, chanting, frequency, teacher expertise and overall intervention duration. Therefore, the findings cannot automatically be generalized to all forms of Yoga.[7]

Confounding factors

Experienced Yoga practitioners may differ from controls in physical activity, diet, stress management, lifestyle, education, socioeconomic factors/other health behaviours.

Neuroplasticity versus association

An increase in grey matter volume or altered functional connectivity is consistent with neuroplastic adaptation, but a cross-sectional MRI finding alone does not demonstrate that Yoga caused neuroplasticity. Furthermore, observed structural differences could theoretically precede and predict Yoga practice (i.e., individuals with certain brain characteristics may be more likely to take up or maintain Yoga practice), rather than being caused by it. This "reverse causation" possibility cannot be ruled out in cross-sectional designs.

Need for longitudinal randomized studies

Future research should use: larger samples, randomized controlled designs, active exercise controls, standardized Yoga protocols, longitudinal MRI/fMRI measurements, molecular biomarkers, cognitive outcomes and long-term follow-up. These methodological improvements are also emphasized by major reviews of Yoga neuroimaging research.[7]

Table 1: Summary of empirical studies investigating the effects of Yoga on neuroplasticity and related neurobiological outcomes.

Author/year	Sample size	Population	Yoga intervention/ practice	Duration/ exposure	Methodology	Key findings
Hariprasad et al 2013[8]	7	Healthy older adults	Hatha Yoga including asana, pranayama and OM chanting	6 months	Structural MRI; voxel-based morphometry	Yoga practice was associated with increased hippocampal grey-matter volume.
Gothe et al 2018[9]	26 (13 Yoga; 13 controls)	Healthy adults	Long-term Hatha Yoga practice	≥3 years	Structural MRI and task-based fMRI	Yoga practitioners showed greater left hippocampal grey-matter volume and lower DLPFC activation during working-memory encoding.
Afonso et al 2017[10]	42 (21 Yoga; 21 controls)	Healthy older women	Long-term Hatha Yoga practice	≥8 years	Structural MRI; cortical-thickness analysis	Long-term Yoga practice was associated with greater cortical thickness in the left prefrontal cortex.
Villemure et al 2015[11]	28 (14 Yoga; 14 controls)	Healthy adults	Long-term Yoga practice involving postures, breathing and meditation	Long-term practice	Structural MRI; voxel-based morphometry	Years and frequency of Yoga practice were associated with grey-matter volume differences in regions including the insula, frontal operculum, orbitofrontal cortex and hippocampus.
Froeliger et al 2012[12]	14 (7 Yoga; 7 controls)	Healthy adults	Hatha Yoga and meditation	≥3 years	Structural MRI, task-based fMRI and resting-state fMRI	Yoga practitioners showed differences in grey matter and neural responses associated with cognitive and emotional processing.
Santaella et al 2019[13]	40 (20 Yoga; 20 controls)	Healthy older women	Long-term Hatha Yoga practice	≥8 years	Resting-state fMRI; functional-connectivity analysis	Yoga practitioners showed greater functional connectivity between the medial prefrontal cortex and right angular gyrus.
Eyre et al 2016[14]	25 (14 Yoga; 11 MET)	Older adults with subjective memory complaints/mild cognitive impairment	Kundalini Yoga and Kirtan Kriya meditation	12 weeks	Randomized controlled Preliminary intervention; resting-state fMRI and cognitive assessment	Yoga-based meditation was associated with changes in functional connectivity and memory-related outcomes.
Cohen et al 2009[15]	4	Yoga-naive participants	Iyengar Yoga	12 weeks	SPECT; regional cerebral blood-flow assessment	Evidence indicated changes in regional cerebral blood flow following Yoga training.
Pal et al 2014[16]	60	Healthy physically active males	Yogasana, pranayama and meditation	3 months	Biochemical, cardiovascular and autonomic assessments	Yoga practice was associated with changes in BDNF and other neurochemical, cardiovascular and autonomic measures.
Naveen et al 2016[17]	54	Adults with major depressive disorder	Yoga therapy	12 weeks	Clinical assessment and serum biochemical analysis	Yoga intervention was associated with changes in serum BDNF and cortisol levels.

Continued.

Author/year	Sample size	Population	Yoga intervention/ practice	Duration/ exposure	Methodology	Key findings
Streeter et al 2007[18]	19-8 Yoga; 11 comparison	Healthy participants	Yoga asana session	Single 60-minute session	Magnetic resonance spectroscopy	A single Yoga session was associated with an increase in brain GABA levels.
Streeter et al 2010[19]	34 (19 Yoga; 15 walking)	Healthy adults	Yoga postures compared with walking	12 weeks	Ranssdomized controlled trial; magnetic resonance spectroscopy	Yoga was associated with changes in thalamic GABA and improvements in mood and anxiety compared with walking.
Froeliger et al 2012a[22]	14 (7 Yoga; 7 controls)	Healthy adults	Long-term Yoga meditation practice	≥3 years	Structural MRI; voxel-based morphometry (VBM)	Greater grey-matter volume in several brain regions; fewer reported cognitive failures in Yoga practitioners.
Cahn et al 2017[23]	38	Healthy adults	Yoga and meditation retreat	3 months	Biochemical and physiological assessments	Increased BDNF; altered cortisol awakening response; changes in inflammatory-marker expression.
Thirthalli et al 2013[24]	60	Patients with major depressive disorder	Yoga intervention	12 weeks	Clinical assessment; serum cortisol analysis	Reduced cortisol levels and improvement in depressive symptoms following Yoga intervention.
Rangan et al 2009[25]	159	School students	Yogic education system	1 year	Cognitive/memory assessment	Yogic education was associated with improved memory performance compared with the modern education system.
Chatterjee et al 2021[26]	30	Healthy adults	Yogic training	12 weeks	Quasi-experimental study; neurocognitive assessment	Improvements in selected neurocognitive variables following 12 weeks of yogic training.

DISCUSSION

The available literature suggests that *Yoga* may influence the brain at multiple interconnected levels.

At the structural level, studies have reported greater grey matter volume or density and cortical thickness in areas including hippocampus, prefrontal cortex, and insula.[8-11]

At the functional level, experienced Yoga practitioners have demonstrated altered activation of the dorsolateral and ventrolateral prefrontal cortex during cognitive and emotional tasks.[9,12]

At the network level, Yoga practice has been associated with altered functional connectivity within the default mode network, including increased connectivity between the medial prefrontal cortex and right angular gyrus in elderly practitioners.[13]

At the molecular level, neurotrophic factors such as BDNF represent plausible biological pathways through which Yoga may influence neuronal adaptation. However, molecular evidence is currently less established than the neuroimaging literature and requires further controlled investigation.

Recent reviews have further expanded the neurobiological interpretation of yogic practices, including their potential effects on neurophysiological and psychological processes, asana-related neurophysiology, and pranayama-related neuroplastic mechanisms.[27-29]

Taken together, these findings support a model in which Yoga may act as a multicomponent behavioural stimulus involving physical activity, respiratory regulation, attentional control, and meditation. These components may independently and synergistically influence neural activity and adaptive brain processes.

Importantly, the term "neuroplasticity" should be used cautiously. Many existing studies are cross-sectional and therefore demonstrate relationships between Yoga practice and brain characteristics rather than definitive causal neuroplastic changes. The strongest evidence comes from

longitudinal intervention studies, but these remain relatively few and often involve small samples.[7]

CONCLUSION

The available neuroimaging, cognitive, and molecular evidence provides promising but preliminary support for an association between Yoga practice and neuroplasticity-related changes.

Yoga has been associated with structural differences in the hippocampus, prefrontal cortex, and insula, functional differences in prefrontal regions, and altered connectivity within the default mode network. The hippocampus appears to be one of the most consistently investigated structural targets, whereas prefrontal and network-level changes may contribute to cognitive and emotional regulation. Molecular pathways involving BDNF and other neurobiological mechanisms provide plausible explanations for some of these effects, although the molecular evidence remains less conclusive.

The findings suggest that Yoga demonstrates promise as a holistic, multicomponent behavioural practice associated with differences in brain structure, regional function, and network-level organization. However, the current literature is limited by small samples, heterogeneous Yoga protocols, cross-sectional designs, and insufficient long-term randomized controlled trials. Therefore, Yoga should currently be considered a promising complementary approach for supporting brain health and potentially promoting adaptive neuroplasticity, rather than a definitively proven neuroplastic treatment. Larger, well-controlled longitudinal studies combining MRI/fMRI, molecular biomarkers, standardized Yoga protocols, and objective cognitive outcomes are required to establish causality and clarify the underlying mechanisms.

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