DOI: 10.7860/JCDR/2025/78278.22171

Review Article

Psychiatry/Mental Health Section

Potential of Yoga Therapy in Modulating Neurotransmitters for Treatment and Prevention of Autism Spectrum Disorder: A Narrative Review

SOCCALINGAM ARTCHOUDANE

(cc) BY-NC-ND

ABSTRACT

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterised by impairments in communication, social interaction, and behaviour. Increasing evidence suggests that maternal psychological stress during pregnancy can lead to neuroinflammation and disruption of neurotransmitter systems. This review aims to critically evaluate the potential role of yoga therapy in regulating neurotransmitter systems to mitigate ASD symptoms in children and reduce maternal psychological stress during pregnancy. A comprehensive literature review was conducted using PubMed and Google Scholar. The keywords used for the search included "Yoga," "pregnancy," "maternal psychological stress," "ASD," and "foetal neurodevelopment" in various permutations and combinations with "neurotransmitters." The focus was on neurotransmitters, including serotonin, dopamine, and Gamma-Aminobutyric Acid (GABA), emphasising their roles in mood regulation, behaviour, and cognitive functions. The review found that yoga therapy modulates neurotransmitter systems by reducing stress and enhancing emotional regulation and cognitive function in the treatment of ASD. It also helps prevent the adverse effects of maternal psychological stress on foetal neurodevelopment during pregnancy.

Keywords: Acetylcholine, Dopamine, Gamma-aminobutyric acid, Neuroplasticity, Serotonin

INTRODUCTION

ASD is a complex neurodevelopmental condition that affects social interaction, communication, and behaviour. Several studies have found that psychological imbalance, as well as sensory and cognitive dysfunctions, play major roles in abnormal brain development, contributing to memory, motor activity, and behavioural dysfunctions [1,2]. These factors indicate defects in nerve cell migration, differentiation, synaptogenesis, apoptosis, and synaptic pruning, which are caused by dysfunctions in neurotransmitter systems in children with ASD [2].

Given the broad distribution of neurotransmitters, the complex and diverse functions of monoamine neurotransmitters are crucial for social communication, as they coordinate sensory, motor, and limbic systems across different brain regions. Several studies have reported alterations in neurotransmitters, including GABA, glutamate, dopamine, norepinephrine, acetylcholine, serotonin, and opioid peptides in children with ASD [3,4]. Despite extensive research over the past three decades on the aetiology and pathophysiology of ASD, the mechanisms behind its pathogenesis remain elusive [5]. Since the root causes of this disorder are not yet fully understood, preventive strategies have yet to be developed.

With the growing prevalence of this condition, current estimates suggest that approximately 1 in 54 children are diagnosed with ASD [6]. Given this increasing incidence and the complex nature of ASD, there is a compelling need for effective interventions that address the multifaceted challenges associated with the disorder and its prevention strategies.

Several studies have found that regular yoga practice:

1. Improves motor coordination, academic-specific building actions, and imitation skills [7];
2. Significantly reduces irritability, hyperactivity, aggression, and social withdrawal [8], as well as behavioural dysfunction [9], promoting a shift towards parasympathetic activity that fosters calmness, self-regulation, and resilience;
3. Helps ameliorate gastrointestinal distress and sleep disorders [10] in children with ASD [11].

Research indicates that yoga may help correct neuroinflammation caused by imbalanced neurotransmitters [12], such as GABA, which is linked to relaxation and anxiety [13], and may help increase serotonin levels, contributing to mood stabilisation [14]. This could potentially improve emotional regulation in children with ASD [15]. Preliminary findings suggest that yoga can positively influence neurotransmitter systems, promoting better mental health and social skills in individuals with ASD [2,16]. Most interventions target children already diagnosed with ASD, leaving a significant research gap regarding preventive measures [17,18].

The purpose of this review is to critically evaluate the potential of yoga therapy as an effective intervention for ASD, both as a therapeutic and preventive measure, with a particular focus on its influence on neurotransmitter alterations and associated neurodevelopmental processes.

REVIEW OF LITERATURE

A comprehensive literature review was performed using electronic databases, including PubMed and Google Scholar. This review examined relevant studies on the aetiopathogenesis of ASD and the effect of yoga therapy on the modulation of neurotransmitters in the treatment of ASD, as well as preventive measures for maternal psychological stress during pregnancy. Keywords used in the search included "Yoga Therapy," "Neurotransmitters," "ASD," "Maternal Psychological Stress," "Serotonin," "GABA," and "Dopamine." Data were extracted from each study, focusing on outcomes related to neurotransmitters or behavioural/emotional changes.

RESULTS

A summary of the effect of yoga interventions on neurotransmitters based on available literature for the treatment of ASD and the prevention of adverse effects of maternal psychological stress on foetal neurodevelopment during pregnancy is provided in [Table/Fig-1] [19-37].

Neurotransmitters and receptors	Imbalanced neurotransmitters	Area of dysfunction	Behavioural dysfunctions	Treatment: YT on behavioural dysfunctions in ASD	Prevention: YT on Maternal psychological stress during pregnancy
Acetylcholine [19-22] Nicotinic, Muscarinic	↓ α4β2 nAChRs in parietal and frontal cortex, ↓ 04, ↑ α7 nAChRs in cerebellum	CNS: Memory, cognition. PNS: Skeletal muscle and parasympathetic nervous system	Irritability, hyperactivity, poor verbal learning; poor thinking ability and memory, frequent mood swings; Inattention in patients with psychiatric disorders such as ASD and ADHD often associated with low levels of acetylcholine.	Improved motor coordination, static and dynamic balance; reduced irritability, aggression, social withdrawl, non compliance, and behavioural dysfunctions [23,24].	Reduced gastrointestinal, respiratory, and mental health symptoms in maternal psychological stress during pregnancy [25,26].
Catecholamine [27] Excites and Inhibits (α1β1; α2β2 β3) Noradrenaline Adrenaline	-	CNS: Opioid regulation. PNS: Sympathetic nervous system	Dysfunction of catecholamine leads to core symptoms of ASD.	Reduced core symptoms of ASD, particularly in latency-age children [8].	
Dopamine [27] DA_B; DA_A	Imbalanced DA in prefrontal cortex	CNS: Motivation, motor control. PNS: BV, GIT, Renal system; Dysregulation of mesocortico-limbic and nigrostriatal circuit	Reduced motivation to pursue social interactions.	Increased ability to stay still without typical fidgeting, improved self-control, enhanced quality of life, and better social responsiveness, communication, cognition, and motivation [24].	
Serotonin [28] 5-HT2,3,4,5,6; 5-HT1-s1	↓ 5-HT2A, 5-HT1A in brain and blood	CNS: sleep, mood. PNS: GIT and skeletal system; Hippocampus	Poor sleep quality and social initiation.	Improved sleep [10].	
GABA [29,30] Inhibits: $GABA_A$, $GABA_B$	↓ GABA in motor, visual, auditory, somatosensory cortex	Inhibits action potential of neurons in superior frontal cortex, parietal cortex and cerebellum; and various brain regions	Poor socio-emotional and cognitive processing, such as difficulty identifying faces and facial expressions, leads to functional deficits in individuals with ASD.	Developed positive social and emotional skills in youth with ASD [31].	
Glutamate [32,33] Excites: $GluR_A$, $GluR_B$	↑ glutamatergic activity	Excites neurons of anterior cingulated cortex and central nervous system	Poor social and communication skills.	Improved social communication and generalised joint attention skills [7].	
Neurotensin (NT) [34] Excites: NK1R	-	CNS and PNS: pain and inflammation	Stimulation of immune cells, especially mast cells, and/or have direct effects on brain inflammation.	Movement-based experiences are multimodal in nature and activate similar "mirror" networks in the brain of participants, thereby forming the basis for social, emotional, and motor coordination in individuals with ASD [35].	
Substance P or Endorphins [36]	↑β endorphin in plasma		Hyperactivity and restlessness.	Improvement in ADHD symptoms such as inattention and hyperactivity, as shown in parent reports [37].	

[Table/Fig-1]: Summary of the effect of YT on neurotransmitters in treatment and prevention of ASD [19-37].
α(4)β(2)nAChRs: alpha-4 beta-2 nicotinic acetylcholine receptors; CNS: Central nervous system; PNS: Peripheral nervous system; ANS: Autonomic nervous system; ADHD: Attention deficit hyperactivity disorder; DA (a or b): Dopamine (alpha or beta) hydroxylase; BV: Blood vessels; GIT: Gastro-intestinal tract; 5-HT: 5-hydroxytryptamine; GABA (a or b): G-protein coupled (alpha or beta) receptors for gamma-aminobutyric acid; (i or m) GluRs: (ionotropic or metabotropic) glutamate receptors; GluR (a or b): subunits of glutamate receptorare functionally expressed on α and β cells; and NK1R: neurokinin 1 receptor

DISCUSSION

Aetiopathogenesis of ASD: According to *Thirumanthiram*, a classical yoga text in Tamil dating back 3,000 years [38,39], Neurodevelopmental Disorders (NDDs) are described as congenital disorders in verse 481, stating:

"Maadha udhara mala migil mandanaam,

Maadha udhara jala migil moongaiyaam,

Maadha udhara irandokkil kannillai,

Maadha udharatthil vanda kuzhavikke."

It is explained that chronic psychological stress during pregnancy can lead to partial evacuation of the mother's bowel, bladder, or both. This may result in transient neuroinflammation in the foetus, potentially manifesting as NDDs such as Intellectual Disability (ID), Attention Deficit Hyperactivity Disorder (ADHD), or ASD [40].

Chronic stress can cause autoimmune diseases. When women with autoimmune diseases consume a high-fat diet during pregnancy and are exposed to pollution and infections, this leads to the development of inflammatory cytokines in plasma, the placenta, and amniotic fluid. Such a state is known as maternal psychological stress—maternal immune activation—which further leads to microglial activation, immune alteration, and neuronal and synaptic dysfunction in the brain of the offspring [17], as shown in [Table/Fig-2].

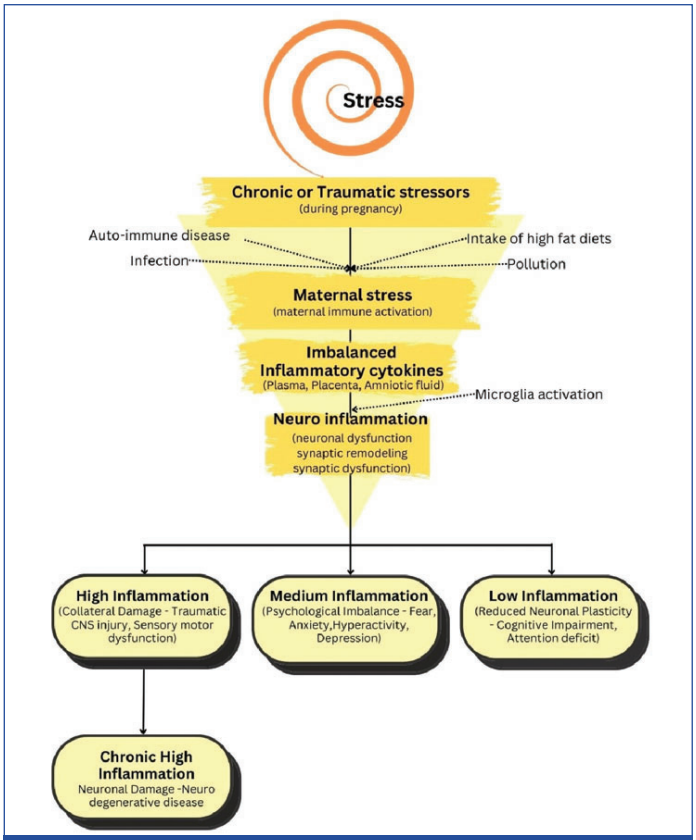
This neuroinflammation leads to:

Collateral neuronal damage: Sensorimotor dysfunction, especially when sensory processes from sound, touch, sight, smell, taste, and the vestibular system remain imbalanced. This can develop into challenging behaviours such as difficulties in catching and throwing, clumsiness, poor attention and perception, failure to perceive extreme odours, increased pica or overeating (spicy food), a high pain threshold, self-harm, and an inability to feel or chew food in the mouth, particularly an inability to acknowledge certain sounds. Overloaded sensory stimuli may increase sensitivity, cause hearing impairments, distortions, and indifference toward people (associated with distinctive perfumes, shampoos, etc.), leading to a restricted diet.

Psychological imbalance: Anxiety, fear, hyperactivity, impulsivity, etc.

Cognitive dysfunction: Resulting from altered neurotransmission processes, which further lead to behavioural impairments in children with ASD, as illustrated in [Table/Fig-2] [18,41,42].

Therapeutic effect of yoga on treatment and prevention of ASD: According to Hatha Yoga Pradipika, a classical yoga text, it is stated that regardless of age or condition, whether young, old, or afflicted, through regular yoga practice, one can attain health and wellbeing, as mentioned in verse 66 [43].



[Table/Fig-2]: Transient neuroinflammation from maternal psychological stress during pregnancy to children with NDDs.

Role of Yoga Therapy in Children with ASD

Yoga therapy includes:

Yogic counseling: Utilises psycho-socio-spiritual principles along with dietary and lifestyle modifications to integrate and restore fundamental bodily systems and psychological processes, thereby fostering improved self-regulation.

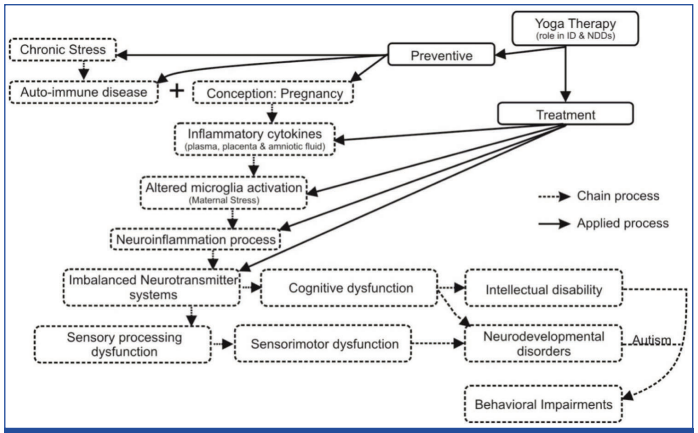
Yogasana: Body-breath coordinated movement enhances awareness, strength, and body stabilisation by stimulating the release of endorphins and mood enhancers.

Pranayama: Regulated breath prepares the body to handle anxiety and stress by modulating the autonomic nervous system and potentially influencing neurotransmitters like acetylcholine, leading to enhanced relaxation and reduced stress responses [44,45].

Yogic relaxation techniques promote deep respiration and calmness in the mind by increasing the production of serotonin and dopamine, neurotransmitters associated with feelings of wellbeing and pleasure, as shown in [Table/Fig-3] [16].

Yoga Therapy on Modulation of Neurotransmitters in Treatment of ASD (as presented in [Table/Fig-1])

1. Dopamine (DA) is a key neurotransmitter that plays a crucial role in regulating social cognition, involuntary movement control, and behaviour [46,47]. Several studies have found that regular yoga practice alleviates stress and anxiety, promoting a state of calmness and mindfulness, potentially due to dopamine release [9]. This activation may improve motivation to engage in social interactions, thereby addressing a core deficit in ASD. Moreover, a yogic diet—including avocados, bananas, pumpkin, sesame seeds, and soy products—may help improve tyrosine levels, while pranayama can increase the release of neurotransmitters associated with positive mood states. Yoga interventions have led to improvements in behavioural outcomes for children with ASD, including increased social engagement and communication skills, potentially mediated by enhanced responsiveness of the dopaminergic system to social stimuli [8,48].



[Table/Fig-3]: Yoga modulates neurotransmitters in ASD: Treatment and Prevention.

2. Serotonin is an important neurotransmitter that influences mood, sleep, and various brain functions. Multiple studies have shown that yoga interventions help achieve homeostasis by balancing sympathetic and parasympathetic activities, thereby maintaining equilibrium in plasma levels of serotonin, melatonin, and glutamate neurotransmitters [49]. Regular yoga practice is associated with higher serotonin levels, resulting in improved mood and reduced anxiety in individuals with ASD [16]. Additionally, following a yogic diet that includes vegetables, fruits, legumes, and whole grains helps increase tryptophan [50], which is crucial since poor sleep has been linked to decreased serotonin production [10]. Yoga therapy enhances Brain-Derived Neurotrophic Factor (BDNF) and serotonin levels, promoting better sleep and facilitating improved emotional regulation and social interaction in children with ASD [51].
3. GABA is a significant inhibitory neurotransmitter that helps regulate brain activity. Several studies have found that yoga significantly reduces cortisol, increases GABA, and enhances the activity of GABAergic systems and peripheral oxytocin, thereby promoting relaxation and reducing anxiety [52-55]. Furthermore, incorporating a yogic diet, particularly with fermented foods, germinated wheat, barley, fresh vegetables (like broccoli and spinach), fruits (such as bananas and berries), nuts (almonds and walnuts), buttermilk, lentils, brown rice, and whole grains, helps increase the enzyme glutamic acid decarboxylase. Additionally, pranayama in yoga practice has been shown to enhance the regulation of the autonomic nervous system, often linked to lowered GABA levels [45]. Thus, yoga therapy is established as an effective intervention for modulating GABA levels, improving socio-emotional regulation, and mitigating anxiety-related behaviours in children with ASD [53].
4. Glutamate is the most common excitatory neurotransmitter that plays a key role in brain function, including memory, cognition, and mood regulation. Numerous studies have found that yoga enhances mood and emotional expression, increases empathy towards others, and improves social skills, which can be correlated with better regulation of glutamate, thereby increasing neuroplasticity in individuals with ASD [31,45,55,56].
5. Acetylcholine (ACh) plays a significant role in memory, learning, attention, and involuntary muscle movement. Multiple studies have shown that yoga enhances parasympathetic nervous system activity, potentially leading to increased ACh and its receptor sensitivity, which are associated with improved neuroplastic effects and neuropsychological functions such as learning, attention, and neuromuscular coordination in individuals with ASD [8,23]. Furthermore, a yogic diet that includes legumes and seeds increases choline levels, facilitating better engagement in social situations and improving cognitive function.

Role of Yoga Therapy in Prevention of ASD

Pregnancy can be impacted by various psychosocial and lifestyle factors that contribute to maternal psychological stress [57]. Yoga intervention reduces stress, cardiometabolic risks, and gestational hypertension, improves foetomaternal outcomes, and shows promise for enhancing newborn outcomes [58,59]. Several studies have demonstrated that yoga therapy significantly improves autonomic nervous system function, GABA activity, and allostatic load [55], as well as serum BDNF levels [60], while reducing serum cortisol [61]. These effects enhance neurotransmitter regulation, helping alleviate maternal psychological stress during pregnancy [59].

This review highlights the significant impact of yoga therapy, emerging as a multifaceted intervention capable of fostering positive behavioural outcomes through the systematic modulation of neurotransmitters, specifically focusing on GABA, glutamate, serotonin, and acetylcholine in children with ASD. Yoga therapy also enhances neurotransmitter regulation during pregnancy, offering a promising approach in reducing the risk of ASD.

Limitation(s)

The study identifies the following specific limitations: a lack of rigorous research (existing studies may have methodological weaknesses, such as small sample sizes, lack of control groups, or potential biases) and standardised research protocols (the lack of uniformity in research protocols makes it difficult to compare results across different studies and draw definitive conclusions). These limitations impact the strength and generalisability of the findings regarding the effect of yoga therapy on neurotransmitters in treating and preventing ASD.

CONCLUSION(S)

Yoga therapy modulates key neurotransmitters in the treatment of ASD, thereby enhancing emotional regulation and social skills. Additionally, it shows potential as a preventive measure for ASD by alleviating maternal psychological stress during pregnancy. While preliminary findings are promising, further research is required to fully validate its therapeutic benefits.

REFERENCES

[1] Cardon GJ. Neural correlates of sensory abnormalities across developmental disabilities. Int Rev Res Dev Disabil. 2018;55:83-143. Available from: https://doi.org/10.1016/bs.irrdd.2018.08.001.

[2] Quaak I, Brouns MR, Van de Bor M. The dynamics of autism spectrum disorders: How neurotoxic compounds and neurotransmitters interact. Int J Environ Res Public Health. 2013;10:3384-408. Available from: https://doi.org/10.3390/ijerph10083384.

[3] Kuo HY, Liu FC. Pathophysiological studies of monoaminergic neurotransmission systems in valproic acid-induced model of autism spectrum disorder. Biomedicines. 2022;10:560. Available from: https://doi.org/10.3390/biomedicines10030560.

[4] Nisar S, Bhat AA, Masoodi T, Hashem S, Akhtar S, Ali TA, et al. Genetics of glutamate and its receptors in autism spectrum disorder. Mol Psychiatry. 2022;27:2380-92. Available from: https://doi.org/10.1038/s41380-022-01506-w.

[5] Canitano R, Scandurra V. Psychopharmacology in autism: An update. Prog Neuropsychopharmacol Biol Psychiatry 2011;35:18-28. Available from: https://doi.org/10.1016/j.pnpbp.2010.10.015.

[6] CDC. Data and Statistics on Autism Spectrum Disorder | CDC. Cent Dis Control Prev 2020. Available from: https://www.cdc.gov/ncbddd/autism/data.html. (Accessed January 13, 2021).

[7] Kaur M, Bhat A. Creative yoga intervention improves motor and imitation skills of children with autism spectrum disorder. Phys Ther. 2019;99:1520-34. Available from: https://doi.org/10.1093/ptj/pzz115.

[8] Rosenblatt LE, Gorantla S, Torres JA, Yarmush RS, Rao S, Park ER, et al. Relaxation response-based yoga improves functioning in young children with autism: A pilot study. J Altern Complement Med N Y N. 2011;17:1029-35. Available from: https://doi.org/10.1089/acm.2010.0834.

[9] Shanker S, Pradhan B. Effect of yoga on the social responsiveness and problem behaviours of children with ASD in special schools: A randomized controlled trial. EXPLORE. 2023;19:594-99. Available from: https://doi.org/10.1016/j.explore.2022.12.004.

[10] Narasingharao K, Pradhan B, Navaneetham J. Efficacy of structured yoga intervention for sleep, gastrointestinal and behaviour problems of ASD children: An exploratory study. J Clin Diagn Res. 2017;11:VC01-VC06. Available from: https://doi.org/10.7860/JCDR/2017/25894.9502.

[11] Radhakrishna S. Application of integrated yoga therapy to increase imitation skills in children with autism spectrum disorder. Int J Yoga. 2010;3:26-30. Available from: https://doi.org/10.4103/0973-6131.66775.

[12] Passarello N, Tarantino V, Chirico A, Menghini D, Costanzo F, Sorrentino P, et al. Sensory processing disorders in children and adolescents: Taking stock of assessment and novel therapeutic tools. Brain Sci. 2022;12:1478. Available from: https://doi.org/10.3390/brainsci12111478.

[13] Liwinski T, Lang UE, Brühl AB, Schneider E. Exploring the therapeutic potential of gamma-aminobutyric acid in stress and depressive disorders through the gut-brain axis. Biomedicines. 2023;11:3128. Available from: https://doi.org/10.3390/biomedicines11123128.

[14] Jenkins TA, Nguyen JCD, Polglaze KE, Bertrand PP. Influence of tryptophan and serotonin on mood and cognition with a possible role of the gut-brain axis. Nutrients. 2016;8:56. Available from: https://doi.org/10.3390/nu8010056.

[15] Rashedi RN, Rowe SE, Thompson RA, Solari EJ, Schonert-Reichl KA. A yoga intervention for young children: Self-regulation and emotion regulation. J Child Fam Stud. 2021;30:2028-41. Available from: https://doi.org/10.1007/s10826-021-01992-6.

[16] Nourollahimoghadam E, Gorji S, Gorji A, Khaleghi Ghadiri M. Therapeutic role of yoga in neuropsychological disorders. World J Psychiatry. 2021;11:754-73. Available from: https://doi.org/10.5498/wjp.v11.i10.754.

[17] Kim S, Kim H, Yim YS, Ha S, Atarashi K, Tan TG, et al. Maternal gut bacteria promote neurodevelopmental abnormalities in mouse offspring. Nature. 2017;549:528-32. Available from: https://doi.org/10.1038/nature23910.

[18] Qing L, Qian X, Zhu H, Wang J, Sun J, Jin Z, et al. Maternal-infant probiotic transmission mitigates early-life stress-induced autism in mice. Gut Microbes. 2025;17:2456584. Available from: https://doi.org/10.1080/19490976.2025.2456584.

[19] Ghaleiha A, Ghyasvand M, Mohammadi MR, Farokhnia M, Yadegari N, Tabrizi M, et al. Galantamine efficacy and tolerability as an augmentative therapy in autistic children: A randomized, double-blind, placebo-controlled trial. J Psychopharmacol Oxf Engl. 2014;28:677-85. Available from: https://doi.org/10.1177/0269881113508830.

[20] Hardan AY, Handen BL. A retrospective open trial of adjunctive donepezil in children and adolescents with autistic disorder. J Child Adolesc Psychopharmacol. 2002;12:237-41. Available from: https://doi.org/10.1089/104454602760386923.

[21] Takechi K, Suemaru K, Kiyoi T, Tanaka A, Araki H. The α4β2 nicotinic acetylcholine receptor modulates autism-like behavioural and motor abnormalities in pentylenetetrazol-kindled mice. Eur J Pharmacol. 2016;775:57-66. Available from: https://doi.org/10.1016/j.ejphar.2016.02.021.

[22] Wu WL, Adams CE, Stevens KE, Chow KH, Freedman R, Patterson PH. The interaction between maternal immune activation and alpha 7 nicotinic acetylcholine receptor in regulating behaviours in the offspring. Brain Behav Immun. 2015;46:192-202. Available from: https://doi.org/10.1016/j.bbi.2015.02.005.

[23] Ju X, Liu H, Xu J, Hu B, Jin Y, Lu C. Effect of yoga intervention on problem behaviour and motor coordination in children with autism. Behav Sci. 2024;14:116. Available from: https://doi.org/10.3390/bs14020116.

[24] Semple RJ. Review: Yoga and mindfulness for youth with autism spectrum disorder: Review of the current evidence. Child Adolesc Ment Health. 2019;24:12-18. Available from: https://doi.org/10.1111/camh.12295.

[25] Simsek Sahin E, Can Gürkan Ö. The effect of prenatal yoga on pregnancy-related symptoms: A pilot quasi-experimental study. Complement Med Res. 2023;30:195-203. Available from: https://doi.org/10.1159/000528801.

[26] Kusaka M, Matsuzaki M, Shiraishi M, Haruna M. Immediate stress reduction effects of yoga during pregnancy: One group pre-post test. Women Birth J Aust Coll Midwives. 2016;29:e82-e88. Available from: https://doi.org/10.1016/j.wombi.2016.04.003.

[27] Rothman J. L1-79 and the role of catecholamines in autism. Autism Spectr Disord - Profile Heterog Neurobiol Interv, IntechOpen; 2020. Available from: https://doi.org/10.5772/intechopen.95052.

[28] Klempin F, Beis D, Mosienko V, Kempermann G, Bader M, Alenina N. Serotonin is required for exercise-induced adult hippocampal neurogenesis. J Neurosci Off J Soc Neurosci. 2013;33:8270-75. Available from: https://doi.org/10.1523/JNEUROSCI.5855-12.2013.

[29] Fatemi SH, Reutiman TJ, Folsom TD, Thuras PD. GABAA receptor downregulation in brains of subjects with autism. J Autism Dev Disord. 2009;39:223-30. Available from: https://doi.org/10.1007/s10803-008-0646-7.

[30] Oblak AL, Gibbs TT, Blatt GJ. Decreased GABAB receptors in the cingulate cortex and fusiform gyrus in autism. J Neurochem. 2010;114:1414-23. Available from: https://doi.org/10.1111/j.1471-4159.2010.06858.x.

[31] Litchke LG, Liu T, Castro S. Effects of multimodal mandala yoga on social and emotional skills for youth with autism spectrum disorder: An exploratory study. Int J Yoga. 2018;11:59-65. Available from: https://doi.org/10.4103/ijoy.IJOY_80_16.

[32] Shimmura C, Suzuki K, Iwata Y, Tsuchiya KJ, Ohno K, Matsuzaki H, et al. Enzymes in the glutamate-glutamine cycle in the anterior cingulate cortex in postmortem brain of subjects with autism. Mol Autism. 2013;4:6. Available from: https://doi.org/10.1186/2040-2392-4-6.

[33] Ozawa S, Kamiya H, Tsuzuki K. Glutamate receptors in the mammalian central nervous system. Prog Neurobiol. 1998;54:581-618. Available from: https://doi.org/10.1016/s0301-0082(97)00085-3.

[34] Angelidou A, Francis K, Vasiadi M, Alysandratos KD, Zhang B, Theoharides A, et al. Neurotensin is increased in serum of young children with autistic disorder. J Neuroinflammation. 2010;7:48. Available from: https://doi.org/10.1186/1742-2094-7-48.

[35] Amonkar N, Su WC, Bhat AN, Srinivasan SM. Effects of creative movement therapies on social communication, behavioural-affective, sensorimotor, cognitive, and functional participation skills of individuals with autism spectrum disorder: A systematic review. Front Psychiatry. 2021;12:722874. Available from: https://doi.org/10.3389/fpsyt.2021.722874.
[36] Roy A, Roy M, Deb S, Unwin G, Roy A. Are opioid antagonists effective in attenuating the core symptoms of autism spectrum conditions in children: A systematic review. J Intellect Disabil Res JIDR. 2015;59:293-306. Available from: https://doi.org/10.1111/jir.12122.
[37] Petsche A. The effect of yoga on attention in students diagnosed with ADHD. Dr Diss. 2016:2016:1141.
[38] Somayajululu JN. Siddha. Tirumular's views on yoga. 2017. Available from: http://yogasomayajulu.blogspot.com/2013/10/siddha-tirumulars-views-on-yoga.html. (Accessed July 17, 2017).
[39] Sage Thirumular Dhyana. Tirumandiram B. Natarajan, Sri Ramakrishna Math, Chennai: Tamil Religious Books; 2010.
[40] Artchoudane S, Ramanathan M, Bhavanani AB. Yoga therapy on cognitive function in neurodevelopmental disorders. Interdiscip. Approaches Altering Neurodev. Disord, IGI-Global. 2020, p. 143-61. Available from: https://doi.org/10.4018/978-1-7998-3069-6.ch009.
[41] Catale C, Gironda S, Lo Iacono L, Carola V. Microglial function in the effects of early-life stress on brain and behavioural development. J Clin Med. 2020;9:468. Available from: https://doi.org/10.3390/jcm9020468.
[42] Wolf SA, Boddeke HWGM, Kettenmann H. Microglia in physiology and disease. Annu Rev Physiol. 2017;79:619-43. Available from: https://doi.org/10.1146/annurev-physiol-022516-034406.
[43] Sahu SK. Siddhis and benefits achieved by practice of hatha yoga and raja yoga. Odisha Rev. 2017:36-40.
[44] Tolbaños Roche L, Miró Barrachina MT, Ibáñez Fernández I, Betancort M. YOGA and self-regulation in management of essential arterial hypertension and associated emotional symptomatology: A randomized controlled trial. Complement Ther Clin Pract. 2017;29:153-61. Available from: https://doi.org/10.1016/j.ctcp.2017.09.012.
[45] Beart P, Hinton T, Johnston G. Yoga and GABA: New insights from the science. Iris Publ. 2020;2:000541. Available from: https://doi.org/10.33552/WJYPR.2020.02.000541.
[46] Báez-Mendoza R, Schultz W. The role of the striatum in social behavior. Front Neurosci. 2013;7:233. Available from: https://doi.org/10.3389/fnins.2013.00233.
[47] Dichter GS, Damiano CA, Allen JA. Reward circuitry dysfunction in psychiatric and neurodevelopmental disorders and genetic syndromes: Animal models and clinical findings. J Neurodev Disord. 2012;4:19. Available from: https://doi.org/10.1186/1866-1955-4-19.
[48] Busch AM, Modica CA, Sheridan ER. The effect of yoga on anxiety, attention and social-emotional symptoms in preschool children: A pilot quasi-experimental study. Child Psychiatry Hum Dev. 2023. Available from: https://doi.org/10.1007/s10578-023-01588-9.
[49] Devi SK, Chansauria JP, Udupa KN. Mental depression and kundalini yoga. Anc Sci Life. 1986;6:112-18.
[50] Young SN. How to increase serotonin in the human brain without drugs. J Psychiatry Neurosci JPN. 2007;32:394-99.
[51] Nirwan M, Halder K, Saha M, Pathak A, Balakrishnan R, Ganju L. Improvement in resilience and stress-related blood markers following ten months yoga practice in Antarctica. J Complement Integr Med. 2021;18:201-07. Available from: https://doi.org/10.1515/jcim-2019-0240.
[52] Khalsa SBS, Butzer B. Yoga in school settings: A research review. Ann N Y Acad Sci. 2016;1373:45-55. Available from: https://doi.org/10.1111/nyas.13025.
[53] Mehta UM, Gangadhar BN. Yoga: Balancing the excitation-inhibition equilibrium in psychiatric disorders. Prog Brain Res. 2019;244:387-413. Available from: https://doi.org/10.1016/bs.pbr.2018.10.024.
[54] Streeter CC, Jensen JE, Perlmutter RM, Cabral HJ, Tian H, Terhune DB, et al. Yoga asana sessions increase brain GABA levels: A pilot study. J Altern Complement Med. 2007;13:419-26. Available from: https://doi.org/10.1089/acm.2007.6338.
[55] Streeter CC, Gerbarg PL, Saper RB, Ciraulo DA, Brown RP. Effects of yoga on the autonomic nervous system, gamma-aminobutyric-acid, and allostasis in epilepsy, depression, and post-traumatic stress disorder. Med Hypotheses. 2012;78:571-79. Available from: https://doi.org/10.1016/j.mehy.2012.01.021.
[56] Krishnakumar D, Hamblin MR, Lakshmanan S. Meditation and yoga can modulate brain mechanisms that affect behaviour and anxiety-a modern scientific perspective. Anc Sci. 2015;2:13-19. Available from: https://doi.org/10.14259/as.v2i1.171.
[57] Saur AM, Dos Santos MA. Risk factors associated with stress symptoms during pregnancy and postpartum: Integrative literature review. Women Health. 2021;61:651-67. Available from: https://doi.org/10.1080/03630242.2021.1954132.
[58] Abera M, Hanlon C, Daniel B, Tesfaye M, Workicho A, Girma T, et al. Effects of relaxation interventions during pregnancy on maternal mental health, and pregnancy and newborn outcomes: A systematic review and meta-analysis. PloS One. 2024;19:e0278432. Available from: https://doi.org/10.1371/journal.pone.0278432.
[59] Ng QX, Venkatanarayanan N, Loke W, Yeo WS, Lim DY, Chan HW, et al. A meta-analysis of the effectiveness of yoga-based interventions for maternal depression during pregnancy. Complement Ther Clin Pract. 2019;34:8-12. Available from: https://doi.org/10.1016/j.ctcp.2018.10.016.
[60] Naveen GH, Varambally S, Thirthalli J, Rao M, Christopher R, Gangadhar BN. Serum cortisol and BDNF in patients with major depression—effect of yoga. Int Rev Psychiatry. 2016;28:273-78. Available from: https://doi.org/10.1080/09540261.2016.1175419.
[61] Thirthalli J, Naveen G, Rao M, Varambally S, Christopher R, Gangadhar B. Cortisol and antidepressant effects of yoga. Indian J Psychiatry. 2013;55:405. Available from: https://doi.org/10.4103/0019-5545.116315.

PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Center for Yogic Sciences, School of Rehabilitation and Behavioral Sciences, Vinayaka Mission's Research Foundation (DU), Puducherry, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Soccalingam Artchoudane,
Assistant Professor, Center for Yogic Sciences, School of Rehabilitation and Behavioral Sciences, Vinayaka Mission's Research Foundation (DU), Vinayaka Missions Puducherry Campus, Kirumampakkam, Puducherry, India.
E-mail: achudaa@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Feb 06, 2025
- Manual Googling: May 16, 2025
- iThenticate Software: May 21, 2025 (11%)

ETYMOLOGY: Author Origin

EMENDATIONS: 5

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 01, 2025**
Date of Peer Review: **Apr 10, 2025**
Date of Acceptance: **May 23, 2025**
Date of Publishing: **Dec 01, 2025**