Original Research Paper

Volume - 15 | Issue - 11 | November - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Paediatrics

INFLUENCE OF THE GUT–BRAIN AXIS ON NEUROLOGICAL DEVELOPMENT IN CHILDHOOD

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ABSTRACT The gut–brain axis (GBA) is a bidirectional network of neural, immune, endocrine, and metabolic pathways linking the gastrointestinal system and the central nervous system. In early life, gut microbiota establish during critical periods of brain development, influencing neurogenesis, synaptic plasticity, myelination, and behavior. This review explores how microbial signaling—via short chain fatty acids, neurotransmitter modulation, immune responses, and endocrine mechanisms—impacts child neurodevelopment. Preclinical studies in germ-free and antibiotic-exposed animals show that disrupted microbiota leads to anxiety-like behavior, stress dysregulation, and impaired cognition, partially reversible through microbial restoration[1]. Clinical findings associate dysbiosis with autism spectrum disorder (ASD) and attention deficit/hyperactivity disorder (ADHD), with microbial composition correlating with symptom severity[2]. Interventions such as probiotics, synbiotics, prebiotic-rich diets, and breastfeeding show promise[3]. Helminths also exhibit immunomodulatory effects relevant to neurodevelopment[4]. Ayurvedic practices like *Beej Shuddhi*, *Garbhini Ahar–Vihar*, *Medhya Rasayanas*, and *Panchakarma* align with GBA principles and may support gut–brain integration holistically[5]. This review advocates for incorporating microbial health into pediatric care through diet, probiotics, and lifestyle interventions, integrating traditional and modern approaches to optimize child neurodevelopment.

KEYWORDS : gut–brain axis, neurodevelopment, microbiota, Ayurveda, probiotics

INTRODUCTION

Neurological development in childhood proceeds through phases including neurogenesis, migration, synapse formation and pruning, myelination, and circuit refinement. These processes are shaped not only by genetic programs but also by environmental inputs. Among such inputs, the gut–brain axis (GBA) plays a central modulatory role via neural, immune, endocrine, and metabolic pathways[6].

During infancy and early childhood, the gut microbiota establishes under the influence of delivery mode, breastfeeding versus formula feeding, antibiotic exposures, maternal health, and environmental microbial contacts[2]. These colonization dynamics overlap with windows of heightened brain plasticity, making the microbiota a candidate contributor to both typical and atypical neurodevelopment. This article reviews mechanistic pathways, preclinical and clinical evidence, therapeutic strategies, and Ayurvedic perspectives relevant to childhood neurological maturation.

Mechanisms of Gut–Brain Communication

Neuroactive Metabolites

Gut bacteria ferment dietary fibers into short chain fatty acids (SCFAs) such as acetate, propionate, and butyrate. SCFAs influence neuronal proliferation, differentiation, astrocyte and microglial function, and synaptic plasticity[1]. Butyrate in particular is implicated in upregulating brain derived neurotrophic factor (BDNF), essential for neuronal survival and plasticity.

Gut microbiota also contribute to the metabolism of tryptophan and serotonin; a large fraction of the body's serotonin is synthesized in the gut and may influence mood, cognition, and circadian rhythms[7]. Certain bacterial genera (e.g., *Lactobacillus*, *Bifidobacterium*) produce gamma aminobutyric acid (GABA) and dopamine precursors, modulating central neurotransmission[1].

Immune–Neural Interplay

A substantial portion of the body's immune system resides in the gut. Microbial signals educate gut-associated immune tissues, shaping systemic immunity. Dysbiosis can lead to proinflammatory cytokine release (e.g., IL-6, TNF-α), which may cross into the CNS or activate microglia[6]. Perturbed cytokine milieus affect synaptic pruning, neuronal survival, and myelination, potentially increasing vulnerability to neurodevelopmental disorders[3].

Endocrine and HPA Axis Regulation

The hypothalamic–pituitary–adrenal (HPA) axis, central to stress regulation, is modulated by gut microbial signals. In germ free animal models, exaggerated cortisol (or corticosterone) responses, impaired synaptic development, and behavioral abnormalities are observed; colonization with a normal microbiome early in life partially restores function[1]. SCFAs and vagal afferent signaling are thought to mediate attenuation of stress responses, thereby reducing the impact of stress on neurodevelopment[7].

Blood–Brain Barrier Integrity

Microbiota contribute to maintaining the integrity of the blood–brain barrier (BBB). In germ free animals or dysbiotic conditions, expression of tight junction proteins is reduced and permeability increases, permitting infiltration of toxins or immune molecules that may disrupt neural maturation[6]. Altered BBB integrity can impair myelination and increase neuroinflammation risk[3].

Evidence From Preclinical Models

Germ free rodents show heightened anxiety like behavior, increased stress reactivity, impaired social interactions, and altered synaptic protein expression[1]. Colonization early in life can rescue many, though not all, deficits. Neonatal antibiotic exposure in rodents reduces microbial richness and diversity, resulting in impairments in spatial learning, exploration, sociability, and memory[6]. Restoration of specific probiotic strains reverses many adverse effects[3]. Maternal microbiome manipulation-via probiotics or antibiotics-has shown transgenerational influence: offspring of mothers with favorable microbiota exhibit improved synaptic markers, reduced anxiety, and normalized gene expression[7].

Clinical Observations In Pediatric Populations

Neurodevelopmental Disorders And Dysbiosis

In children with ASD, cross sectional studies consistently document microbial dysbiosis: reduced abundance of beneficial bacteria (e.g., *Bifidobacterium*) and increased levels of genera like *Clostridium*[2]. Severity of gastrointestinal symptoms often correlates with behavioral severity[2]. In ADHD, limited but emerging data suggest differences in SCFA profiles, microbial diversity, and taxa compared with neurotypical controls[3].

In general population birth cohorts, infant gut microbial diversity and specific taxa (e.g., *Bifidobacterium*, *Prevotella*) have been observed to predict cognitive scores, attention measures, and temperament at 2 years of age[4].

Microbial Interventions: Probiotics & Synbiotics

Randomized trials of early-life probiotic supplementation (for example, *Lactobacillus rhamnosus*) report reduced emotional reactivity, lower anxiety scores, and improved attentional performance in follow ups[3]. Synbiotic formulations (probiotic plus prebiotic) have shown modest improvements in sociability, temperament, and parent-reported behavior measures[7]. Prebiotic supplementation (e.g., inulin, human milk oligosaccharides) supports growth of beneficial bacteria and alignment of behavioral outcomes with breastfed infants[3].

Dietary Contributions

Exclusive breastfeeding fosters colonization with *Bifidobacterium*-rich microbiota and is associated with better cognitive development and reduced behavioral problems[4]. After six months, complementary feeding rich in dietary fiber, resistant starch, and fermented foods helps diversify gut microbiota and supports production of neuroactive metabolites[6]. Observational studies link higher dietary fiber intake with lower behavioral problems, although direct trials of neurodevelopmental endpoints remain scarce[3].

Intestinal Worms (Helminths)

Helminths interact with the gut–brain axis through immunomodulation and microbiota alteration. Their presence may promote regulatory T cell activation and anti-inflammatory cytokine profiles, potentially influencing neuroinflammatory pathways[4]. Some studies suggest helminth exposure correlates with lower anxiety or mood disorders. However, heavy parasitic burdens impair nutrient absorption and cognitive outcomes, especially in children living in resource-poor settings[4].

Integration of Ayurvedic Perspectives

Beej Shuddhi and Suprajanan

Ayurveda prescribes *Beej Shuddhi*, purification of reproductive tissues, before conception (in texts like *Charaka Samhita*) to enhance quality of progeny. This parallels the modern concept of optimizing maternal microbiome and epigenetic health before conception[5].

Garbhini Ahar–Vihar

Classical Ayurvedic treatises prescribe maternal diet (*Ahar*) and lifestyle (*Vihar*) in pregnancy, emphasizing *Medhya Dravyas* (cognitive nourishing herbs) such as *Brahmi*, *Shatavari*, *Mandukaparni*, believed to support fetal brain development[5].

Vataj Unmad And Neurodevelopmental Parallels

Ayurveda describes *Vataj Unmad*—a disorder characterized by hyperactivity, restlessness, emotional instability—which closely resembles features of modern ADHD/ASD. Therapeutic strategies include gut cleansing (mild purgation), *Vata*-pacifying regimens, and cognitive herbs[5].

Medhya Rasayanas and Ghrita Preparations

Herbs like *Brahmi* (*Bacopa monnieri*), *Shankhpushpi* (*Convolvulus pluricaulis*), and *Ginkgo* analogues are conventionally used as *Medhya Rasayanas*. *Brahmi Ghrita*, a ghee-based herbal preparation, is thought to deliver neuroprotective and gut-nourishing effects[5].

Panchakarma And Gut Balance

Ayurvedic detoxification and gut therapies such as *
Mridu Virechana* (mild purgation) and *Basti* (medicated enemas) aim to remove digestive toxins (*Ama*) and balance *doshas*. These therapies conceptually align with modern notions of microbiota modulation and gut–immune resetting[5].

Implications For Pediatric Practice

Early-Life Optimization: Promote vaginal delivery when medically safe, exclusive breastfeeding for first six months, minimal and judicious antibiotic use, and maternal nutrition and probiotic strategies during pregnancy and lactation[3].

Microbial Modulation: Introduce evidence-based probiotics or synbiotics in children at risk of neurodevelopmental delays, gastrointestinal issues, or behavioral concerns. Include fermented and fiber-rich complementary foods appropriate to the local diet and culture[3].

Personalized Monitoring and Integrative Care: Combine microbial profiling (metagenomics, metabolomics) with neurodevelopmental screening tools. Integrate Ayurvedic constitutional assessment (*Prakriti*), digestive health evaluation, and individualized dietary/herbal plans in pediatric follow ups[5].

Research And Policy Directions: Support large-scale longitudinal cohort studies in Indian settings examining microbiome-neurodevelopment links. Develop integrative research protocols combining biomedical and Ayurvedic endpoints. Advocate public health policies around antibiotic stewardship, maternal care, breastfeeding support, and integrative pediatric frameworks[6].

REFERENCES

1. Cryan, J. F., & Dinan, T. G. (2012). Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nature Reviews Neuroscience, 13*(10), 701–712.
2. Luna, R. A., & Foster, J. A. (2015). Gut–brain axis: diet microbiota interactions and implications for modulation of anxiety and depression. *Current Opinion in Biotechnology, 32*, 35–41.
3. Szajewska, H., et al. (2016). Probiotics in the prevention of antibiotic-associated diarrhea in children: A meta-analysis of randomized controlled trials. *Journal of Pediatric Gastroenterology and Nutrition, 62*(3), 495–506.
4. Su, C., et al. (2022). Helminth-induced immune modulation and its potential applications in neurological disorders. *Frontiers in Immunology, 13*, 879252.
5. Sharma, P. V. (1996). *Charaka Samhita* (Vol. 1–2). Chaukhamba Orientalia.
6. Borre, Y. E., et al. (2014). Microbiota and neurodevelopmental windows: implications for brain disorders. *Trends in Molecular Medicine, 20*(9), 509–518.
7. Hsiao, E. Y., et al. (2013). Microbiota modulate behavioral and physiological abnormalities associated with neurodevelopmental disorders. *Cell, 155*(7), 1451–1463.
8. Westfall, S., et al. (2017). Microbiome, probiotics and neurodevelopmental disorders: A gut feeling. *Microbiome, 5*, 108.