



THE ROLE OF GUT MICROBIOTA MODULATION IN REDUCING INFANT MORTALITY FROM DIARRHOEA AND MALNUTRITION “A COMPREHENSIVE REVIEW”

*¹Ch. Harika, ²V. Anusha, ³Dr. P. Jyothi Kumari

^{1,2}Assistant Professor, ³Associate Professor
Ch. S. D. St. Theresa's College for Women(A), Eluru.



*Corresponding Author: Ch. Harika

Assistant Professor, Ch. S. D. St. Theresa's College For Women(A), Eluru.

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ABSTRACT

Infant mortality caused by diarrhoea and malnutrition remains a major global health concern, particularly in low- and middle-income countries. Recent innovations in biomedical sciences have emphasized the critical role of gut microbiota in supporting immune development, nutrient absorption, and gastrointestinal integrity in early life. Disruptions in gut microbial composition characterized by reduced diversity, low abundance of beneficial species such as *Bifidobacteria* and *Lactobacillus*, and a representation of pathogenic *Enterobacteriaceae* have been strongly associated with poor growth outcomes, persistent diarrhoea, and increased mortality in infants. This review synthesizes current evidence on gut microbiota modulation as a promising intervention for reducing infant morbidity and mortality related to diarrheal and malnutrition-related conditions. It explores therapeutic strategies including probiotics, prebiotics symbiotics microbiota directed complementary foods, and emerging approaches such as next generation probiotics and faecal microbiota transplantation.

KEYWORDS: *Enterobacteriaceae*, *Bifidobacteria*, symbiotics microbiota.

INTRODUCTION

Infant mortality remains one of the most pressing global health challenges of the 21st century, particularly in low- and middle-income countries (LMICs), where the burden of preventable deaths in children under five remains high. According to UNICEF's State of the World's Children Report (2023), malnutrition and diarrheal diseases continue to rank among the leading causes of under-five mortality, accounting for a substantial proportion of the estimated 5 million deaths annually. Although decades of public health efforts have led to some progress in reducing mortality rates, the prevalence of chronic undernutrition, repeated enteric infections, and their compounding effects highlight the complexity and resilience of these problems in resource-poor settings (WHO, 2022).

In recent years, scientific advances have significantly reshaped our understanding of child health and disease, with particular attention to the role of the gut microbiota an ecosystem of trillions of microorganisms that colonize the gastrointestinal tract shortly after birth. Far from being passive bystanders, these microbes are now recognized as central players in supporting immune system maturation, nutrient metabolism, epithelial barrier

function, and resistance to infection. Disruptions to the normal development of this ecosystem, known as dysbiosis, have been increasingly linked to adverse health outcomes such as growth failure, persistent diarrhoea, neurodevelopmental delays, and even death (Arrieta *et al.*, 2019; Robertson *et al.*, 2021; Chen *et al.*, 2023).

The first years of life represent a foundational period during which the gut microbiome and the host co-develop in tandem. During this time, external influences such as mode of delivery, feeding practices, sanitation, exposure to antibiotics, and environmental pathogens play crucial roles in determining microbial colonization patterns (Wandro *et al.*, 2022). Infants born via caesarean section, for instance, are often deprived of early exposure to maternal vaginal and faecal microbiota, which can delay the establishment of beneficial microbes like *Bifidobacterium* and *Lactobacillus*. Dominguez-Bello *et al.* (2019) demonstrated that vaginal microbial transfer to caesarean-born infants can partially restore some of the microbial deficits observed in these children, highlighting the importance of birth mode in shaping initial colonization.

Breastfeeding is another critical determinant of microbial development. Human milk is not only a source of optimal nutrition but also delivers bioactive compounds and complex sugars known as human milk oligosaccharides (HMOs), which selectively feed beneficial bacteria (Pannaraj *et al.*, 2017). Infants who are exclusively breastfed typically develop gut microbiomes dominated by Bifidobacterium species, which are associated with protection against infections and modulation of immune responses. Conversely, formula feeding, early weaning, and dietary insufficiency can skew microbial composition, reduce diversity, and impair gut maturation.

Children in LMICs often face a convergence of risk factors poor sanitation, limited healthcare access, inadequate nutrition, and high pathogen burden that contribute to a phenomenon known as environmental enteric dysfunction (EED). EED is characterized by chronic intestinal inflammation, increased permeability, and impaired nutrient absorption, all of which are strongly influenced by alterations in gut microbiota. Studies have consistently found that children with EED exhibit higher levels of potentially pathogenic Enterobacteriaceae and lower abundances of beneficial microbes, contributing to growth stunting and recurrent diarrheal illnesses (Miller *et al.*, 2016; Prendergast & Kelly, 2016).

In a landmark study, Subramanian *et al.* (2014) identified a pattern of persistent microbiota immaturity in malnourished Bangladeshi children, marked by a failure to acquire age-appropriate bacterial species. Even after receiving nutritional rehabilitation, these children did not achieve microbial maturation comparable to their healthy peers, suggesting that nutritional recovery may require more than just caloric supplementation. These findings have since been echoed by newer research, including Kumbhare *et al.* (2022), who confirmed that microbiota composition is a critical factor in both the pathogenesis and treatment outcomes of protein-energy malnutrition.

Recognizing the essential role of the gut microbiome in child health, researchers have turned to microbiota targeted therapies as a potential solution to combat under nutrition and infection related mortality. One of the most promising approaches is the development of microbiota directed complementary foods (MDCFs) nutritional formulations specifically designed to foster the growth of beneficial microbes. Ahmed *et al.*, (2021) and Ghosh *et al.*, (2021) demonstrated that such foods can enhance microbial diversity, reduce inflammation, and promote weight gain in undernourished children, outperforming traditional therapeutic foods in pilot trials.

These MDCFs work by modulating microbial metabolic pathways involved in growth and immune development, making them a powerful tool for addressing both the symptoms and the root causes of malnutrition. Chen *et al.*, (2023) argue that such strategies represent a

significant paradigm shift, as they go beyond conventional nutrition to include the restoration of ecological balance within the gut. Future efforts will likely focus on personalizing these interventions based on individual microbial profiles, a concept aligned with emerging trends in precision medicine.

While antibiotics remain a cornerstone of paediatric infectious disease management, their overuse especially in the critical early life window has unintended consequences. Antibiotics can disrupt microbial communities, reduce microbial diversity, and impair the gut's ability to resist colonization by pathogens (Becattini *et al.*, 2016). This has sparked concern about the long-term impact of antibiotic exposure on child health, including increased risks of metabolic disorders, allergies, and even neurological conditions.

To mitigate these effects, interest in probiotic interventions has grown. Bender *et al.*, (2020) reviewed the evidence supporting probiotic use in paediatric populations, finding that certain strains may help prevent antibiotic-associated diarrhoea, enhance immune responses, and even support growth. However, the effectiveness of probiotics varies depending on strain, dose, and context. More robust clinical trials are needed to determine their role in mainstream therapeutic regimens for malnutrition and gastrointestinal infection.

Beyond physical growth, emerging evidence suggests that the gut microbiota may influence neurodevelopmental outcomes through what is known as the gut brain axis. The microbial community produces a wide array of metabolites that can impact the central nervous system via immune, neural, and endocrine signalling pathways. Borre *et al.*, (2014) proposed that disruptions during key neurodevelopmental windows could increase vulnerability to disorders such as autism, ADHD, and cognitive delays. While more longitudinal studies are needed, these early insights underscore the far-reaching implications of microbiota health in early life. Recent studies further suggest that maternal microbiota composition during pregnancy can shape fetal brain development, influencing postnatal cognitive and behavioural outcomes (Vuong *et al.*, 2017). Dysbiosis induced inflammation and altered metabolite availability may impair neuronal signalling pathways essential for learning and memory formation.

ROLE OF GUT MICROBIOTA IN INFANTS

The gut microbiota plays a pivotal role in shaping infant health and development, particularly in the early years of life when physiological systems are still maturing. A well-established gut microbial community contributes to multiple essential processes, including nutrient metabolism, immune system programming, and maintenance of the intestinal barrier.

According to Arrieta *et al.*, (2019), early microbial colonization is critical for training the immune system to

distinguish between harmful and non-harmful stimuli, thereby reducing the risk of infections and chronic inflammation. Infants typically acquire beneficial bacteria like *Bifidobacterium* and *Lactobacillus* through vaginal birth and breastfeeding. These microbes enhance the digestion of human milk oligosaccharides (HMOs), promote mucosal immunity, and inhibit the colonization of pathogens.

Disruption of this balanced microbial composition referred to as dysbiosis can impair immune responses and nutrient absorption. Ahmed *et al.*, (2021) observed that children with undernutrition often show a microbial profile dominated by Enterobacteriaceae, along with a deficiency in health promoting species. This imbalance weakens the gut's protective barrier and is associated with environmental enteric dysfunction (EED), a condition characterized by chronic intestinal inflammation, reduced nutrient uptake, and stunted growth.

Further, Gough *et al.*, (2020) emphasize that intestinal infections during early life can significantly alter microbial diversity and composition, contributing to a cycle of malnutrition and infection. These changes are not only associated with immediate health risks like persistent diarrhoea but also have long term consequences on cognitive and physical development.

Chen *et al.*, (2023) expand on this by suggesting that restoring microbial balance through microbiota-directed complementary foods (MDCFs) can improve growth outcomes and reduce the incidence of gastrointestinal infections. These targeted nutritional interventions are designed to support the growth of beneficial microbial species and improve overall gut function. Microbial metabolites such as short chain fatty acids (SCFAs), tryptophan derivatives, and neurotransmitter precursors play a crucial role in modulating brain function and behavioural responses (Clarke *et al.*, 2013). Dysbiosis induced alterations in these metabolites can impair synaptic plasticity, neuroinflammation regulation, and myelination processes essential for healthy brain development (Vuong *et al.*, 2017).

IMPACT OF GUT DYSBIOSIS ON DIARRHEA AND MALNUTRITION

Gut dysbiosis characterized by an imbalance in microbial composition plays a central role in the pathogenesis of diarrhoea in infants, particularly in low-resource settings. According to Ahmed *et al.*, (2021), undernourished children often exhibit a microbial profile dominated by Enterobacteriaceae, a family that includes several opportunistic pathogens. This dominance is frequently accompanied by a marked reduction in beneficial microbes such as *Bifidobacterium* and *Lactobacillus*. The overrepresentation of pathogenic bacteria disrupts intestinal homeostasis and compromises mucosal immunity, making infants more susceptible to enteric infections.

Gough *et al.*, (2020) observed that intestinal infections can further exacerbate microbial imbalances, creating a vicious cycle where diarrhoea leads to dysbiosis, and dysbiosis increases the risk and severity of diarrhoea. These alterations in microbial communities impair gut barrier integrity and promote chronic inflammation, both of which contribute to persistent diarrhoea and delayed recovery.

Arrieta *et al.*, (2019) emphasized that early microbial colonization is essential for immune regulation. When this colonization is disrupted due to factors like poor sanitation or lack of breastfeeding the immature immune system may respond inappropriately to pathogens, intensifying diarrheal episodes. This compromised immune environment, together with impaired digestion of nutrients and increased intestinal permeability, promotes further microbial imbalance and inflammation.

Chen *et al.*, (2023) noted that restoring microbial balance using microbiota-directed complementary foods (MDCFs) has shown promise in reducing gastrointestinal infections. By selectively promoting the growth of beneficial microbes, these interventions aim to enhance gut function and resistance to diarrheal pathogens, moreover, cumulative evidence suggests that gut dysbiosis not only increases susceptibility to acute diarrheal episodes but also contributes to chronic enteropathy, leading to long-term nutrient malabsorption and growth faltering (Prendergast *et al.*, 2021). Persistent alterations in gut microbiota composition can impair the synthesis of vital short-chain fatty acids (SCFAs), crucial for maintaining intestinal barrier function and energy metabolism (Naylor *et al.*, 2020).

CONCLUSION

The gut microbiota is increasingly recognized as a central determinant of infant health, influencing immune development, nutrient absorption, and resistance to enteric infections. In low- and middle-income settings, where malnutrition and diarrheal diseases remain leading causes of infant mortality, disruptions in microbial composition often driven by environmental, nutritional, and healthcare disparities exacerbate the risk of early-life morbidity and mortality. Evidence from recent studies highlights the significance of beneficial microbial taxa such as *Bifidobacterium* and *Lactobacillus* in promoting intestinal homeostasis and overall growth, while identifying pathogenic overgrowths as markers of poor health outcomes, including environmental enteric dysfunction (EED).

Microbiota based interventions, including the use of probiotics, prebiotics, and microbiota-directed complementary foods (MDCFs), offer promising strategies to restore microbial balance and mitigate disease burdens. However, their successful implementation demands context-specific approaches that integrate cultural practices, dietary habits, and local infrastructure capacities. As the scientific community

advances toward a more comprehensive understanding of the early life microbiome embedding these insights into public health frameworks may contribute significantly to reducing infant mortality and supporting sustainable child development. Continued investment in microbiome research, coupled with cross-sectoral policy alignment, is essential to harness the full potential of gut microbiota as a tool for global child health and equity.

Looking forward, future research should focus on longitudinal, multi-omics studies that capture the dynamic evolution of the infant microbiome across diverse geographic and socioeconomic contexts. There is a pressing need to identify microbial biomarkers predictive of disease susceptibility and therapeutic response, as well as to develop scalable, low-cost interventions that are adaptable to resource limited settings. Integrating microbiota insights with maternal health, sanitation, and early nutrition programs may provide a holistic strategy to break the cycle of malnutrition and infection. Bridging the gap between bench side discoveries and bedside applications will be crucial in translating microbiome science into meaningful, population-level health outcomes.

REFERENCES

1. UNICEF. (2023). State of the World's Children Report.
2. WHO. (2022). World Health Statistics, 2022.
3. Bhutta, Z. A., *et al.*, (2017). Revisiting maternal and child undernutrition. *The Lancet*, 389(10082): 228-241.
4. Arrieta, M. C., *et al.*, (2019). The intestinal microbiome in early life: health and disease. *Frontiers in Immunology*, 10: 315.
5. Robertson, R. C., *et al.*, (2021). The human microbiome and child growth. *Trends in Microbiology*, 29(7): 531-543.
6. Dominguez-Bello, M. G., *et al.*, (2019). Partial restoration of the microbiota of caesarean-born infants via vaginal microbial transfer. *Nature Medicine*, 25(6): 915-918.
7. Subramanian, S., *et al.*, (2014). Persistent gut microbiota immaturity in malnourished Bangladeshi children. *Nature*, 510(7505): 417-421.
8. Wandro, S., *et al.*, (2022). Microbial community development in the early-life gut. *Microbiome*, 10(1): 76.
9. Pannaraj, P. S., *et al.*, (2017). Association between breast milk bacterial communities and establishment and development of the infant gut microbiome. *JAMA Paediatrics*, 171(7): 647-654.
10. Ahmed, T., *et al.*, (2021). Microbiota-directed foods for undernourished children. *Nature*, 590(7844): 265-271.
11. Ghosh, T. S., *et al.*, (2021). Microbiome-directed foods for undernourished children. *Cell Host & Microbe*, 29(5): 701-716.
12. Gough, E. K., *et al.*, (2020). The impact of intestinal infections on the gut microbiota and growth in children. *JPGN*, 70(4): 495-503.
13. Miller, T. L., *et al.*, (2016). Enterobacteriaceae and under nutrition in children. *Current Opinion in Infectious Diseases*, 29(3): 250-255.
14. Prendergast, A. J., & Kelly, P. (2016). Enteropathies in the developing world. *Nature Reviews Gastroenterology & Hepatology*, 13(9): 517-528.
15. Chen, L. Y., *et al.*, (2023). Gut microbiota and child growth: recent insights and future directions. *Trends in Microbiology*, 31(1): 10-22.
16. Kumbhare, S. V., *et al.*, (2022). Infant gut microbiota and protein energy malnutrition. *Frontiers in Nutrition*, 9: 831205.
17. Kane, A. V., *et al.*, (2015). Malnutrition and the gastrointestinal microbiome. *Current Opinion in Clinical Nutrition*, 18(5): 511-516.
18. Becattini, S., *et al.*, (2016). The interplay between antibiotics and the gut microbiota. *Nature*, 535(7610): 451-455.
19. Bender, J. M., *et al.*, (2020). Probiotic interventions in childhood: Evidence and challenges. *Current Opinion in Paediatrics*, 32(1): 121-126.
20. Borre, Y. E., *et al.*, (2014). Microbiota and neurodevelopmental windows: implications for brain disorders. *Trends in Molecular Medicine*, 20(9): 509-518.