The microbiome in early life: Setting the stage for optimal early life health in infants

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Researchers at the University of South Florida Microbiomes Institute are exploring exciting new areas in microbiome research; here, they discuss the essential role that the microbiome plays in early life health

When we think about what makes a baby healthy, we often think about a balanced diet, vaccines, and regular doctor visits. But we less often consider that a microscopic and powerful feature also plays a huge role in early life health: the microbiome.

What is the microbiome?

The microbiome exists mainly within the gastrointestinal tract, but also on the skin, in the mouth, and in many other areas of the body. These trillions of bacteria, viruses, and fungi play important roles in human health, including helping to digest food, making vitamins, protecting against harmful microbes, and training the immune system. At birth, a baby's microbiome is essentially a blank slate. How it begins to develop depends on many factors, including how the baby is delivered, where they live, their environmental exposures (including antibiotics), and how they are fed.

The first year: a time of rapid change

For infants, the first year of life is a critical period not only for their development but also the development of their microbiomes, and this process has long-lasting effects on their health. During and shortly after birth, babies acquire their first doses of microbes from their mother and surroundings. Vaginally delivered infants pick up bacteria colonizing their mother's birth canal and gut, which typically includes an abundance of healthy types of bacteria like Lactobacillus, Bacteroides, and Bifidobacterium. Babies born by cesarean section have a different starting point, often acquiring bacteria commonly found on the skin, like Staphylococcus, Cutibacterium, and opportunistic pathogens. However, as babies grow, their microbiome quickly diversifies and matures. By the age of three to four, their gut microbiome begins to resemble that of an adult's. But the foundation laid in the first year can set the stage for health outcomes later in life, influencing the development of allergies, asthma, obesity, and autoimmune conditions.

How breastfeeding supports healthy infants and healthy microbiomes

Early and exclusive breastfeeding for the first six months is considered the optimal form of nutrition for most infants. Beyond providing infants with nutrition, breastfeeding plays a powerful role in shaping the infant's microbiome and immune system. As one example,

the third most abundant component in breast milk is human milk oligosaccharides (HMOs), sugars babies are unable to digest, but their gut bacteria can. HMOs feed beneficial bacteria, especially Bifidobacterium, helping them grow and thrive. Research has shown that breastfed babies typically have gut microbiomes dominated by Bifidobacterium species, especially B. longum subsp. infantis, which are linked to improved digestion and protection against harmful bacteria. In comparison, formula-fed babies often have a more diverse gut microbiome with less helpful or even potentially harmful bacteria. Breast milk also contains hundreds to thousands of important antimicrobials (e.g., lactoferrin, Immunoglobulin A, bioactive lipids) and immune-boosting components, such as growth and anti-inflammatory factors, which work together with the microbiome to protect babies from infections and support healthy immune development and outcomes.

The preterm infant microbiome

Babies born premature or preterm, before 37 weeks of pregnancy, face unique challenges when it comes to their microbiomes. As preterm infants often spend time in neonatal intensive care units (NICUs) away from their parents, receive frequent antibiotics, and may not receive breast milk right away, their gut microbiomes follow a different developmental trajectory from those of full-term babies. As a result, the preterm infant gut microbiome tends to have a lower abundance of beneficial bacteria and higher abundances of potentially harmful bacteria. This imbalance, often referred to as a dysbiosis, puts them at an increased risk for serious infections and complications like necrotizing enterocolitis (NEC), a particularly dangerous disease of the gastrointestinal tract.

Doctors and researchers are working to improve the microbiome in preterm babies by using strategies such as providing more of the mother’s own breast milk and carefully evaluating the need for antibiotics. But there is still much to learn about the safest and most effective ways to support these vulnerable infants. Emerging research is also revealing that breast milk exposure and safely promoting growth and colonization of beneficial bacteria like Bifidobacterium in preterm infants may confer protection against many adverse health outcomes, including NEC.

Why the microbiome matters for long-term health

The early-life microbiome plays a critical role in training the immune system to differentiate beneficial versus harmful microbes and has been linked to a wide range of health outcomes.

A well-balanced microbiome helps prevent the immune system from overreacting to typically harmless things, like pollen or certain foods, which can lead to the development of allergies. Numerous studies indicate that breastfed babies have healthier microbiomes and are less likely to develop conditions such as respiratory infections, allergies, asthma, obesity, type 2 diabetes, inflammatory bowel diseases, as well as autoimmune disorders.

Knowledge gaps

Drs Pace, Ho, and other scientists at the University of South Florida Microbiomes Institute have made great progress in understanding the infant microbiome, and are working to address many unanswered questions:

- Which bacteria are the most important for long-term health?
- What are the critical components in breastmilk, and how much is needed to protect against infections?
- How exactly do alterations in the development of the microbiome cause disease?
- What is the most effective way to restore a healthy microbiome after antibiotics or illness?
- How can we safely and effectively use probiotics in preterm infants?
- What are the effects of modern lifestyles on the developing microbiome, like highly sanitized environments and changes in diet?
- How do interactions among the gut microbiome, nutrients, and the infant determine short-term and long-term outcomes?

The future of microbiome research

Scientists at the USF Microbiomes Institute are exploring exciting new frontiers in microbiome research. This includes work on next-generation probiotics made from bacteria of human origin, and how a mother's own microbiome during pregnancy and over the course of lactation influences her baby's microbiome and health. Personalized medicine approaches may one day allow doctors to tailor treatments and nutritional interventions based on an infant's unique microbiome.

As we learn more, one thing is clear: supporting the healthy development of the microbiome in early life, through the promotion and support of breastfeeding and careful medical care, can have profound impacts on both short-term and long-term health outcomes.

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