**Gut microbiomes of young children linked to cognitive development**

**Abstract**

 In recent years, the study of the human gut microbe’s effect on health has greatly increased. Specific interest has been given to the bacteria that colonize the guts of young children, especially in the first two years of life. Understanding the composition of bacteria in these early years may help scientists and doctors to monitor and adjust for various health needs. Recently, research has begun to look at how the microbiome of an infant affects the child’s neurodevelopment and cognitive ability. A study by several researchers published in the journal for *The Society of Biological Psychiatry* examines the links between microbiomes and cognitive development. The study looked at the link between the two at 12 months and 24 months after birth. It is the first study to show a correlation between infant gut health and brain development. It creates a starting point for researchers to examine the factors influencing bacterial profiles and how they affect biological processes. Currently, there are still many details to account for that were not considered by this study. Studies that expand on the findings of this one are necessary for establishing causation and potential benefits.

**Introduction**

 The term gut microbiome refers to the populations of microbes like bacteria, fungi, and viruses that inhabit the human gastrointestinal tract. While the exact composition varies greatly from person to person, certain increases and decreases have been linked to diseases like inflammatory bowel disease and bacterial vaginosis (2). The amount of variation in species from one individual to another is known as alpha diversity (α-diversity) (1).

 The gut microbiome of infants is thought to play a role in their neurodevelopment and therefore impact their cognitive abilities (1). This is especially true in the first year of life. The microbiome is being founded, and the brain is ever-changing (1). Certain factors are known to affect bacterial colonization. Whether a baby is delivered vaginally or via caesarean section, if they are breastfed or formula fed, if they spend time with other children in settings like daycare, and if they encounter illness or antibiotic treatment can all change the microbiome (1). This happens at a key time in brain development. Glial cells that support neurons are formed and migrate while axons are myelinated (1). The composition of tissues changes, and new cognitive functions are learned (1). Cognitive ability can be tested and quantified by an Early Learning Composite (ELC), which includes tests for gross and fine motor skills, visual reception, and expressive and receptive language skills (1).

**Recent Progress**

 In this study, infant microbiomes were categorized into three clusters. Cluster 1 (C1) was high in *Faecalibacterium*, Cluster 2 (C2) was high in *Bacteriodes*, and Cluster 3 (C3) was high in an unnamed genus from Ruminococcaceae family (1). While the exact composition of each infant varied greatly, the abundance of these particular groups decided the cluster in which they were grouped. Two of these clusters, 2 and 3, showed similarities to two of the three clusters of bacterial colonization that have been observed in adult microbiome studies (1).

 Several factors were linked to the clustering. Breastfeeding at the one-year mark, as well as vaginal delivery, was more common in C2 infants. (1) The researchers attributed these links to previous research showing that microbiomes tend to mature when breastfeeding stops and that c-sections often result in reduced levels of *Bacteriodes* (1). C2 had 91% white paternal ethnicity, while C3 had 71%, and C1 only had 57% (1). Having an older sibling and more paternal ethnic diversity were shown to increase α-diversity for the infant (1).

 At one year, no significant difference in ELC scores was found between the clusters. (1) They did, however, predict the cognitive ability of the children at 2 years old. The cognitive differences at this point were significant. C2 had the highest ELC scores, while C1 had the lowest scores (1). The same results were seen in specific abilities like language skills, with C2 being highest followed by C3 and then C1 (1).

 In 2019, more researchers set out to see if there was link between antibiotic use in the first to years of life and cognitive ability at 11 years old (3). This built on the result of previously mentioned study by focusing on one factor known to influence microbiome composition and following the children through adolescence (3). They found that intelligence quotients (IQs) and verbal comprehension were lower for those children who had antibiotic treatment before they were six months old (3). The later children were exposed to antibiotics, the higher they tested on all cognitive tests used by the researchers (3).

**Discussion**

This study shows a correlation between infant microbiomes and cognitive development. The researchers suggest a mechanism of influence involving the genetic profiles of the infants (1). For example, C2 infants had more genes related to vitamins and cofactors needed for development while genes that interfered with microbes were decreased (1). For the study, the microbial profiles at 1 year of age were predictive of a child’s cognitive abilities at 2 years of age (1). The study also challenges previous thoughts about α-diversity. Higher α-diversity was previously thought to be a sign of faster development due to the microbiome more closely resembling that of a mature adult (1). Health issues like type 1 diabetes and asthma have also been linked to lower α-diversity (1). However, the increased ELC at lower α-diversity shows that increased α-diversity is not necessarily indicative of good development (1). The researchers propose that delayed microbiome development into a more adult composition might allow more time for brain plasticity, leading to better neurodevelopment (1).

 This study continues the effort of the scientific community to understand the human microbiome. It has shown a link between early bacterial composition and future cognitive ability in a period of life known to be critical to development. However, it only begins to look at the factors that can affect the gut microbiome in infants. The variation between individuals is great, so it is not clear that these higher levels of certain bacteria are causing the differences in development. The microbiomes were also only assessed at the one-year mark, so nothing is known about the composition at the time of the cognitive ability tests that showed significant differences. It was the first to show a link between the two, though, and over 60 papers have been written citing this study.

 The scientific community continues to look for how the gut microbiome affects brain development in function. The relationship has been termed the ‘microbiota-gut-brain axis’ (4). Studies have shown the role it plays in neural development by looking at mice with no microbiome (4). Significant differences are seen in multiple areas of fundamental processes necessary for healthy brain function like myelination of axons, the formation of new neurons, and formation of supportive glial cells (4). Increasing α-diversity has been determined to be a sign of appropriate aging (4). All of these details were seen in the study discussed. The preliminary results of this first study have been built upon for the past two years. As research looks to find the causes of neurological disease and cognitive impairment, this study provides a starting point in the first two years of life.

**References**

1. Carlson, Alexander L., Xia, Kai, Azcarate-Peril, M. Andrea, Goldman, Barabra D., Ahn, Mihye, Styner, Martin A., Thompson, Amanda L., Geng, Xiujuan, Gilmore, John H., Knickmeyer, Rebecca C. “Infant Gut Microbiome Associated with Cognitive Development.” Society of Biological Psychiatry. 83 (2018): 148-159.
2. Yang, Joy. “The Human Microbiome Project: Extending the definition of what constitutes a human.” National Human Genome Research Institute. 16 July 2012.
3. Slykerman, R., Coomarasamy, C., Wickens, K., Thompson, J., Stanley, T., Barthow, C., Kang, J., Crane, J., Mitchell, E. “Exposure to antibiotics in the first 24 months of life and neurocognitive outcomes at 11 years of age.” Psychopharmacology, 236 (2019), 1573-1582.
4. Cryan, John F, O'Riordan, Kenneth J., Sandhu, Kiran, Peterson, Veronica, Dinan, Timothy G. “The gut microbiome in neurological disorders.” The Lancet. Neurology. (2019).