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Microbial Maturity Index Reveals Delayed Gut Microbiome Development and Disease-Associated Features in Pediatric Inflammatory Bowel Disease

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The gut microbiome rapidly changes after birth, with stage-specific dominance of microbial taxa and age-dependent shifts essential for immune maturation, health, and development. Delayed maturation is linked to pediatric inflammatory bowel disease(PIBD). In this study, we constructed a microbiome-based age model, defined as microbial maturity index(MMI), to quantify gut microbial maturation in children and examined its association with PIBD using metagenome data from children aged 1 month to the adolescence period. The model showed moderate prediction performance (R^2 = 0.6), and MMI values were lower than chronological age in adolescents, suggesting a slowdown of gut microbial maturation during this period. Network analysis revealed no global structural differences between high- and low-MMI groups, but local interaction changes were observed for specific taxa. The PIBD group exhibited increased abundance and network connectivity of potentially pathogenic taxa, with network features resembling those of the low-MMI group. These findings demonstrate that the MMI provides a quantitative measure of gut microbial maturation in children and offer a valuable tool for investigating microbial changes associated with PIBD, as well as identifying features of delayed maturation that may serve as therapeutic targets.