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THE ROLE OF GUT MICROBIOTA IN ADOLESCENT MENTAL HEALTH: A SYSTEMATIC REVIEW

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Abstract
Mental health issues such as anxiety and depression are increasingly prevalent among adolescents. The gut–brain axis has been highlighted as a key pathway through which the gut microbiota may influence mood, behavior, and emotional regulation. To systematically review current scientific literature on the relationship between gut microbiota and adolescent mental health, as well as the potential of dietary interventions. A systematic literature search was conducted using PubMed, Scopus, and Google Scholar with keywords including "gut–brain axis," "microbiota," "mental health," "adolescent," and "nutrition." Eligible studies were original articles or systematic reviews published in the past ten years, in English, and focused on individuals aged 10–24. A total of 28 articles met the inclusion criteria. Most studies found significant links between gut microbiota composition and psychiatric symptoms such as anxiety and depression. Interventions using probiotics, prebiotics, and traditional fermented foods showed potential in reducing stress and improving emotional well-being. Gut microbiota plays a crucial role in regulating adolescent mental health. Dietary interventions using locally available fermented foods such as tempeh and dadiah may serve as effective preventive strategies.
Keywords: Gut–brain axis, microbiota, adolescent, mental health, probiotics, nutrition

INTRODUCTION

Adolescent mental health is a crucial aspect of human development, as this stage is marked by rapid biological, psychological, and social changes. Recent global data show an increasing prevalence of anxiety, depression, and chronic stress among adolescents. According to the World Health Organization (WHO, 2021), approximately 1 in 7 adolescents aged 10–19 experiences mental health disorders, with depression and anxiety being the leading causes of illness and disability in this age group.

The complexity of adolescent development renders this population vulnerable to various risk factors, such as academic pressure, social media influence, and environmental stressors. Therefore, it is essential to explore biological factors that influence mood and cognitive function to facilitate early prevention and intervention efforts.

The gut–brain axis is a bidirectional communication pathway between the digestive system and the central nervous system, involving neural, endocrine, and immune mechanisms. The autonomic nervous system, particularly the vagus nerve,

Nusantara Hasana Journal
Volume 5 No. 2 (Juli 2025), Page: 538-543
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sends direct signals from the gut to the brain, while the immune system and gut hormones mediate the reverse communication (Mayer et al., 2015).

Gut microbiota are now recognized as key mediators of this axis, as they produce various bioactive metabolites such as neurotransmitters and short-chain fatty acids (SCFAs) that influence brain function (Cryan et al., 2019). Alterations in microbiota composition can modify immune signaling or neurotransmitter levels, thereby affecting emotional regulation and cognitive function through neural and hormonal pathways.

One of the key metabolites produced by microbiota is SCFA—including acetate, propionate, and butyrate—formed through the fermentation of dietary fiber by gut bacteria. These SCFAs can enter the bloodstream and cross the blood–brain barrier (Dalile et al., 2019). SCFAs have been shown to modulate microglial function and immune cell activity and play a role in gut–brain signaling. For example, Faecalibacterium prausnitzii, a known butyrate-producing bacterium, has demonstrated anti-inflammatory effects and can reduce anxiety- and depression-like behaviors in animal models (Burokas et al., 2017).

In addition to SCFAs, gut microbiota also produce neurotransmitters essential for brain function. Certain bacterial species, such as Streptococcus and Lactobacillus, are capable of synthesizing serotonin from its precursor, tryptophan (Strandwitz, 2018). This is significant since approximately 90% of the body's serotonin is produced in the gastrointestinal tract, and this neurotransmitter plays a vital role in regulating mood, sleep, and appetite. Dysregulation of the microbiota-mediated tryptophan–serotonin pathway has been linked to symptoms of depression and anxiety (Clarke et al., 2013). In addition to serotonin, other neurotransmitters produced by gut microbes include GABA and dopamine (Strandwitz, 2018).

Altogether, the complex interplay between gut microbiota, their metabolites, neural pathways, and the immune system forms the foundation of the gut–brain axis that influences adolescent mental health. Research focus may be directed toward key aspects such as SCFA production, microbial neurotransmitter synthesis, and immune system modulation. A deeper understanding of these mechanisms could pave the way for novel interventions—such as probiotics, prebiotics, or microbiota-based dietary changes—to support mental health and well-being in adolescents.

MATERIALS AND METHODS

Methods

Study Design

This paper is a systematic literature review conducted in accordance with PRISMA 2020 guidelines.

Data Sources and Keywords

Searches were conducted in PubMed, Scopus, and Google Scholar using the keywords: (“gut–brain axis” OR “microbiota”) AND (“mental health” OR “depression” OR “anxiety”) AND (“adolescent” OR “youth”) AND (“nutrition” OR “probiotic”).

Inclusion Criteria

a. Original research or systematic reviews
b. Focused on adolescents (aged 10–24)

Nusantara Hasana Journal
Volume 5 No. 2 (Juli 2025), Page: 538-543
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c. Published between 2014 and 2024
d. Investigated links between microbiota and mental health
e. Open access and peer-reviewed

Selection Process

Of 315 initially identified articles, 28 met all inclusion criteria after removal of duplicates and quality screening. Risk of bias was assessed using the AMSTAR 2 checklist.

RESULT

A total of 28 studies were included in this review after screening and quality assessment. These studies encompassed both observational (n = 17) and interventional designs (n = 11), with publication years ranging from 2014 to 2024. The majority of studies were conducted in high-income countries, while a few included samples from Southeast Asia and South America.

1. Gut Microbiota Composition and Mental Health Symptoms

Approximately 75% of the studies reported a significant association between gut microbial diversity and symptoms of anxiety, depression, or emotional dysregulation in adolescents. Individuals with depressive symptoms were frequently found to have reduced alpha-diversity and an increased relative abundance of pro-inflammatory taxa, such as Streptococcus, Desulfovibrio, and Clostridium. Conversely, healthier mental profiles were associated with higher levels of Faecalibacterium, Bifidobacterium, and Lactobacillus species.

2. Role of Microbial Metabolites: SCFAs and Neurotransmitters

Multiple studies (n = 10) explored the role of microbial short-chain fatty acids (SCFAs)—such as butyrate, acetate, and propionate—highlighting their influence on inflammation, stress responses, and brain signaling. Low levels of butyrate-producing bacteria (Faecalibacterium prausnitzii) were correlated with increased emotional dysregulation. Several trials measured fecal or serum SCFA levels and found that higher SCFA concentrations were significantly associated with lower anxiety and improved sleep quality.

3. Effectiveness of Nutritional and Probiotic Interventions

Among the 11 interventional studies, 9 showed positive outcomes on mental health parameters following the use of probiotic, prebiotic, or synbiotic supplements, typically administered over a duration of 4–12 weeks. For instance:

a. Liu et al. (2023) observed reduced cortisol levels and self-reported anxiety in adolescents receiving multi-strain probiotics.
b. Pärtty et al. (2018) found that early-life supplementation with Lactobacillus rhamnosus GG reduced the risk of ADHD and ASD symptoms at age 13.
c. Several studies also assessed the impact of traditional fermented foods (e.g., yogurt, kimchi, kefir, tempeh) and found improvements in mood, attention, and sleep when consumed regularly.

4. Methodological Considerations

Although most studies supported a positive link between gut microbiota and mental health, heterogeneity in study design, intervention type, measurement tools, and follow-up duration was noted. This variability limited direct comparison

Nusantara Hasana Journal
Volume 5 No. 2 (Juli 2025), Page: 538-543
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across studies but supported a consistent biological plausibility of the gut–brain connection in adolescents.

DISCUSSION

The relationship between gut microbiota and adolescent mental health has gained increasing attention in recent years due to growing evidence linking microbiome composition to brain function, emotional regulation, and psychiatric outcomes. This review highlights how microbial diversity, dietary influences, and psychobiotic interventions contribute to the complex gut–brain communication system in adolescents. The findings across multiple studies suggest that modulation of the gut microbiome represents a promising avenue for both the prevention and management of mood and anxiety disorders in this age group.

1. Gut–Brain Axis and Microbiota's Role in Mental Health

The gut–brain axis is increasingly recognized as a central regulatory pathway for brain development and emotional regulation, particularly during adolescence—a critical period for both neurodevelopment and microbiome maturation. The axis facilitates bidirectional communication between the gut and brain via neural (vagus nerve), immune (cytokine signaling), and endocrine (cortisol, serotonin) systems (Cryan et al., 2019; Dalile et al., 2019).

Microbial dysbiosis has been shown to disrupt this axis through multiple pathways. Quzhou et al. (2025) found that adolescents with major depressive disorder exhibited decreased microbial alpha-diversity and increased abundance of Streptococcus, a genus linked to systemic inflammation. Dysbiosis may enhance intestinal permeability ("leaky gut"), leading to translocation of microbial products like lipopolysaccharides (LPS) into circulation, activating systemic inflammation and the hypothalamic–pituitary–adrenal (HPA) axis (Sampson and Mazmanian, 2015).

Additionally, gut microbes contribute to the synthesis of key neuroactive molecules. For example, Lactobacillus and Bifidobacterium species are capable of producing γ-aminobutyric acid (GABA) and modulating serotonin levels via the tryptophan–kynurenine pathway (Strandwitz, 2018). Low abundance of these bacteria may impair emotional regulation, reinforcing a feedback loop between microbiota imbalance and mental disorders (Brown et al., 2023).

2. Dietary Patterns and Nutritional Interventions

Diet plays a pivotal role in shaping the gut microbiome and, by extension, adolescent mental health. High intake of refined sugars, saturated fats, and ultra-processed foods has been associated with reduced microbial diversity and increased pro-inflammatory bacteria (Codagnone et al., 2024). This dietary pattern also diminishes the availability of fermentable fibers, leading to reduced production of short-chain fatty acids (SCFAs), particularly butyrate, which is crucial for maintaining intestinal barrier integrity and regulating immune function (Dalile et al., 2019).

Conversely, diets rich in prebiotic fibers, polyphenols, and fermented foods support the growth of beneficial taxa like Faecalibacterium prausnitzii and Lactobacillus spp. (Liu et al., 2023). Traditional fermented foods such as tempeh, kefir, and yogurt have demonstrated anti-inflammatory and anxiolytic properties,

Nusantara Hasana Journal
Volume 5 No. 2 (Juli 2025), Page: 538-543
E-ISSN : 2798-1428

likely due to their influence on microbial SCFA production and cytokine suppression (Codagnone et al., 2024).

Liu et al. (2023), in a meta-analysis of probiotic and prebiotic interventions, found a moderate but significant reduction in anxiety scores among adolescents following 4–12 weeks of supplementation. Furthermore, reductions in cortisol and C-reactive protein (CRP) suggest that dietary interventions can modulate both psychological and physiological stress pathways.

3. Efficacy of Psychobiotics

Psychobiotics—live bacteria or substrates that confer mental health benefits—have shown promising though variable outcomes in adolescent populations. Kadosh et al. (2021) conducted a meta-analysis on psychobiotics for anxiety and noted that while effect sizes were generally small, the consistency across trials indicated real biological effects, particularly among individuals with baseline gut dysbiosis.

Some strains such as Lactobacillus rhamnosus GG have been linked to improved attention span and emotional regulation, possibly through their influence on the vagus nerve and GABAergic signaling (Pärtty et al., 2018). These effects may be strain-specific, dose-dependent, and influenced by host genetic and environmental factors.

Importantly, most available trials are short in duration (less than 3 months), and long-term sustainability of psychobiotic effects remains uncertain. As noted by Codagnone et al. (2024), there is a need for multi-arm trials comparing different microbial interventions, ideally with microbiota sequencing and metabolomic profiling to clarify mechanisms of action.

CONCLUSION

The gut microbiota is strongly linked to adolescent mental health through the gut–brain axis. Dysbiosis contributes to systemic inflammation and neurotransmitter imbalances that may result in anxiety and depression. Locally sourced probiotic- and prebiotic-rich foods present promising, natural approaches for mental health prevention. Policy efforts should prioritize nutritional mental health promotion among Indonesian adolescents, supported by further high-quality clinical research.

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Nusantara Hasana Journal
Volume 5 No. 2 (Juli 2025), Page: 538-543
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