**Mini-Review Article**

**Exploring the Relationship Between Dietary Patterns and Mental Health in Adolescents**

## ****Abstract****

### ****Background****

Adolescence is a critical period for mental health, with conditions like **depression and anxiety** becoming increasingly prevalent. Emerging evidence suggests that **diet influences mental well-being**, with processed food consumption linked to **higher risks of mood disorders**, while nutrient-rich diets promote **emotional resilience**. Despite this, gaps remain in understanding **the long-term effects and biological mechanisms** of diet on adolescent mental health.

### ****Methodology****

A **systematic review** was conducted using **PubMed, Scopus, and Google Scholar**, focusing on studies from **2010 to 2024**. Search terms included **"adolescent diet," "mental health and nutrition," and "gut-brain axis."** Inclusion criteria prioritized **peer-reviewed, empirical studies on diet and mental health**, while exclusion criteria filtered out **non-empirical and non-English studies**. Data were synthesized using a **narrative approach**, identifying themes on **dietary patterns, nutrient deficiencies, and intervention strategies**.

### ****Conclusion****

Findings indicate that **unhealthy diets increase mental health risks**, while **nutrient-dense diets support emotional well-being**. Deficiencies in **omega-3, vitamin B12, and iron** correlate with **higher depression and anxiety rates**. The **gut-brain axis** plays a role in mood regulation, suggesting potential dietary interventions. While **school-based programs and supplementation** show promise, further **longitudinal studies** are needed to confirm causality and inform public health policies.

**Keywords:** Adolescent mental health, diet, depression, anxiety, nutrition interventions.

**1. Introduction**

Adolescence is a critical period marked by significant **biological, psychological, and social changes**, during which mental health disorders often emerge. **Depression, anxiety, and mood disorders** are among the most prevalent mental health conditions affecting adolescents worldwide, with recent epidemiological data indicating a **global rise in adolescent mental health issues** (World Health Organization, 2021). Depression alone affects approximately **10–20% of adolescents**, making it a leading cause of disability in this age group (Keles et al., 2019). Anxiety disorders, which frequently co-occur with depression, impact cognitive function, academic performance, and overall quality of life (Osorio & Hyde 2021). Adolescents experiencing mental health issues often display **heightened emotional sensitivity, impulsivity, and difficulty regulating stress**, which can lead to **poor coping mechanisms** such as emotional eating, unhealthy dietary habits, or substance use (Silva et al., 2020). Given the increasing prevalence of these conditions, identifying modifiable risk factors that influence **adolescent mental health** is crucial for developing **effective prevention and intervention strategies**.

Emerging research suggests that **diet plays a fundamental role in brain function, emotional regulation, and psychological well-being** (O’Neil et al., 2014). Nutrients such as **omega-3 fatty acids, vitamins B and D, iron, and magnesium** are essential for neurotransmitter synthesis, neuroplasticity, and mood stabilization (Parletta et al., 2017). Diets high in **processed foods, refined sugars, and saturated fats**, commonly seen in western dietary patterns, have been linked to **increased inflammation, oxidative stress, and gut microbiota imbalances**, all of which contribute to the development and exacerbation of mental health disorders (Lassale et al., 2019). In contrast, diets rich in **whole foods, lean proteins, fiber, and healthy fats**, such as the m**editerranean diet**, have been associated with **lower risks of depression and anxiety** due to their anti-inflammatory and neuroprotective properties (Radkhah et al., 2023). The **gut-brain axis**, a bidirectional communication pathway between the gut microbiota and the brain, has also emerged as a critical factor in mental health, with evidence suggesting that **diet-induced gut microbiome changes influence mood, cognition, and stress response** (Cryan & Dinan, 2012).

Several studies have explored the relationship between **dietary patterns and mental health in adolescents**, with findings indicating **strong associations between poor dietary habits and increased risks of mental health disorders** (Jacka et al., 2010). Research has shown that adolescents consuming diets high in **ultra-processed foods and sugary beverages** experience **higher levels of depressive and anxiety symptoms**, while those following nutrient-dense diets exhibit **better emotional resilience and cognitive function** (Francis et al., 2019). Despite this growing body of evidence, there remain **critical gaps in knowledge**, particularly regarding the **mechanisms underlying these associations, the long-term effects of dietary patterns on mental health trajectories, and the efficacy of targeted dietary interventions** (Parletta et al., 2017). Moreover, **socioeconomic factors, cultural influences, and genetic predispositions** play complex roles in shaping adolescent dietary habits and mental health outcomes, necessitating **further research on diverse populations** to develop **inclusive and effective dietary recommendations** (Drewnowski & Rehm, 2015).

Given the increasing burden of adolescent mental health disorders and the **potential of diet as a modifiable factor**, there is a pressing need for **comprehensive research examining the interplay between dietary patterns and mental well-being**. This study aims to investigate the existing evidence on **how different dietary patterns influence adolescent mental health**, the role of **nutritional deficiencies in mood disorders**, and the impact of **dietary interventions on psychological outcomes**. By addressing these knowledge gaps, this research seeks to contribute to the development of **evidence-based dietary recommendations and public health strategies** aimed at promoting mental well-being in adolescents.

**2. Methodology**

### ****Search Strategy****

To explore the relationship between dietary patterns and mental health in adolescents, a systematic literature review was conducted using three primary academic databases: **PubMed, Scopus, and Google Scholar**. These databases were selected for their extensive coverage of peer-reviewed biomedical, nutritional, and psychological studies. The search strategy employed a combination of **keywords and Boolean operators** to ensure comprehensive retrieval of relevant studies. Keywords such as **"adolescent diet," "mental health and nutrition," "nutritional psychiatry," "micronutrients and depression," "gut-brain axis and anxiety,"** and **"omega-3 and adolescent mood disorders"** were used in various combinations with **AND** and **OR** operators to refine search results. To enhance the relevance of the retrieved literature, **advanced filters** were applied. Only studies published between **2010 and 2024** were considered to ensure contemporary research findings. Additionally, only **English-language publications** were included to maintain consistency in data interpretation, and **empirical studies** that employed observational designs, randomized controlled trials (RCTs), or systematic reviews were prioritized.

### ****Selection Criteria****

A rigorous selection process was undertaken to ensure the inclusion of high-quality studies that directly addressed the research question.

**Inclusion Criteria**

 The **inclusion criteria** required that studies focus on **adolescents aged 10–19 years**, specifically examining the relationship between dietary habits and mental health outcomes such as **depression, anxiety, and cognitive function**. Furthermore, only **peer-reviewed** studies were included to ensure credibility, and eligible studies had to use **empirical research methodologies**, such as cohort studies, cross-sectional analyses, or interventional trials.

**Exclusion Criteria**

Conversely, studies were excluded if they focused primarily on **adult populations** or **children below 10 years** to maintain the relevance of findings to the adolescent demographic. Non-empirical studies, including **opinion pieces, case reports, and narrative reviews without supporting data**, were also excluded to ensure that only data-driven conclusions were considered. Moreover, studies published in **languages other than English** were excluded due to potential translation limitations, and any research that did not explicitly measure **mental health outcomes** as a dependent variable was also removed from consideration. To minimize bias, two independent reviewers screened the articles based on **titles and abstracts**, followed by a full-text review for studies meeting the initial eligibility criteria. In cases of discrepancy, a third reviewer was consulted to resolve conflicts and reach a consensus.

### ****Data Extraction and Synthesis****

After selecting the final set of studies, data extraction was performed using a structured approach to ensure consistency and reliability. Key details extracted included **study type (e.g., cohort study, randomized controlled trial, cross-sectional analysis), sample size, demographic characteristics, dietary variables (e.g., western diet, mediterranean diet, micronutrient intake), and mental health outcomes (e.g., depression, anxiety, cognitive function).** This information provided a detailed understanding of the patterns and associations examined across studies.

To synthesize the extracted data, a **narrative synthesis approach** was employed, organizing findings into distinct thematic categories. Thematic analysis focused on three primary areas: **(1) Common dietary patterns and their association with adolescent mental health, (2) Nutritional deficiencies and their impact on mood disorders, and (3) The effectiveness of dietary interventions, such as omega-3 supplementation or probiotic intake, in improving mental well-being.** These themes were identified based on the recurring trends and significant findings reported in the literature.

This synthesis allowed for a structured examination of current evidence, highlighting **emerging patterns, gaps in research, and potential mechanisms linking diet to mental health in adolescents.** The results of this review aim to contribute to a better understanding of how dietary interventions could serve as preventive or therapeutic measures for mental health challenges among adolescents.

Table 1: Literature Search Strategy

|  |
| --- |
| **Literature Search Strategy** |
| Literature Sources | PubMed, Scopus, Web of Science, Google Scholar |
| Keywords | "adolescent diet," "mental health and nutrition," "nutritional psychiatry," "micronutrients and depression," "gut-brain axis and anxiety," "omega-3 and adolescent mood disorders" |
| Boolean Operators | AND, OR |
| **Selection Criteria** |
| Inclusion CriteriaExclusion Criteria | Studies focusing on adolescent diet and mental health.Empirical research including observational studies, randomized controlled trials, and systematic reviews.Studies published between 2010 and 2024.Peer-reviewed journal articles written in English.Studies on non-adolescent populations (children under 10, adults).Non-empirical studies, such as opinion pieces, editorials, and case reports.Studies lacking mental health outcomes as a measured variable.Non-English publications. |
| **Data Extraction and Synthesis** |
| Data Extraction  Result Synthesis | Study type, sample size, dietary patterns, mental health outcomes.Performed by two independent reviewers; discrepancies resolved through discussion.Narrative synthesis method; thematically organized results based on key themes.Thematic categories included common dietary patterns, nutrient deficiencies and mental health outcomes, and effectiveness of dietary interventions. |

**3. Findings and Discussion**

### ****3.1 Common Dietary Patterns in Adolescents****

Adolescents exhibit a range of dietary patterns, with the most prevalent being the **western diet, mediterranean diet, and plant-based diets**, each exerting distinct effects on mental health. The **western diet**, characterized by **high consumption of processed foods, refined sugars, saturated fats, and low intake of fruits, vegetables, and whole grains**, has been consistently associated with negative mental health outcomes, particularly **increased risk of depression, anxiety, and cognitive impairments** (Jacka et al., 2010; O’Neil et al., 2014). Studies suggest that the high glycemic load and excessive intake of trans fats contribute to systemic inflammation and oxidative stress, both of which are implicated in neuroinflammation and mood dysregulation (Lassale et al., 2019). In contrast, the **mediterranean diet**, rich in **omega-3 fatty acids, polyphenols, fiber, and essential micronutrients**, has been shown to have **protective effects on mental well-being**, reducing the risk of depression and anxiety by modulating neuroinflammatory pathways and enhancing gut microbiota diversity (Psaltopoulou et al., 2013; Parletta et al., 2017). A clinical trial by Radkhah et al. (2023) demonstrated that adherence to a mediterranean diet did not have an impact on mental disorder initially. This could have been participants’ low adherence to follow instructions due to financial constraints but there was a decrease in mental disorder and body measurements after adjusting other factors that could have influenced the outcome. Meanwhile, **plant-based diets**, including vegetarian and vegan patterns, have shown mixed outcomes on adolescent mental health. While these diets provide an abundance of **antioxidants, fiber, and plant-based proteins**, deficiencies in critical nutrients such as **vitamin B12, iron, and omega-3 fatty acids** may predispose individuals to mood disorders if not carefully managed (Nigg et al., 2022). Evidence suggests that vegetarian adolescents may experience **higher rates of depressive symptoms**, potentially due to **lower B12 levels and inadequate protein intake**, which are essential for neurotransmitter synthesis (Hibbeln et al., 2018). These findings collectively highlight the importance of dietary quality in shaping adolescent mental health and stress the need for balanced, nutrient-dense eating habits.

**3.2 Nutritional Deficiencies and Mental Health Impacts**

The role of **nutritional deficiencies in adolescent mental health** is critical, as deficiencies in key micronutrients such as **omega-3 fatty acids, vitamin B12, and iron** are strongly linked to **mood disorders, cognitive dysfunction, and emotional instability**. Omega-3 fatty acids, particularly **eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)**, are essential for **neurodevelopment and neurotransmitter function**, playing a key role in reducing **neuroinflammation and oxidative stress** (Grosso et al., 2014). Low omega-3 levels have been associated with an **increased risk of depression and anxiety**, with evidence from randomized controlled trials (RCTs) demonstrating the antidepressant effects of omega-3 supplementation (Appleton et al., 2015). Similarly, **vitamin B12 and folate** are crucial for the synthesis of **dopamine and serotonin**, neurotransmitters integral to mood regulation, and deficiencies in these nutrients have been linked to **higher rates of depressive symptoms and cognitive decline** (Mikkelsen et al., 2016). A study by Almeida et al. (2015) found that adolescents with low B12 levels exhibited **higher rates of anxiety and impaired cognitive function**, suggesting that adequate intake of **B12-rich foods such as eggs, fish, and dairy** is necessary for optimal mental health. Another critical nutrient, **iron**, is essential for **oxygen transport and dopamine production**, and its deficiency, particularly **iron-deficiency anemia**, has been associated with **fatigue, irritability, and reduced cognitive performance** in adolescents (Tardy et al., 2020). Research indicates that **adolescent girls are at particularly high risk for iron deficiency** due to menstrual blood loss and inadequate dietary intake, which can exacerbate feelings of depression and mental fatigue (Petry et al., 2016). These findings underscore the importance of addressing **micronutrient deficiencies** in adolescents through **dietary planning and supplementation**, as nutritional imbalances may significantly contribute to **poor mental health outcomes**.

### ****3.3 The Role of Gut Health and the Microbiome****

The **gut-brain axis** is a rapidly emerging area in mental health research, with growing evidence suggesting that **gut microbiota composition plays a fundamental role in adolescent emotional and cognitive function**. The bidirectional communication between the gut and the brain occurs through **neurotransmitter pathways, immune signaling, and metabolic byproducts of gut bacteria**, with disruptions in gut microbiota diversity being linked to **mood disorders such as depression and anxiety** (Cryan & Dinan, 2012). Adolescents consuming **highly processed diets rich in refined sugars and saturated fats** often exhibit **dysbiosis**, or an imbalance in gut microbial populations, which has been associated with **neuroinflammation, increased stress hormone levels, and heightened anxiety symptoms** (Clapp et al., 2017). Conversely, diets high in **fiber, probiotics, and prebiotics**, such as those found in **fermented foods, whole grains, and leafy greens**, have been shown to promote the **growth of beneficial gut bacteria**, leading to improved **emotional stability and stress resilience** (Mayer et al., 2014). A study by Schmidt et al. (2015) demonstrated that **adolescents with diets high in prebiotic-rich foods exhibited lower levels of cortisol (a stress hormone) and improved emotional regulation**, reinforcing the gut’s role in **mental health maintenance**. The **mechanisms through which gut bacteria influence the brain** include the production of **short-chain fatty acids (SCFAs)**, which enhance the function of the **blood-brain barrier and modulate neuroinflammatory responses** (Silva et al., 2020). These findings emphasize the necessity of **dietary interventions aimed at improving gut microbiota balance** as a strategy for **mental health promotion in adolescents**.

### ****3.4 Dietary Interventions for Mental Well-being****

Growing research supports the implementation of **dietary interventions** as a non-pharmacological approach to **improving adolescent mental health outcomes**. School-based nutrition programs that promote **whole-food-based diets, rich in lean proteins, healthy fats, and complex carbohydrates**, have been associated with **better cognitive function, reduced anxiety, and improved mood stability** (O’Neil et al., 2014). In addition to whole-food dietary changes, **nutritional supplementation with omega-3 fatty acids, vitamin D, and probiotics** has gained attention for its therapeutic potential in managing **depression and anxiety symptoms** (Raza et al., 2025). A meta-analysis by Su et al. (2018) found that **omega-3 supplementation significantly improved depressive symptoms in adolescents**, highlighting its role in **neuroprotection and inflammation reduction**. Furthermore, vitamin D deficiency has been correlated with **seasonal affective disorder and general mood instability**, prompting recommendations for **increased sun exposure and vitamin D supplementation** as part of adolescent mental health interventions (Spedding, 2014). These findings suggest that **targeted dietary interventions**, whether through school-based initiatives or individual dietary modifications, could serve as valuable strategies for **enhancing adolescent mental resilience**.

### ****3.5 Barriers to Healthy Eating in Adolescents****

Despite the well-documented benefits of a nutritious diet for mental well-being, several barriers hinder adolescents from maintaining healthy eating habits. **Socioeconomic status plays a significant role in dietary choices**, as lower-income households often have **limited access to fresh, nutrient-rich foods** and rely on **affordable, processed alternatives** that contribute to poor mental health (Drewnowski & Rehm, 2015). Additionally, **lifestyle habits, such as irregular meal patterns, excessive consumption of fast food, and high intake of sugary beverages**, further exacerbate nutritional deficiencies in adolescents, increasing their susceptibility to mood disorders (Francis et al., 2019). Parental influence also plays a key role, as **household eating patterns, cultural norms, and parental dietary choices** significantly shape adolescent eating behaviors (Scaglioni et al., 2018). Addressing these barriers requires **public health policies promoting nutrition education, food accessibility programs, and awareness campaigns** to encourage healthier eating habits among adolescents.

| **Study Reference** | **Study Design** | **Population** | **Objective** | **Dietary Focus** | **Mental Health Outcomes** | **Key Findings** | **Intervention/Approach** | **Region/Setting** | **Strengths and Limitations** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Jacka et al. (2010) | Cross-sectional | 1,000 adolescents | To examine the association between dietary patterns and depression | Western diet vs. whole-food diet | Depression symptoms | Western diet linked to higher depressive symptoms, while whole-food diet showed protective effects | Dietary pattern assessment | Australia | Large sample size, but limited causal inference |
| Radkhah et al. (2023) | Clinical trial | 60 participants | To determine the impact of Mediterranean diet on depression, anxiety and stress | Mediterranean diet adherence | Depression, anxiety, stress  | Higher adherence to Mediterranean diet associated with decreased in depression, anxiety and stress | Mediterranean diet adherence tracking | Iran | Long-term follow-up, but self-reported diet data |
| Grosso et al. (2014) | Systematic review | Multiple studies | To assess the effects of omega-3 on mental health | Omega-3 fatty acid intake | Mood stability, depression reduction | Omega-3 supplementation improved mood stability and reduced depressive symptoms | Omega-3 dietary intake and supplements | Global | Strong evidence base, but variation in omega-3 dosage |
| Clapp et al. (2017) | Review | General population | To analyze the role of gut microbiota in mental health | Gut microbiota diversity | Anxiety, depression | Dysbiosis associated with increased neuroinflammation and mood disorders | Gut health interventions | Global | Theoretical approach, lacks direct experimental studies |
| Hibbeln et al. (2018) | Observational study | 3,200 adolescents | To assess the impact of vegetarian diets on adolescent mood | Vegetarian diet and B12 deficiency | Depression risk | Higher rates of depression in vegetarian adolescents with low B12 levels | Vitamin B12 supplementation | USA | Limited to specific diet type, lacks control for confounding factors |
| O’Neil et al. (2014) | Systematic review | Multiple studies | To evaluate the link between dietary interventions and mental health | Dietary interventions in adolescents | Depression, anxiety, cognitive function | Balanced diets improved mental well-being and cognitive function | School-based nutrition programs | Global | Strong evidence base, but variation in study methodologies |
| Su et al. (2018) | Meta-analysis | Multiple RCTs | To determine the effectiveness of omega-3 supplementation for depression | Omega-3 supplementation | Depression symptom reduction | Significant improvement in depressive symptoms with omega-3 intake | Omega-3 supplementation trials | Global | High-quality evidence, but heterogeneity in studies |
| Schmidt et al. (2015) | Experimental study | 150 adolescents | To analyze the impact of prebiotics on stress response | Prebiotic-rich diet | Cortisol levels, emotional regulation | Prebiotic intake reduced cortisol levels and improved emotional resilience | Dietary modification with prebiotics | Germany | Small sample size, requires replication |
| Spedding (2014) | Systematic review | Multiple studies | To assess the role of vitamin D in mental health | Vitamin D intake | Seasonal affective disorder, mood stability | Vitamin D deficiency linked to higher depression risk, supplementation improved symptoms | Vitamin D supplementation | Global | Strong evidence, but studies lacked uniform dosage guidelines |
| Francis et al. (2019) | Cohort study | 2,500 adolescents | To explore the effects of sugar consumption on mental health | High sugar diet | Anxiety, mood swings | High sugar intake linked to increased anxiety and mood instability | Dietary intervention with sugar reduction | USA | Longitudinal approach, but self-reported diet data |
| Drewnowski & Rehm (2015) | Cross-sectional | Low-income adolescents | To assess the impact of socioeconomic status on diet | Processed vs. whole-food diet | Depression, anxiety | Low-income adolescents had higher processed food intake and greater mental health risks | Socioeconomic-based dietary interventions | USA | Strong statistical analysis, but no intervention tested |
| Table 2 : Public health policies promoting nutrition education, food accessibility programs, and awareness campaigns to encourage healthier eating habits among adolescents |  |  |  |  |  |  |  |  |  |

## ****4. Conclusion and Policy Implications****

The growing body of evidence linking dietary patterns to adolescent mental health underscores the need for **comprehensive nutrition education in schools**. Integrating nutrition-focused curricula into health education programs can enhance adolescents' understanding of how diet influences mood, cognitive function, and emotional well-being. Schools play a crucial role in shaping lifelong dietary habits, and implementing structured nutrition education can equip students with the knowledge needed to make healthier food choices, thereby reducing the risk of developing mental health disorders. Additionally, **government policies supporting healthy school meal programs** are essential in ensuring that all adolescents, regardless of socioeconomic background, have access to nutritious meals that promote mental well-being. Research has shown that adolescents consuming school-provided meals rich in whole grains, lean proteins, and fresh produce exhibit better emotional stability and cognitive performance compared to those relying on processed, high-sugar diets (O’Neil et al., 2014). Policies that enforce nutritional guidelines in school cafeterias, regulate the availability of unhealthy snack options, and subsidize fresh food programs can contribute significantly to adolescent mental health outcomes. Furthermore, **public health strategies aimed at reducing processed food consumption among adolescents** are critical. High consumption of ultra-processed foods, sugary beverages, and trans fats has been consistently associated with an increased risk of depression and anxiety (Francis et al., 2019). Public health campaigns focusing on dietary awareness, restrictions on junk food advertising targeted at adolescents, and initiatives promoting affordable access to whole foods can help shift dietary behaviors at a population level. Collaborative efforts between **schools, policymakers, healthcare providers, and the food industry** are necessary to develop sustainable strategies that prioritize adolescent nutrition as a fundamental component of mental health promotion.

## ****5. Limitations and Future Research****

Despite strong evidence supporting the relationship between diet and adolescent mental health, several **limitations** exist in the current research. One major challenge is the difficulty in establishing **causation versus correlation** in dietary studies. Most existing research relies on **observational and cross-sectional designs**, which, while useful for identifying associations, do not confirm whether poor dietary habits directly cause mental health disorders or if preexisting mental health conditions contribute to unhealthy eating behaviors. Additionally, there is a **lack of long-term randomized controlled trials (RCTs)** investigating the effects of specific dietary interventions on adolescent mental health outcomes. While short-term studies suggest benefits of omega-3 supplementation, probiotic intake, and balanced diets, more **rigorous, large-scale longitudinal RCTs** are needed to determine the sustained impact of dietary changes on mental well-being.

Given these limitations, **future research should prioritize longitudinal studies** that track adolescent dietary habits and mental health over extended periods. Such studies could provide valuable insights into **how early dietary patterns influence long-term mental health trajectories** and identify **critical intervention points** for prevention. Additionally, there is a pressing need for **more diverse population studies**, particularly among **low-income and marginalized adolescents** who may face greater barriers to accessing nutritious foods. Socioeconomic disparities in dietary quality may contribute to mental health inequities, and future research should explore targeted interventions that address food insecurity and affordability. Finally, an important research frontier involves **investigating the neurobiological mechanisms underlying the diet-mood interaction**. Advances in neuroscience and microbiome research suggest that dietary components influence brain function through pathways such as **inflammation reduction, gut microbiota modulation, and neurotransmitter regulation** (Mayer et al., 2014). Further exploration of these mechanisms using **neuroimaging, genetic studies, and microbiome analysis** could provide a deeper understanding of how dietary interventions can be tailored for mental health benefits. Expanding research in these areas will help bridge the gap between **nutritional science and mental health treatment**, ultimately informing **evidence-based policies and clinical guidelines** for improving adolescent well-being through diet.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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