QUALITY IN SPORT

eISSN 2450-3118 · Open Access · Peer-reviewed

apcz.umk.pl/QS Nicolaus Copernicus University in Toruń

Cite as: BIAŁAS, Julia, KODURA, Alicja, MORDARSKA, Milena, PALUCHOWSKA, Joanna, PIWOWARCZYK, Alicja, ŁOZOWSKI, Jan, PIĄTEK, Przemysław, MERC, Artur and SZYMAŃSKI, Łukasz. Oral butyrate supplementation as a supportive therapy in the treatment of anorexia nervosa. Quality in Sport. 2026;58:72450. https://doi.org/10.12775/QS.2026.58.72450

ARTICLE TIMELINE

Received: 23.05.2026. Accepted: 20.06.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines: Medical Sciences; Health Sciences.

Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Nauki medyczne; Nauki o zdrowiu.

Oral butyrate supplementation as a supportive therapy in the treatment of anorexia nervosa

Julia Białas, ORCID https://orcid.org/0009-0008-5128-1611

E-mail julia.bialas@10g.pl

District Hospital in Limanowa Name of the Divine Mercy, Limanowa, Poland

Alicja Kodura, ORCID https://orcid.org/0009-0004-8410-1673

E-mail alicja@kodura.pl

Specialist Hospital Stefan Żeromski in Kraków, Osiedle Na Skarpie 66, 31-913 Kraków, Poland

Milena Mordarska, ORCID https://orcid.org/0009-0002-3318-8006

E-mail milenamordarska06@gmail.com

The University Hospital in Krakow, ul. Macieja Jakubowskiego 2, 30-688 Kraków, Poland

Przemysław Piątek, ORCID https://orcid.org/0009-0000-8121-7647

E-mail przemek.piatek@onet.pl

Father Rafał Hospital SPZOZ in Proszowice, Kopernika 13, 32-100 Proszowice, Poland

Joanna Paluchowska, ORCID https://orcid.org/0009-0002-7762-7410

E-mail joanna.paluchowska@student.uj.edu.pl

Ludwik Rydygier Specialist Hospital in Kraków, Osiedle Złotej Jesieni 1, 31-820 Kraków, Poland

Jan Łozowski, ORCID https://orcid.org/0009-0006-1355-0740

E-mail janlozowski02@gmail.com

Gabriel Narutowicz Municipal Hospital in Kraków, ul. Prądnicka 35-37, 31-202 Kraków, Poland

Łukasz Szymański, ORCID https://orcid.org/0009-0001-7172-9953

E-mail szymanskilukasz@onet.pl

Frydrychowice Health Center, ul. Floriańska 7, 34-108 Frydrychowice, Poland

Artur Merc, ORCID https://orcid.org/0009-0002-1651-018X

E-mail artur.merc@gmail.com

Independent Public Health Care Facility in Myślenice; ul. Szpitalna 2 32-400 Myślenice, Poland

Alicja Piwowarczyk, ORCID https://orcid.org/0009-0005-8850-3925

E-mail alicja.m.piwowarczyk@gmail.com

Independent Public Health Care Facility in Myślenice; ul. Szpitalna 2 32-400 Myślenice, Poland

Corresponding Author

Julia Białas, E-mail julia.bialas@10g.pl

Abstract

Background. Anorexia nervosa (AN) is an eating disorder manifested by extremely low body weight and a disturbed perception of the patient's own body. Genetic predisposition and psychological factors are considered the most important causes. However, it has been suggested that altered intestinal microbiota composition and microbial metabolite profiles may contribute to the pathogenesis or persistence of AN.

Aim. The aim of this review is to present current knowledge on the role of short-chain fatty acids (SCFAs) and the potential of oral butyrate supplementation in the treatment of patients with AN.

Material and methods. We conducted a narrative review by searching the Scopus, PubMed, and Web of Science databases up to April 2026 for studies addressing AN, the microbiota, and SCFAs.

Results. The reviewed studies indicate that AN is associated with gut microbiota dysbiosis, altered microbial metabolite profiles, and reduced concentrations of SCFAs, particularly butyrate. SCFAs play an important role in maintaining intestinal homeostasis, regulating appetite, and supporting gut–brain axis communication. Butyrate contributes to intestinal barrier integrity and promotes anti-inflammatory pathways. Its reduced availability has been associated with impaired intestinal permeability, low-grade systemic inflammation, neurotransmitter imbalance, increased severity of psychiatric symptoms, and disturbances in eating behavior.

Conclusions. Current evidence suggests that AN is associated with gut microbiota dysbiosis, reduced levels of SCFAs, and low-grade inflammation, all of which may contribute to disease pathophysiology and psychiatric symptom severity. Due to the recognized involvement of SCFAs in intestinal homeostasis and gut–brain axis signaling, enteral butyrate administration may represent a promising adjunctive therapy in AN. However, because only a limited number of studies have been initiated and no trial results are currently available, further research is needed.

Key words: anorexia nervosa, intestinal microbiota, gut-brain axis, dysbiosis, short-chain fatty acids, butyrate, postbiotic

1. Introduction

Anorexia nervosa (AN) is a psychiatric disease classified as an eating disorder characterized by severe weight loss, a strict, extremely low-calorie diet, fear of gaining weight, disturbed perception of the body, and high psychiatric comorbidity (Korten et al., 2025, Prochazkova et al., 2025). This disorder is a serious clinical concern due to its highest mortality rate among all mental illnesses. It is a challenge for doctors of different specialties, including psychiatry, gastroenterology, and intensive care medicine. Psychotherapy is important to reach an understanding with the patient and begin effective cooperation in recovery, but AN is increasingly no longer considered a purely psychiatric disease. The exact mechanism of AN development remains unclear, but its complex etiology probably also includes genetic, environmental, and, as it has been recently investigated, metabolic factors (Ghenciulescu et al., 2021, Korten et al., 2025).

Recently, interest in microbiota has increased greatly, and many studies have emerged confirming its impact on various aspects of the body's functioning, e.g., digestion, appetite, satiety, and also mood and behavior. That is why attempts are being made to support the treatment of mental illnesses from the gut by influencing the composition of the microbiota. Studies have demonstrated significant differences in the composition of gut microbiota and microbial metabolites in people with AN compared to healthy individuals (Ghenciulescu et al., 2021, Prochazkova et al., 2019).

In this review, we will focus on the validity of oral butyrate supplementation in the treatment of anorexia nervosa (AN).

2. Research materials and methods

We searched literature up to April 2026 from databases PubMed, Scopus, Web of Science and Google Scholar using combinations of the keywords, such as “anorexia nervosa” and “microbiota” or “short-chain fatty acid” or "SCFA” or “butyric acid” or “butyrate” or “postbiotic”. We preferred human studies in our analysis, but we also included animal studies if they delivered valuable information. Exclusion criteria included non-English publications.

3.1. Anorexia nervosa and microbiota connection

The gut microbiota refers to all the microorganisms that inhabit the human digestive tract. It consists of numerous species of bacteria, protozoa, fungi, archaea, and viruses, which together create a rich ecosystem and exist in symbiosis with the human body, influencing many metabolic and immunological processes. (Garcia et al., 2023, van de Wouw et al., 2017). The vast majority of studies on the connection between anorexia and microbiota have been published in the last 10 years. These studies indicate an association of anorexia nervosa and abnormalities in the microbiome composition, and that is why AN is increasingly defined as a metabo-psychiatric disease (Garcia et al., 2023).

The intestinal microbiota is connected to the brain through the microbiota-gut-brain axis. This term refers to communication and interaction between those organs, and microbiota is considered to play the main role in this context, influencing the CNS through neuroimmune and neuroendocrine mechanisms. This occurs via numerous biochemical substances produced by microorganisms, such as short-chain fatty acids (SCFAs), neurotransmitters, hormones, bile acids, tryptophan metabolites, and immune system intermediates (Garcia et al., 2023, Prochazkova et al., 2021, Wagner-Skacel et al., 2020). The main microbial metabolites include

SCFAs: acetate, propionate, and butyrate. They are produced by the fermentation of indigestible carbohydrates by the colon microbiota (Navarro-Tapia et al., 2021). Some of them may penetrate into the blood and then through the blood-brain barrier into the brain tissue and thus affect the central nervous system and cognitive functions (Prochazkova et al., 2021). Some SCFAs can stimulate enterochromaffin cells, which, together with the activity of gut bacteria, are necessary for the production and metabolism of essential neurotransmitters such as gamma-aminobutyric acid (GABA) and serotonin (Lodovico et al., 2021). Therefore, changes in patients' gut microbiota and its metabolites may have important implications for brain functioning. It is suspected that dysbiosis is one of the factors causing mental illnesses. (Marano et al., 2025b, Smitka et al., 2021, Trinh et al.,2023).

The microbiota-gut-brain axis also influences the regulation of eating behavior, but the exact mechanisms are unknown (Wei et al., 2022, Li et al., 2024). Various microbial metabolites are involved, among the most important are SCFAs and their derivatives (Navarro-Tapia et al., 2021). These substances can affect the systems regulating satiety, insulin pathways, appetite, and the perception of specific nutrients, and thus modify eating behavior (Scala et al., 2025, van de Wouw et al., 2017). Jensen et al. reported that SCFAs can decrease ghrelin levels in both animals and humans (Jensen 2020). Gamma-aminobutyric acid (GABA) produced by Bacteroides stimulates appetite by inhibiting the secretion of satiety hormones, thereby increasing food intake (Frank et al., 2001, Li et al., 2024). Akkermansia muciniphila may influence feeding behavior by modulating gut peptides, producing SCFAs, particularly propionate, which regulates satiety (Navarro-Tapia et al., 2021). Accordingly, an altered intestinal microbiome, and consequently altered composition of the metabolites it produces, may disturb hunger-satiety regulation, and thus be one of the causes of eating disorders (Li et al., 2024, Marano et al., 2025a, Navarro-Tapia et al., 2021). That is why we should consider adding microbiota-targeted strategies: probiotic and fecal microbiota transplantation, and also postbiotic supplementation to standard psychiatric treatment of AN.

3.2. Dysbiosis in AN patients

There are some studies that have revealed that AN patients had lower species diversity in their intestine compared to the healthy control group (Carbone et al., 2020, Ghenciulescu et al., 2021, Marano et al., 2025b, Wei et al., 2022, Landini et al., 2023). Differences were observed in the measurements of the α-diversity in stool samples. A decrease in alpha-diversity is considered a feature of dysbiosis and is also observed in malnutrition, obesity, and inflammatory bowel disease (Ghenciulescu et al., 2021). Many researchers have confirmed the negative impact of

microbiota from AN patients in animal experiments (Fan et al., 2023, Hata et al., 2019, Zheng et al., 2016). Germ-free mice after fecal microbiota transplantation from AN patients began to exhibit symptoms characteristic of the disease, including weight loss, compared with mice transplanted with microbiota from healthy donors. However, Glenny et al. showed a constant level of tissue deposition in mice before and after FMT, so more research is still needed to confirm this precisely due to differences in results and methods of the studies (Glenny et al., 2021).

Impaired gut microbiota may have an impact on brain functioning. According to Scala et al., changes in the microbiome were associated with symptoms of anxiety and depression due to neurotransmitter imbalances. Landini et al. reported that drastic dietary changes can significantly impact the composition of the intestinal microbiota, and the resulting dysbiosis may contribute to the development or persistence of conditions associated with AN, including anxiety, depression, disturbances in appetite regulation and gastrointestinal issues (Dhopatkar et al., 2023, Landini et al., 2023). Although we do not know exactly whether AN causes dysbiosis through fasting or whether dysbiosis precedes the AN development and is a risk factor for the disease (Dhopatkar et al., 2023), dysbiosis itself and its direct complications in the form of microbial metabolites imbalances are worth trying to treat.

3.3. SCFA-producing bacteria and SCFA levels in AN

The importance of individual types of bacteria constituting the intestinal microbiota and their metabolites was also investigated. Many studies have shown that patients with AN have lower levels of SCFAs in their stool samples compared to controls.

Prochazkova et al. detected a decreased level of butyrate and acetate in AN patients' stool samples (Prochazkova et al., 2021). Borgo et al. reported that *Clostridium*, *Roseburia*, and *Ruminococcus* were depleted in examined AN patients according to observed reduction in the level of total SCFA, butyrate, and propionate (Borgo et al. 2017). Morita et al. found that patients' acetic acid and propionic acid levels were significantly lower than in the control group (Morita et al., 2015). Speranza et al. observed significantly reduced butyrate and propionate fecal concentrations in AN patients (Speranza et al., 2018). Mack et al. reported a lower level of butyrate-producing Roseburia in AN patients and its correlation with the level of butyrate in each studied group. AN patients had comparable concentrations of total SCFA, acetate, propionate, and butyrate, but had increased concentrations of total branched-chain fatty acids (BCFA) and valerate concentrations. Therefore, the BCFA ratio to total SCFA was higher than

in the control group, and the butyrate and propionate ratio to the total SCFA was lower, which might be caused by a higher proportion of protein and a lower proportion of carbohydrates in the diet of AN patients (Mack et al., 2016). Elevated levels of protein-derived fermentation metabolites, including BCFAs, together with disturbances in fatty acid composition, may adversely affect intestinal function and gastrointestinal motility (Navarro-Tapia et al., 2021). According to Speranza et al., limited starch intake significantly reduced the numbers of the butyrate-producing species, with a simultaneous reduction in the butyrate levels in the feces. Reduced fecal SCFA excretion is suspected to be a compensatory mechanism for lower energy and carbohydrate intake (Speranza et al., 2018). Xu et al. reported that AN patients, both in the active phase of the disease and after treatment, had significantly lower plasma concentrations of butyric acid, but in contrast to Mack et al., isobutyric and isovaleric acid plasma concentrations compared to the control group were also lower (Xu et al., 2022). Carbone et al. and Igudesman et al. also reported lower levels of fecal SCFAs in AN patients compared to controls and suggested a link with reduced butyrate-producing Roseburia, carbohydrate-fermenting genera Ruminococcus and Clostridium (Carbone et al., 2020, Igudesman et al., 2019).

Overall, current evidence consistently indicates that AN is associated with reduced SCFA availability and alterations in SCFA-producing gut microbiota.

3.4. Consequences of decreased SCFA levels

Microbial metabolites play a role in maintaining intestinal homeostasis. SCFAs are essential for keeping the integrity and tightness of the mucosa. The main one, butyrate, is a source of energy for colonocytes and is essential for the immunological aspect of the mucosal barrier (Borgo et al., 2017). It has an impact on immunological processes in the intestines: regulates Claudin-1 and synaptopodin expression, affects macrophages, reduces the amount of pro-inflammatory cytokines (such as IL-6 and IL-12) and induces those with anti-inflammatory activity (IL-10), thus exerting an anti-inflammatory effect, and also inhibits oncogenic pathways (Nikolova 2021, Zhao 2024). Moreover, butyrate limits the growth of pathogenic bacteria such as E. coli and Salmonella by affecting the metabolism of colonocytes and causing a state of epithelial hypoxia (Zhao 2024).

Butyrate deficiency is associated with inflammation and damage to the intestinal barrier. Reduced abundance of carbohydrate-fermenting bacteria, such as *Roseburia*, causes multiplication of mucin-degrading microorganisms and slows down the intestinal transit, which

leads to destruction of the protective mucus layer. The resulting increase in intestinal permeability allows for penetration of the bacterial products into the blood circulation, causing disturbance of the immune response, low-grade systemic inflammation, which is increasingly recognized as a factor contributing to mental pathology, sepsis, or chronic diseases (Ghenciulescu et al., 2021, Lodovico et al., 2021, Prochazkova et al., 2019).

Many studies confirm the importance of SCFAs, whose low levels are associated with depressive and anxiety symptoms. According to Borgo et al., butyrate concentrations are inversely correlated with depression and anxiety levels (Borgo et al. 2017). Lodovico et al. reported that this so-called "sickness behaviour" occurs in 80% of people with eating disorders. It may be related to persistent low-grade inflammation and neurotransmitter imbalance modulated by changes in the availability of SCFA (Lodovico et al., 2021, Scala et al., 2025).

There are also indications that SCFAs influence the production of gut hormones related to nutrition, and thus the regulation of appetite and energy metabolism. Scala et al. reported that SCFAs can modulate insulin pathways and thus affect eating behaviours (Scala et al., 2025). In the study by Borgo et al., propionate concentrations correlated directly with insulin levels (Borgo et al., 2017). According to Xu et al., plasma concentrations of SCFA are correlated to BMI (Xu et al., 2022). Similarly, Lodovico et al. reported a positive correlation between BMI and butyrate-producing bacteria (Lodovico et al., 2021).

Therefore, when butyrate levels are reduced due to altered microbiota composition, especially decreased abundance of butyrate-producing species, there is a possibility of low-grade inflammation, disturbances in appetite, and psychiatric symptoms. Each of these conditions may be one of the causes of AN onset or its resistance to treatment (Lodovico et al., 2021, Zhao 2024).

3.5. Treatment of AN

Standard treatment includes refeeding, although it remains uncertain whether this intervention is sufficient to restore intestinal microbiota composition and microbial metabolite levels. According to some researchers, the presence of macronutrients in the diet can significantly reduce dysbiosis (Carbone et al., 2020), but according to other studies, regaining pre-illness body weight does not equate to regaining species diversity among commensal microorganisms. Alpha diversity appears to improve after short-term weight regain, but beta diversity remains unchanged (Marano et al., 2025b). Similarly, Mack et al. reported that in the studied AN patients, as body weight increased, microbial richness increased, but disturbances in gut

microbiome and SCFA profiles, as well as a range of gastrointestinal symptoms, did not subside (Mack et al., 2016). Other researchers also report that patients who have partially regained their body weight still have disturbed microbiota composition and insufficient levels of SCFAs and neurotransmitters (Prochazkova et al., 2021). This disruption of intestinal microbial homeostasis may be the reason why AN recurs so frequently - in 40% of patients, symptoms of anorexia nervosa persist even after 10 years of treatment (Landini et al., 2023). Furthermore, the introduction of a high-calorie diet in patients is often associated with symptoms from the gastrointestinal tract, such as constipation, gastric and duodenal ulcers (Ghenciulescu et al., 2021), but also pancreatitis and ischaemia (Jafar et al., 2021). This may also be caused by dysbiosis, as a sudden change in the gut environment (introduction of a high-calorie diet) may be too drastic for the poorly differentiated and unstable intestinal ecosystem (Landini et al., 2023). Thus, persistent gastrointestinal symptoms despite weight regain may indicate ongoing disturbances in microbial homeostasis, and restoration of this balance may be essential for preventing these ailments and, most importantly, future relapses.

In general, in less severe cases, changing eating habits is likely sufficient, but in recurrent cases or with extreme presentation, supporting this process with additional treatment methods, such as microbiome-based interventions, including probiotics, fecal microbiota transplants, and postbiotic supplementation, may prove to be crucial (Smitka et al., 2021).

3.6. SCFA supplementation

A reduced abundance of butyrate-producing bacteria has also been observed in patients with inflammatory bowel disease compared with healthy individuals. These findings support the role of butyrate in maintaining intestinal barrier integrity, as demonstrated in experimental studies, and further emphasize its anti-inflammatory properties. Consequently, the overall capacity of the gut microbiota to produce butyrate may be more clinically relevant than the relative abundance of specific bacterial taxa at the species, family, or phylum level (Mörkl et al., 2018). SCFA supplementation represents a microbiota-targeted intervention aimed at restoring intestinal homeostasis. At present, butyrate supplementation is not considered a standard therapeutic approach for anorexia nervosa, and clinical evidence supporting its efficacy remains unavailable, as only two ongoing studies have been initiated and no results have yet been published (Quagebeur et al., 2023, AN-BUTIX trial). Nevertheless, butyrate supplementation has been investigated in disorders such as irritable bowel syndrome and inflammatory bowel disease, both of which, similarly to AN, are associated with impaired intestinal barrier integrity.

Researchers reported that this therapy can be effective in relieving gastrointestinal symptoms and has a positive impact on the mucosal barrier. Butyrate supplementation has been shown to beneficially influence the composition of the gut microbiota by increasing the abundance of bacterial groups associated with SCFA production, including *Lachnospiraceae*, *Clostridia*, and the *Ruminococcus gauvreauii*. These microbes play an important role in breaking down dietary fibers and generating SCFA that support intestinal balance. Through these shifts in microbial populations, butyrate may help strengthen the intestinal barrier and promote a more regulated immune response with reduced inflammatory activity, which was also observed in the reduction of inflammatory markers such as calprotectin and C-reactive protein (Cristofori et al., 2025, Serrano-Fernández et al., 2025).

Collectively, these changes are associated with improved gut function, decreased intestinal leakage, reduced inflammation, and its consequences.

4. Discussion

In diseases associated with intestinal barrier dysfunction, SCFA supplementation has been shown to exert beneficial effects by enhancing barrier integrity and reducing inflammation. Due to the reduced SCFA levels observed in patients with anorexia nervosa (AN), and considering that some symptoms of AN may be partially related to impaired intestinal permeability and subsequent low-grade inflammation, butyrate supplementation may represent a reasonable adjunctive therapeutic approach. This rationale is further supported by the ability of butyric acid to nourish colonocytes and improve intestinal barrier function, modulate immune responses and inflammatory activity, as well as potentially influence neurotransmitter balance and gut–brain axis signaling, which may contribute to the alleviation of psychiatric symptoms. Additionally, increasing the concentration of butyrate in the intestine will reduce the ratio of BCFA to total SCFA, which may translate into alleviation of symptoms associated with impaired intestinal motility.

There are currently no studies with published results on SCFA supplementation in AN. Notably, even studies specifically investigating SCFA alterations in anorexia nervosa do not discuss oral SCFA or butyrate supplementation as a therapeutic approach. Current research primarily concentrates on microbiota-targeted interventions, including probiotic supplementation and fecal microbiota transplantation, aimed at restoring a healthy gut microbial composition. Considering the established role of microbial metabolites in maintaining intestinal homeostasis and mediating gut–brain axis signaling, a more direct strategy to enhance their systemic

availability—namely, exogenous administration of SCFAs—may also represent a promising therapeutic approach. Because only a limited number of studies have been initiated and no completed clinical trials are currently available, further research is required to better establish the potential therapeutic value of SCFA supplementation in anorexia nervosa. Additional studies are also needed to clarify the specific roles of individual SCFAs and their effects on gut microbiota composition, intestinal function, appetite regulation, and gut–brain axis communication.

5. Conclusions

Accumulating evidence indicates that AN is associated with gut microbiota dysbiosis, contributing to alterations in both the composition and concentration of microbial metabolites within the gastrointestinal tract. In particular, individuals with AN have been reported to exhibit reduced levels of SCFAs, including butyrate. Given the key role of butyrate in maintaining intestinal homeostasis and the involvement of SCFAs in appetite regulation, these alterations may be clinically significant, especially in light of the reported association between butyrate levels and the severity of psychiatric symptoms. Furthermore, low-grade systemic inflammation has been described in AN and may represent an additional factor contributing to disease pathophysiology. In light of the beneficial effects of SCFA supplementation reported in conditions such as irritable bowel syndrome and ulcerative colitis, enteral administration of SCFAs may constitute a potential adjunctive therapeutic strategy in AN. However, evidence in this field remains limited, as only a small number of studies have been initiated and no completed clinical trials are currently available.

Disclosure

Author Contributions

Conceptualization: Julia Białas, Alicja Kodura, Przemysław Piątek, Joanna Paluchowska

Methodology: Milena Mordarska, Alicja Piwowarczyk, Artur Merc

Software: not applicable

Check: Alicja Kodura, Przemysław Piątek, Milena Mordarska

Formal analysis: Julia Białas, Alicja Kodura, Joanna Paluchowska, Przemysław Piątek

Investigation: Joanna Paluchowska, Jan Łozowski

Resources: Artur Merc

Data curation: Łukasz Szymański, Alicja Piwowarczyk

Writing -rough preparation: Julia Białas, Alicja Kodura, Milena Mordarska, Przemysław Piątek, Jan Łozowski, Alicja Piwowarczyk, Joanna Paluchowska, Łukasz Szymański, Artur Merc

Writing -review and editing: Julia Białas, Alicja Kodura, Milena Mordarska, Przemysław Piątek, Jan Łozowski, Alicja Piwowarczyk, Joanna Paluchowska, Łukasz Szymański, Artur Merc

Visualization: Przemysław Piątek, Artur Merc

Supervision: Joanna Paluchowska

Project administration: Julia Białas, Alicja Kodura

All authors have read and agreed with the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The authors confirm that the data supporting the study are available in the article's references.

Conflicts of Interest

The authors deny any conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process.

AI-assisted technologies (ChatGPT, Grammarly) were used in the writing process to ensure grammatical correctness and improve language and readability. After proofreading by artificial intelligence, the authors checked the text and approved it.

References

Azienda Ospedaliero-Universitaria Careggi. Effect of Treatment With Butyric Acid in Anorexia Nervosa (AN-BUTIX). ClinicalTrials.gov. Updated December 17, 2025. Accessed May 16, 2026. https://clinicaltrials.gov/study/NCT07289581

Borgo F, Riva A, Benetti A, et al. Microbiota in anorexia nervosa: The triangle between bacterial species, metabolites and psychological tests. PLoS One. 2017;12(6):e0179739. Published 2017 Jun 21. doi:10.1371/journal.pone.0179739

Carbone EA, D'Amato P, Vicchio G, De Fazio P, Segura-Garcia C. A systematic review on the role of microbiota in the pathogenesis and treatment of eating disorders. Eur Psychiatry. 2020;64(1):e2. Published 2020 Dec 16. doi:10.1192/j.eurpsy.2020.109

Cristofori F, Calabrese FM, Iacobellis I, et al. Calcium butyrate efficacy in pediatric irritable bowel syndrome: Randomized placebo-controlled multiomics-based clinical trial. J Pediatr Gastroenterol Nutr. 2025;81(3):551-561. doi:10.1002/jpn3.70154

Dhopatkar N, Keeler JL, Mutwalli H, Whelan K, Treasure J, Himmerich H. Gastrointestinal symptoms, gut microbiome, probiotics and prebiotics in anorexia nervosa: A review of mechanistic rationale and clinical evidence. Psychoneuroendocrinology. 2023;147:105959. doi:10.1016/j.psyneuen.2022.105959

Fan Y, Støving RK, Berreira Ibraim S, et al. The gut microbiota contributes to the pathogenesis of anorexia nervosa in humans and mice. Nat Microbiol. 2023;8(5):787-802. doi:10.1038/s41564-023-01355-5

Frank GK, Kaye WH, Sahu A, Fernstrom J, McConaha C. Could reduced cerebrospinal fluid (csf) galanin contribute to restricted eating in anorexia nervosa?. Neuropsychopharmacology. 2001;24(6):706-709. doi:10.1016/S0893-133X(00)00251-7

Garcia N, Gutierrez E. Anorexia nervosa and microbiota: systematic review and critical appraisal. Eat Weight Disord. 2023;28(1):1. Published 2023 Feb 8. doi:10.1007/s40519-023-01529-4

Ghenciulescu A, Park RJ, Burnet PWJ. The Gut Microbiome in Anorexia Nervosa: Friend or Foe?. Front Psychiatry. 2021;11:611677. Published 2021 Jan 12. doi:10.3389/fpsyt.2020.611677

Glenny EM, Fouladi F, Thomas SA, et al. Gut microbial communities from patients with anorexia nervosa do not influence body weight in recipient germ-free mice. Gut Microbes. 2021;13(1):1-15. doi:10.1080/19490976.2021.1897216

Hata T, Miyata N, Takakura S, et al. The Gut Microbiome Derived From Anorexia Nervosa Patients Impairs Weight Gain and Behavioral Performance in Female Mice. Endocrinology. 2019;160(10):2441-2452. doi:10.1210/en.2019-00408

Igudesman D, Sweeney M, Carroll IM, Mayer-Davis EJ, Bulik CM. Gut-Brain Interactions: Implications for a Role of the Gut Microbiota in the Treatment and Prognosis of Anorexia

Nervosa and Comparison to Type I Diabetes. Gastroenterol Clin North Am. 2019;48(3):343-356. doi:10.1016/j.gtc.2019.04.003

Jafar W, Morgan J. Anorexia nervosa and the gastrointestinal tract. Frontline Gastroenterol. 2021;13(4):316-324. Published 2021 Aug 20. doi:10.1136/flgastro-2021-101857

Jensen EA, Young JA, Mathes SC, et al. Crosstalk between the growth hormone/insulin-like growth factor-1 axis and the gut microbiome: A new frontier for microbial endocrinology. Growth Horm IGF Res. 2020;53-54:101333. doi:10.1016/j.ghir.2020.101333

Kelly JR, Borre Y, O' Brien C, et al. Transferring the blues: Depression-associated gut microbiota induces neurobehavioural changes in the rat. J Psychiatr Res. 2016;82:109-118. doi:10.1016/j.jpsychires.2016.07.019

Korten NM, Thelen AC, Voelz C, et al. Exploring the Link Between the Gut Microbiota and Epigenetic Factors in Anorexia Nervosa. Brain Behav. 2025;15(8):e70733. doi:10.1002/brb3.70733

Landini L, Dadson P, Gallo F, Honka M-J, Cena H. Microbiota in anorexia nervosa: potential for treatment. Nutrition Research Reviews. 2023;36(2):372-391. doi:10.1017/S0954422422000130

Li S, Liu M, Han Y, et al. Gut microbiota-derived gamma-aminobutyric acid improves host appetite by inhibiting satiety hormone secretion. mSystems. 2024;9(10):e0101524. doi:10.1128/msystems.01015-24

Di Lodovico L, Mondot S, Doré J, Mack I, Hanachi M, Gorwood P. Anorexia nervosa and gut microbiota: A systematic review and quantitative synthesis of pooled microbiological data. Prog Neuropsychopharmacol Biol Psychiatry. 2021;106:110114. doi:10.1016/j.pnpbp.2020.110114

Mack I, Cuntz U, Grämer C, et al. Weight gain in anorexia nervosa does not ameliorate the faecal microbiota, branched chain fatty acid profiles, and gastrointestinal complaints. Sci Rep. 2016;6:26752. Published 2016 May 27. doi:10.1038/srep26752

Marano G, Rossi S, Sfratta G, et al. Gut Microbiota in Women with Eating Disorders: A New Frontier in Pathophysiology and Treatment. Nutrients. 2025;17(14):2316. Published 2025 Jul 14. doi:10.3390/nu17142316

Marano G, Sfratta G, Marzo EM, Cozzo G, Abate F, Traversi G, Mazza O, Capristo E, Gaetani E, Mazza M. The Pediatric Microbiota–Gut–Brain Axis: Implications for Neuropsychiatric Development and Intervention. Children. 2025; 12(11):1561. https://doi.org/10.3390/children12111561

Morita C, Tsuji H, Hata T, et al. Gut Dysbiosis in Patients with Anorexia Nervosa. PLoS One. 2015;10(12):e0145274. Published 2015 Dec 18. doi:10.1371/journal.pone.0145274

Mörkl S, Lackner S, Meinitzer A, et al. Gut microbiota, dietary intakes and intestinal permeability reflected by serum zonulin in women. Eur J Nutr. 2018;57(8):2985-2997. doi:10.1007/s00394-018-1784-0

Navarro-Tapia E, Almeida-Toledano L, Sebastiani G, Serra-Delgado M, García-Algar Ó, Andreu-Fernández V. Effects of Microbiota Imbalance in Anxiety and Eating Disorders:

Probiotics as Novel Therapeutic Approaches. Int J Mol Sci. 2021;22(5):2351. Published 2021 Feb 26. doi:10.3390/ijms22052351

Nikolova VL, Smith MRB, Hall LJ, Cleare AJ, Stone JM, Young AH. Perturbations in Gut Microbiota Composition in Psychiatric Disorders: A Review and Meta-analysis. JAMA Psychiatry. 2021;78(12):1343-1354. doi:10.1001/jamapsychiatry.2021.2573

Prochazkova P, Roubalova R, Dvorak J, et al. Microbiota, Microbial Metabolites, and Barrier Function in A Patient with Anorexia Nervosa after Fecal Microbiota Transplantation. Microorganisms. 2019;7(9):338. Published 2019 Sep 10. doi:10.3390/microorganisms7090338

Prochazkova P, Roubalova R, Dvorak J, et al. The intestinal microbiota and metabolites in patients with anorexia nervosa. Gut Microbes. 2021;13(1):1-25. doi:10.1080/19490976.2021.1902771

Prochazkova P, Jezkova J, Roubalova R, et al. Microbiome and metabolic disruption in acute vs. severe and enduring anorexia nervosa. NPJ Biofilms Microbiomes. 2025;11(1):217. Published 2025 Nov 26. doi:10.1038/s41522-025-00847-y

Quagebeur R, Dalile B, Raes J, Van Oudenhove L, Verbeke K, Vrieze E. The role of short-chain fatty acids (SCFAs) in regulating stress responses, eating behavior, and nutritional state in anorexia nervosa: protocol for a randomized controlled trial. J Eat Disord. 2023;11(1):191. Published 2023 Oct 26. doi:10.1186/s40337-023-00917-6

Scala M, Tabone M, Paolini M, et al. Unlocking the link between gut microbiota and psychopathological insights in anorexia nervosa: a systematic review. Eur Eat Disord Rev. 2025;33:700-718. doi:10.1002/erv.3179

Serrano-Fernández V, Carmona-Torres JM, López-Fernández-Roldán Á, et al. Short-chain fatty acids in the treatment of ulcerative colitis: systematic review and meta-analysis. Inflamm Res. 2025;74:142. doi:10.1007/s00011-025-02112-6

Smitka K, Prochazkova P, Roubalova R, et al. Current Aspects of the Role of Autoantibodies Directed Against Appetite-Regulating Hormones and the Gut Microbiome in Eating Disorders. Front Endocrinol (Lausanne). 2021;12:613983. Published 2021 Apr 19. doi:10.3389/fendo.2021.613983

Speranza E, Cioffi I, Santarpia L, et al. Fecal Short Chain Fatty Acids and Dietary Intake in Italian Women With Restrictive Anorexia Nervosa: A Pilot Study. Front Nutr. 2018;5:119. Published 2018 Nov 29. doi:10.3389/fnut.2018.00119

Trinh S, Keller L, Herpertz-Dahlmann B, Seitz J. Fäkale Mikrobiotatransplantationen im Zusammenhang mit (kinder- und jugend-)psychiatrischen Erkrankungen [Fecal Microbiota Transplants in the Context of (Child and Adolescent) Psychiatric Disorders]. Z Kinder Jugendpsychiatr Psychother. 2023;51(6):431-440. doi:10.1024/1422-4917/a000928

Wagner-Skacel J, Dalkner N, Moerkl S, et al. Sleep and Microbiome in Psychiatric Diseases. Nutrients. 2020;12(8):2198. Published 2020 Jul 23. doi:10.3390/nu12082198

Wei Y, Peng S, Lian C, Kang Q, Chen J. Anorexia nervosa and gut microbiome: implications for weight change and novel treatments. Expert Rev Gastroenterol Hepatol. 2022;16(4):321-332. doi:10.1080/17474124.2022.2056017

van de Wouw M, Schellekens H, Dinan TG, Cryan JF. Microbiota-Gut-Brain Axis: Modulator of Host Metabolism and Appetite. J Nutr. 2017;147(5):727-745. doi:10.3945/jn.116.240481

Xu J, Landberg R, Lavebratt C, Bulik CM, Landén M, Nilsson IAK. Plasma Concentrations of Short-Chain Fatty Acids in Active and Recovered Anorexia Nervosa. Nutrients. 2022;14(24):5247. Published 2022 Dec 9. doi:10.3390/nu14245247

Zhao W, Kodancha P, Das S. Gut Microbiome Changes in Anorexia Nervosa: A Comprehensive Review. Pathophysiology. 2024;31(1):68-88. Published 2024 Feb 2. doi:10.3390/pathophysiology31010006

Zheng P, Zeng B, Zhou C, et al. Gut microbiome remodeling induces depressive-like behaviors through a pathway mediated by the host's metabolism. Mol Psychiatry. 2016;21(6):786-796. doi:10.1038/mp.2016.44