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Strain-specific effects of probiotics on depression and anxiety: a meta-analysis

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Abstract

Introduction Depression and anxiety are pervasive mental health disorders with substantial global burdens. Probiotics, live microorganisms known for their health benefits, have emerged as a potential therapeutic intervention for these conditions. This systematic review and meta-analysis aim to evaluate the strain-specific effects of probiotics on relieving depressive and anxiety symptoms while elucidating underlying mechanisms.

Methods EMBASE, Cochrane CENTRAL and PubMed/Medline were systematically queried to identify studies released until May 15, 2024. Randomized Controlled Trials (RCTs) that employed standardized assessment tools for depression and anxiety namely Beck Depression Inventory (BDI), Hamilton Depression Rating Scale (HAMD), Depression Anxiety Stress Scales (DASS), or Montgomery-Asberg Depression Rating Scale (MADRS) were included.

Results 12 RCTs involving 707 participants were included. Seven RCTs utilizing the BDI questionnaire demonstrated a significant decrease in depressive symptoms favoring probiotics containing strains such as *Lactobacillus acidophilus*, *Lactobacillus paracasei*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus salivarius*, *Bifidobacterium bifidum*, *Bifidobacterium lactis*, *Bifidobacterium breve*, *and Bifidobacterium longum* (MD: -2.69, CI95%: -4.22/-1.16, p value: 0.00). Conversely, RCTs using HAMD showed a non-significant reduction in depressive symptoms (MD: -1.40, CI95%: -3.29/0.48, p value: 0.14). RCTs employing DASS and MADRS scales also showed no significant differences.

Conclusion This meta-analysis offers valuable insights into the strain-specific effects of probiotics containing Lactobacillus and Bifidobacterium species on depressive and anxiety symptoms. While our findings suggest a significant reduction in depressive symptoms based on the BDI scale favoring probiotics, the lack of significant effects observed on the HAMD, DASS, and MADRS scales underscores the complexity inherent in these conditions. It is imperative to acknowledge the mixed results across different measurement scales, indicating the need for cautious interpretation. Therefore, we advocate for a nuanced understanding of probiotics' impacts on various dimensions of mood, emphasizing the necessity for further research.

Keywords Mental Health, Probiotic, Mood, Depression, Anxiety systematic review, Meta-analysis

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Introduction

Depression and anxiety, two prevailing and often co-occurring mental health disorders, constitute a substantial global health challenge [1–3]. The profound impact of these conditions transcends individual suffering, encompassing economic burdens, compromised quality of life, and an extensive societal footprint. While conventional therapeutic modalities have provided significant relief to many, a growing body of scientific inquiry has ventured into the intriguing domain of the gut-brain axis, where the microbiota, specifically probiotics, may offer innovative solutions to these complex conditions [4–7]. Probiotics, live microorganisms with established health benefits, have ignited interest in the realm of mental health research [8–11]. Their potential influence on the gut-brain axis represents a paradigm shift in our understanding of the biological underpinnings of depression and anxiety [10, 12]. Current hypotheses propose that probiotics influence this axis by modulating inflammation, producing neurotransmitters, and improving gut barrier function. While some studies suggest positive effects on mood and anxiety, the field is still in its early stages [10, 12]. Despite existing studies, recent advancements in research, ongoing clinical trials, and evolving methodologies may not be adequately reflected in earlier reviews. Current reviews often adopt broad inclusion criteria, encompassing a wide range of probiotic interventions without delineating the specific effects of individual strains. Moreover, while previous reviews may touch upon the potential mechanisms underlying probiotics' effects on mood and anxiety, they often lack in-depth exploration due to scope limitations. Therefore, the aim of the current systematic review and meta-analysis is to elucidate the strain-specific effects of probiotics on mood and anxiety. This approach recognizes the importance of precision medicine in optimizing treatment outcomes. Additionally, the review seeks to delve deeper into the mechanisms underlying these effects, offering valuable insights into the biological underpinnings of probiotic-mediated effects on mental health.

Methods

The current investigation adhered to and reported in accordance with the PRISMA guidelines (ID: CRD42023464805) [13].

Search strategy

Medical databases, namely PubMed/Medline, EMBASE, and Cochrane CENTRAL, were systematically explored for studies released until May 15, 2024. Only randomized controlled trials (RCTs) written in English were included in the selection process. The search utilized specific combinations of MeSH terms and keywords, including 'Probiotics,' 'Depression,' and 'Anxiety' (Supplementary file). Additionally, backward and forward citation searches were conducted within the selected studies to identify additional relevant publications.

Study selection

All collected records were consolidated, and duplicates were eliminated using EndNote X8 (Thomson Reuters, Toronto, ON, Canada). Each record underwent independent screening by two reviewers (MG) or M.R) to assess eligibility criteria. Unrelated studies were excluded based on title and abstract, followed by a full-text examination. In instances of discrepancies between the two reviewers, the lead investigator evaluated the record (MN). Eligible studies met the following criteria based on Population, Intervention, Comparator, Outcome (PICO):

Study design RCTs that employed standardized assessment tools for depression and anxiety (e.g., Beck Depression Inventory (BDI), Hamilton Depression Rating Scale (HAMD), Depression Anxiety Stress Scales (DASS), and Montgomery-Asberg Depression Rating Scale (MADRS)).

Patients The eligible studies were required to involve individuals with a clinical diagnosis or symptoms of depression and/or anxiety, as defined by the authors of the respective studies.

Interventions Probiotics were used either alone, as adjunctive treatments to existing antidepressants, or in combination with minerals or vitamins.

Comparisons Placebo.

Outcomes Relief of depressive and anxiety symptoms diagnosed with BDI, HAMD, DASS, and MADRS.

The BDI is a self-report questionnaire widely recognized for its sensitivity in capturing cognitive and affective symptoms of depression. In contrast, the HAMD is clinician-administered and emphasizes observable symptoms of depression. The DASS and MADRS provide broader assessments encompassing multiple dimensions of mood disorders, including anxiety-related symptoms.

Excluded from consideration were reviews, conference abstracts, expert opinions, editorials, study protocols, and case reports.

Data extraction

Two reviewers (M.N or MR) collaboratively developed a data extraction form and proceeded to extract data from all included studies. Each record's data were independently extracted by the two reviewers, and any discrepancies were resolved through consensus. The extracted information encompassed the following details: first author names, study design, mean age, number of

participants, interventions, follow-up duration, control group details, and outcomes.

Quality assessment

Two reviewers (AHSB, AK) conducted the assessment of each study's quality, and a third reviewer (MD) was engaged to resolve any inconsistencies. The evaluation encompassed items such as study population, sampling, methods of identification and measurement of the condition, and statistical analysis. The Cochrane bias assessment tool was employed for this purpose [14].

Data analysis

Statistical analyses were conducted using Comprehensive Meta-Analysis software, version 2.0 (Biostat Inc., Englewood, NJ, USA). Pooled mean differences (MDs) for continuous variables were calculated with their corresponding 95% confidence intervals (CIs). Between-study heterogeneity was evaluated through Cochran's Q test and the I2 statistic. Statistical assessment of publication bias was performed using Begg's test, considering a P-value less than 0.05 as indicative of statistically significant publication bias.

Result

The initial searches yielded 723 citations from database searches. Following the title and abstract screening, we acquired full-paper copies for 27 citations that appeared potentially eligible for inclusion in the review. However, 16 full-text studies were subsequently excluded based on the reasons outlined in Fig. 1. Consequently, 12 RCTs, involving 707 participants, met the requirements and were included in the analysis.

Risk of bias assessment

As detailed in Table 2, our risk of bias assessment revealed that the included studies generally exhibited a low risk of bias across several crucial domains. These

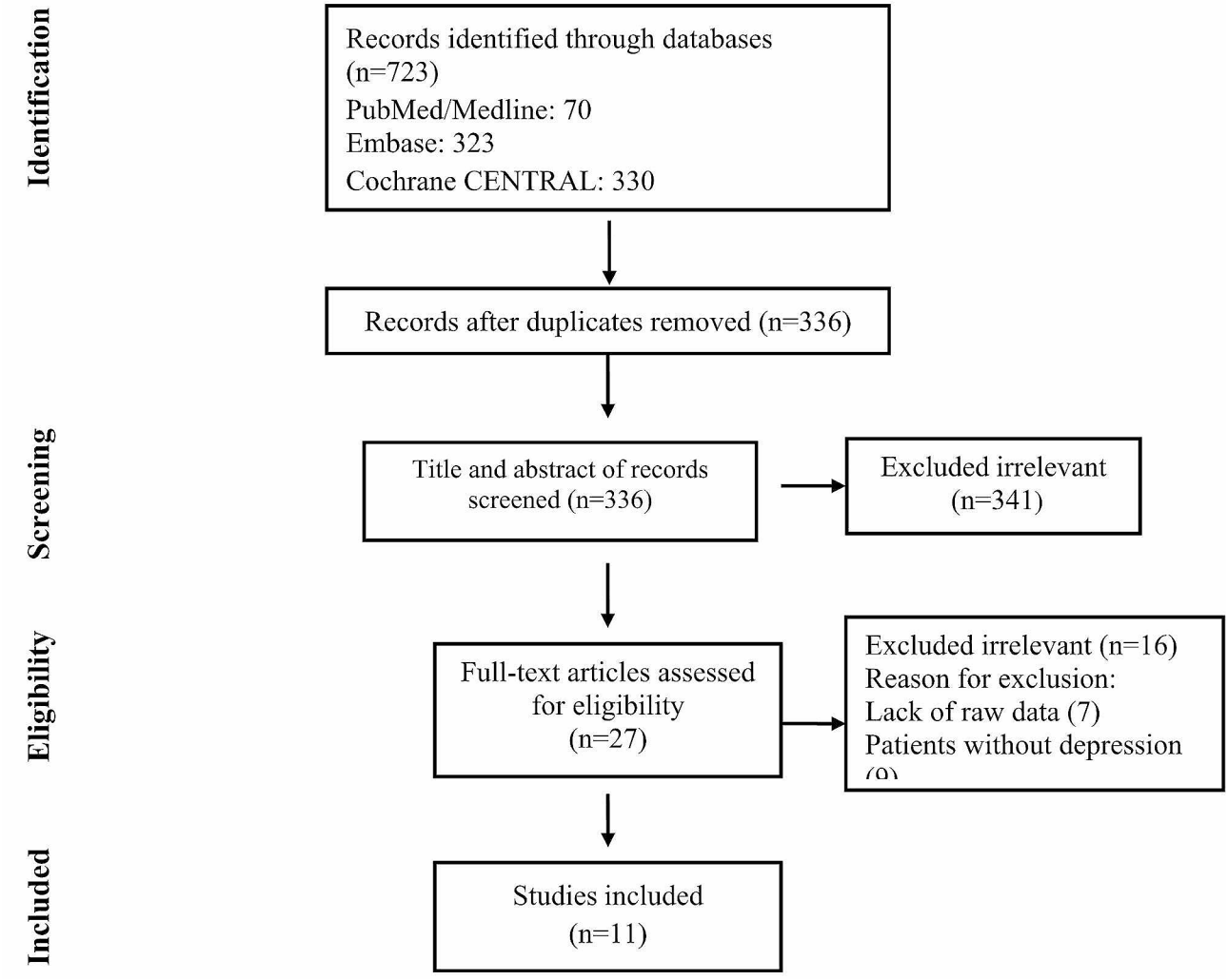

Fig. 1 Flow chart of study selection for inclusion in the systematic review and meta-analysis

Table 1 Studies characteristics

First Author, Year	Study design/Duration	Sample size Probiotic/control	Type of patient, Mean age	Intervention	Control	Questionnaires
Nikolova, 2023 [31]	RCT/8 weeks	24/25	Patients with depression, 32	Probiotic capsule (2×10^9 CFU/g): *Bacillus subtilis*, *Bifidobacterium bifidum*, *Bifidobacterium breve*, *Bifidobacterium infantis*, *Bifidobacterium longum*, *Lactobacillus acidophilus*, *Lactobacillus delbrueckii subsp bulgaricus*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus rhamnosus*, *Lactobacillus helveticus*, *Lactobacillus salivarius*, *Lactococcus lactis*, *and Streptococcus thermophilus*	Placebo with no probiotic bacteria	HAMD
Yamanbaeva, 2023 [32]	RCT/4 weeks	14/18	Patients with depression, 37	Probiotic capsule (1.0×10^9 CFU/g): *Streptococcus thermophilus* NCIMB 30,438 *Bifidobacterium breve* NCIMB 30,441 *Bifidobacterium longum* NCIMB 30,435 *Bifidobacterium infantis* NCIMB 30,436 *Lactobacillus acidophilus* NCIMB 30,442 *Lactobacillus plantarum* NCIMB 30,437 *Lactobacillus paracasei* NCIMB 30,439 *Lactobacillus delbrueckii* subsp *Bulgaricus* NCIMB 30,440	Placebo with no probiotic bacteria	HAMD
Mahboobi 2022 [33]	RCT/9 weeks	39/35	Patients with obesity and depressed mood, 36	Magnesium + Probiotic capsule (1.8×10^9 CFU/g): *Lactobacillus rhamnosus* *Bifidobacterium animalis* subsp. *Lactis*	Placebo with no probiotic bacteria	BDI
Kreuzer 2022 [34]	RCT/4 weeks	28/29	Patients with major depressive disorder, 43	Probiotic capsule (7.5×10^9 CFU/g): *Bifidobacteria bifidum* W23 *Bifidobacteria lactis* W51 *Bifidobacteria lactis* W52 *Lactobacilli acidophilus* W22 *Lactobacilli casei* W56 *Lactobacilli paracasei* W20 *Lactobacilli plantarum* W62 *Lactobacilli salivarius* W24 *Lactobacilli lactis* W19	Placebo with no probiotic bacteria	HAMD BDI
Ullah 2022 [35]	RCT/6 weeks	33/32	Patients with depression, 41	Methionine + Probiotic capsule (3.0×10^9 CFU/g): *Lactobacillus helveticus* *Bifidobacterium longum*	Placebo with no probiotic bacteria	HAMD
Zhang 2021 [36]	RCT/9 weeks	38/31	Patients with depression, 47	Probiotic capsule (1.0×10^9 CFU/g): *Lacticaseibacillus paracasei*	Placebo with no probiotic bacteria	HAMD BDI

Table 1 (continued)

First Author, Year	Study design/Duration	Sample size Probiotic/control	Type of patient, Mean age	Intervention	Control	Questionnaires
Reininghaus 2020 [37]	RCT/4 weeks	28/30	Patients with depression, 42	Vitamin B7 + Probiotic capsule (2×10^9 CFU/g): *Bifidobacterium bifidum* W23 *Bifidobacterium lactis* W51 *Bifidobacterium lactis* W52 *Lactobacillus acidophilus* W22 *Lactobacillus casei* W56 *Lactobacillus paracasei* W20 *Lactobacillus plantarum* W62 *Lactobacillus salivarius* W24 *Lactobacillus lactis* W19	Placebo with no probiotic bacteria	HAMD BDI
Chahwan 2019 [38]	RCT/8 weeks	34/36	Patients with depression, 36	Probiotic capsule (2.5×10^9 CFU/g): *Bifidobacterium bifidum* W23 *Bifidobacterium lactis* W51 *Bifidobacterium lactis* W52 *Lactobacillus acidophilus* W37 *Lactobacillus brevis* W63 *Lactobacillus casei* W56 *Lactobacillus salivarius* W24 *Lactococcus lactis* W19 *Lactococcus lactis* W58	Placebo group received maltodextrin capsules	BDI DASS
Kazemi 2019 [39]	RCT/8 weeks	38/36	Patients with major depressive disorder, 34	Probiotic capsule (10×10^9 CFU/g): *Lactobacillus helveticus* R0052 *Bifidobacterium longum* R0175	Placebo group received maltodextrin capsules	BDI
Majeed 2018 [40]	RCT/ 12 weeks	20/20	Patients with major depressive disorder, 42	Probiotic capsule (2.0×10^9 CFU/g): *Bacillus coagulans* MTCC 5856	Placebo with no probiotic bacteria	MADRS HAMD
Romjin 2017 [41]	RCT/8 weeks	39/40	Patients with depression, 35	Probiotic capsule (3.0×10^9 CFU/g): *Lactobacillus helveticus* R0052 *Bifidobacterium longum* R0175	Placebo with no probiotic bacteria	MADRS DASS
Akkasheh, 2016 [42]	RCT/8 weeks	20/20	Patients with major depressive disorder, 37	Probiotic capsule (3.0×10^9 CFU/g): *Lactobacillus acidophilus* *Lactobacillus casei* *Bifidobacterium bifidum*	Placebo with no probiotic bacteria	BDI

Table 2 Quality Assessment

Author	Random Sequence Generation	Allocation Concealment	Blinding Of Participants And Personnel	Blinding Of Outcome Assessment	Incomplete Outcome Data	Selective Reporting
Nikolova	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Yamanbaeva	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Mahboobi	Low Risk	Low Risk	Low Risk	Unclear	Low Risk	Low Risk
Kreuzer	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Ullah	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Zhang	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Reininghaus	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Chahwan	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Kazemi	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Majeed	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Romjin	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk
Akkasheh	Low Risk	Unclear	Low Risk	Unclear	Low Risk	Low Risk

Table 3 Subgroup analysis based on the relief of depressive and anxiety symptoms

Questionnaires	No. of study	No. of participants	Pooled mean difference (CI 95%)	*P* value for overall effect	I2%
BDI	7	430	-2.69 (-4.22/-1.16)	0.00	0.0
HAMD	7	371	-1.40 (-3.29/0.48)	0.14	69.0
DASS	2	149	2.57 (-0.71/5.80)	0.12	0.0
MADRS	2	119	-2.41 (-9.18/5.73)	0.56	86.0

domains included key criteria such as randomization procedures, blinding of participants and assessors, completeness of outcome data, selective reporting, and potential sources of bias. However, it is noteworthy that there was insufficient data available to ascertain the level of risk associated with allocation concealment and blinding of outcome assessment.

Study characteristics

Table 1 provides an overview of study characteristics, including details related to setting, study design, number of participants, mean age, criteria utilized, and follow-up duration. Of the 12 RCTs, 8 studies used only probiotics and the remaining used probiotics with magnesium, methionine and vitamin b7. In relation to the control group, all studies compared the interventions studied with placebo with no probiotic bacteria. The status of depression reported in included trials were assessed using four different questionnaires; BDI, HAMD, DASS and MADRS.

Probiotics

The intervention in the study consisted of various probiotic capsules, each containing different strains and quantities of beneficial bacteria. These probiotic capsules included strains such as *Lactobacillus acidophilus*, *Lactobacillus paracasei*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus salivarius*, *Bifidobacterium bifidum*, *Bifidobacterium lactis*, *Bifidobacterium breve* and *Bifidobacterium longum*. Some capsules were supplemented with additional nutrients like magnesium, methionine, or vitamin B7.

Relief of depressive and anxiety symptoms

BDI Questionnaires: Seven RCTs assessed the relief of depressive and anxiety symptoms using the BDI questionnaires. The meta-analysis revealed a significant decrease in depressive symptoms in favor of probiotics compared to the placebo group. The MD was −2.69, with a 95% CI ranging from −4.22 to -1.16, and a p-value of 0.00. This result suggests that probiotics had a notable positive impact on relieving depressive symptoms when assessed with the BDI (Table 3; Fig. 2). There was no evidence of publication bias (p-value > 0.05).

HAMD Questionnaires: Seven RCTs utilized the HAMD questionnaires to assess the relief of depressive and anxiety symptoms. In this case, the meta-analysis indicated a non-significant decrease in depressive symptoms favoring probiotics compared to the placebo. The MD was −1.40, with a 95% CI ranging from −3.29 to 0.48, and a p-value of 0.1. This finding suggests that the effects of probiotics on depressive symptoms, as measured by the HAMD, did not reach statistical significance (Table 3; Fig. 3). There was no evidence of publication bias (p-value > 0.05).

DASS and MADRS Scales: The meta-analysis of RCTs employing the DASS and MADRS scales revealed no significant differences between the probiotic and

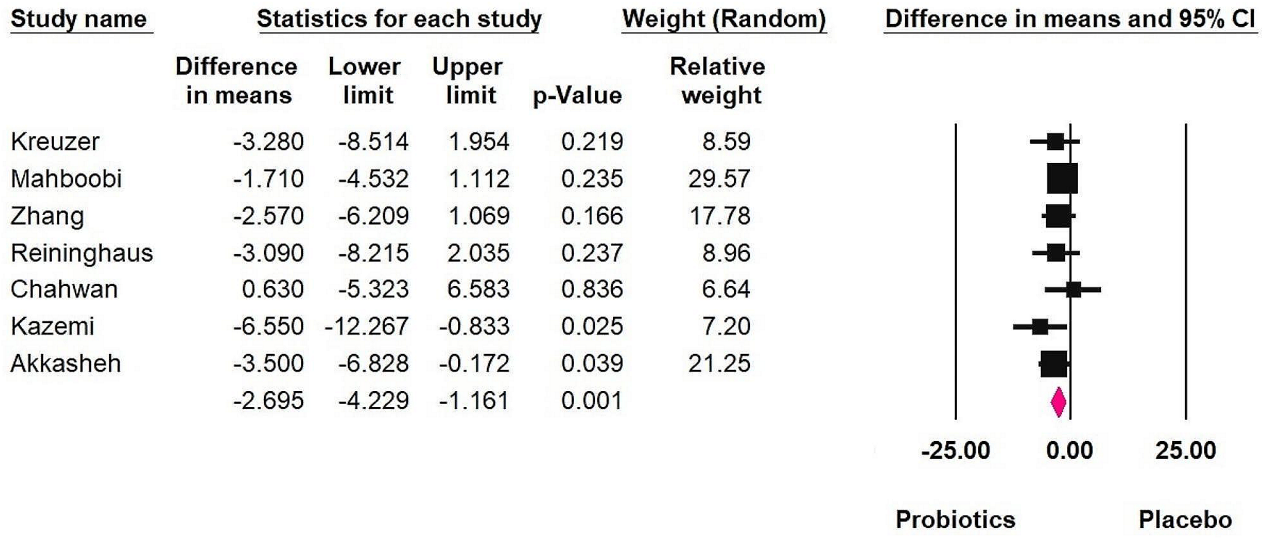

Fig. 2 Pooled mean difference in the alleviation of depressive symptoms assessed by BDI scores

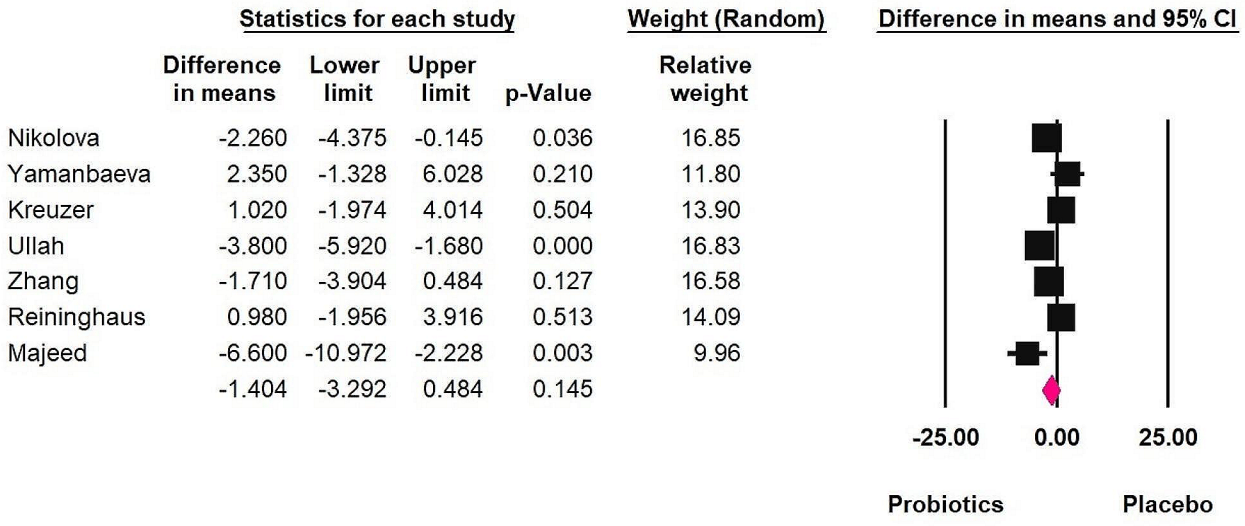

Fig. 3 Pooled mean difference in the alleviation of depressive symptoms assessed by HAMD scores

placebo groups. These scales encompass various dimensions of mood and depressive symptoms, and the results imply that probiotics did not show significant effects in relieving symptoms when assessed using these tools (Table 3). There was no evidence of publication bias (p-value > 0.05).

Adverse effects

Commonly reported adverse effects associated with probiotic use encompass a spectrum of mild gastrointestinal symptoms, which may include bloating, flatulence, abdominal discomfort, and occasionally, diarrhea.

Discussion

The results of this systematic review and meta-analysis shed light on the potential impact of probiotics as a therapeutic intervention for the relief of depressive and anxiety symptoms. The most notable finding from our analysis is the significant decrease in the relief of depressive symptoms favoring probiotics when assessed using the BDI questionnaire. The MD of -2.69, with a 95% CI of -4.22 to -1.16, indicates a clinically meaningful reduction in depressive symptomatology. This result aligns with the emerging body of evidence suggesting a potential role for probiotics in ameliorating depressive symptoms, supporting the notion that the gut-brain axis plays a pivotal role in mood regulation [15–20]. However, when examining the HAMD questionnaire data, our analysis reveals a

non-significant decrease in the relief of depressive symptoms favoring probiotics. Furthermore, our analysis of RCTs employing the DASS and MADRS scales did not demonstrate a significant difference in symptom relief between the probiotic and placebo groups.

The discrepancy between the findings with the BDI and the findings with HAMD, DASS, and MADRS highlights the complexity of assessing depressive symptoms. The BDI, a self-reported tool, captures subjective experiences and cognitive-affective symptoms, making it more sensitive to changes in mood and well-being due to probiotics. In contrast, clinician-administered scales like HAMD, DASS, and MADRS are typically considered the gold standard for assessing depressive symptoms as they emphasize observable symptoms and broader depressive dimensions, including somatic aspects, which might not capture subtle mood changes as effectively. This difference in measurement focus, sensitivity to change, and patient perception can influence outcomes. The BDI's responsiveness to cognitive and emotional symptoms suggests probiotics may more effectively target these areas. Further research should use both self-reported and clinician-administered scales, explore probiotics' mechanisms on different depression dimensions, and consider longer treatments and varied strains to fully understand their impact.

These findings also suggest that the effectiveness of probiotics in managing depression and anxiety may vary depending on the specific assessment tools used. It is crucial to recognize that these scales measure various dimensions of mood, and probiotics may exert their influence differently across these dimensions. Additionally, the choice of probiotic strains, dosages, and treatment durations may contribute to the variations in outcomes observed across included studies. Individual factors, such as a person's baseline gut microbiota composition, genetics, and lifestyle, can also influence the response to probiotics.

Furthermore, the observed variations in the effectiveness of probiotics across different assessment tools warrant a deeper exploration of the mechanisms through which probiotics may impact depressive and anxiety symptoms.

Gut microbiota modulation Probiotics are known to exert their primary effects by modulating the composition and diversity of the gut microbiota. The gut microbiota has emerged as a critical player in the gut-brain axis, influencing neuroimmune and neuroendocrine pathways. Probiotics may restore microbial balance, reducing the production of pro-inflammatory cytokines and promoting the synthesis of anti-inflammatory compounds. These changes can potentially alleviate neuroinflammation, which has been implicated in the pathogenesis of depression and anxiety [21–24].

Neurotransmitter production The gut is a significant site for neurotransmitter production, with serotonin, often called the "feel-good" neurotransmitter, being of particular relevance. Probiotics may enhance the synthesis of serotonin and other neurotransmitters within the gut. These neurotransmitters can then signal the brain through the vagus nerve, influencing mood and emotional regulation [25, 26].

Immune system modulation Probiotics can influence the immune system, which plays a crucial role in mood regulation. Dysregulation of the immune response, characterized by increased inflammation, has been associated with depression and anxiety. Probiotics may mitigate this immune dysregulation by promoting anti-inflammatory responses and reducing the release of pro-inflammatory molecules [26–28].

Metabolite production Probiotics can produce various metabolites during their fermentation processes. These metabolites have been shown to have anti-inflammatory and neuroprotective effects. They may modulate the gut-brain axis by acting as signaling molecules and influencing neural function [29, 30].

Synaptic plasticity and neurogenesis Some probiotic strains may promote synaptic plasticity and neurogenesis in the brain. These processes are essential for learning, memory, and emotional regulation. Probiotics may indirectly support these mechanisms by reducing neuroinflammation and promoting a neuroprotective environment in the brain [26].

Differential effects of probiotic strains

In our meta-analysis, we evaluated the effects of various probiotic strains, including *Lactobacillus acidophilus*, *Lactobacillus paracasei*, *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus salivarius*, *Bifidobacterium bifidum*, *Bifidobacterium lactis*, *Bifidobacterium breve*, *and Bifidobacterium longum*, on depressive and anxiety symptoms. Each of these strains has been studied for its potential to influence mood through mechanisms such as gut-brain axis modulation, neurotransmitter production, and immune system regulation.

Our findings indicate differential effects across these probiotic strains, particularly notable in their impact on various assessment scales. For instance, studies utilizing the BDI consistently showed a significant reduction in depressive symptoms with probiotics containing strains such as *Lactobacillus acidophilus* and *Bifidobacterium bifidum*. In contrast, the HAMD did not consistently

demonstrate significant improvements, suggesting potential variations in sensitivity to changes in mood dimensions captured by different scales.

The observed effects may be attributed to the unique physiological properties of each strain, including their ability to produce neurotransmitters like serotonin, regulate inflammatory responses, and maintain gut barrier integrity. Lactobacillus strains, known for their anti-inflammatory properties and potential to enhance serotonin production in the gut, may exert more pronounced effects on self-reported mood symptoms measured by the BDI. On the other hand, strains like *Bifidobacterium bifidum*, which contribute to gut microbial balance and immune modulation, could influence broader aspects of depressive and anxiety symptoms captured by comprehensive scales like DASS and MADRS.

These strain-specific nuances underscore the importance of tailored probiotic interventions in mental health management. Future research should explore optimal combinations of probiotic strains, dosages, and treatment durations to maximize therapeutic outcomes. Additionally, investigating individual factors such as baseline microbiota composition, genetic predispositions, and lifestyle influences will further elucidate personalized approaches in probiotic therapy for mood disorders.

Our systematic review and meta-analysis, while informative, are subject to some limitations. A significant limitation of our study is the use of clinical instruments such as BDI, HAMD, DASS, and MADRS, which primarily assess depressive symptoms and may not sufficiently capture the presence or severity of anxiety symptoms. As state or trait anxiety cannot be clinically evaluated through these scales, our findings on anxiety should be interpreted with caution. Heterogeneity in study designs, including variations in probiotic strains ranging from single bacterial species to combinations of up to ten different bacterial species, as well as differences in treatment parameters, may introduce variability in treatment effects. Additionally, the utilization of diverse assessment tools capturing different dimensions of depression and anxiety could contribute to discrepancies in outcomes. Another notable limitation is the transient and temporary nature of shifts in gut microbiota induced by probiotic treatment. Alterations in gut microbiota composition may not be sustained over time, potentially necessitating longer treatment durations to achieve significant and lasting therapeutic effects. This transient effect could explain why some trials fail to observe substantial changes in the gut microbiome or improvements in mood within shorter intervention periods. Therefore, future research should prioritize evaluating the duration and sustainability of probiotic-induced microbiota changes to better understand their long-term impact on mental health outcomes and optimize treatment protocols.

Moreover, a limitation worth noting is the potential impact of confounders. While we conducted subgroup analyses based on relief from depressive and anxiety symptoms and ensured consistent treatment durations, other factors such as participants' baseline health, concurrent medications, lifestyle, and dietary habits were not consistently reported or controlled for across studies. This lack of detailed information makes it challenging to assess their potential impact on outcomes. Additionally, some of the included studies in our meta-analysis were marked as 'unclear' regarding blinding and allocation concealment, introducing uncertainty regarding the internal validity of the studies and the reliability of their outcomes. The presence of unclear blinding and allocation concealment raises concerns about the risk of performance and detection bias, which may influence the interpretation of the results.

Conclusions

This meta-analysis offers valuable insights into the strain-specific effects of probiotics containing Lactobacillus and Bifidobacterium species on depressive and anxiety symptoms. While our findings suggest a significant reduction in depressive symptoms based on the BDI scale favoring probiotics, the lack of significant effects observed on the HAMD, DASS, and MADRS scales underscores the complexity inherent in these conditions. It is imperative to acknowledge the mixed results across different measurement scales, indicating the need for cautious interpretation. Therefore, we advocate for a nuanced understanding of probiotics' impacts on various dimensions of mood, emphasizing the necessity for further research. Future studies should explore optimal probiotic formulations, treatment durations, and robust methodologies to better elucidate probiotics' therapeutic potential in managing depression and anxiety.

Abbreviations

BDI	Beck Depression Inventory
HAMD	Hamilton Depression Rating Scale
DASS	Depression Anxiety Stress Scales
MADRS	Montgomery-Asberg Depression Rating Scale
RCTs	Randomized Controlled Trials
CI	Confidence Interval
MD	Mean Difference

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13099-024-00634-8.

Supplementary Material 1

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Author contributions
All authors contributed equally to the conception, design, data collection, analysis, interpretation, and writing of the manuscript. All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors have consented to the publication of this manuscript.

Competing interests
The authors declare no competing interests.

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