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Effect of Modulation of Gut Microbiota through Dietary Interventions on Metabolic Health Indicators

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Abstract

The human gastrointestinal tract harbors a complex and diverse community of microorganisms, collectively referred to as the gut microbiota. This ecosystem, composed of bacteria, archaea, viruses, and fungi, plays a critical role in host health by contributing to digestion, nutrient absorption, immune function, and metabolic regulation. In recent years, research has increasingly highlighted the link between gut microbiota composition and metabolic disorders such as obesity, type 2 diabetes mellitus (T2DM), dyslipidemia, metabolic syndrome, and non-alcoholic fatty liver disease (NAFLD). Dysbiosi, which is an imbalance in the microbial community, has been implicated in the pathogenesis and progression of these conditions. Dietary interventions aimed at modulating the gut microbiota have emerged as promising strategies for managing and potentially reversing metabolic disorders. This systematic review evaluates the current evidence on the effects of various dietary interventions such as the Mediterranean diet, ketogenic diet, low-fat vegan diet, low-carbohydrate diet, and supplementation with probiotics, prebiotics, and synbiotics on gut microbiota composition and key metabolic indicators in adults with metabolic disorders. Following PRISMA guidelines and the PICO framework, fifteen randomized controlled trials and crossover studies published between 2010 and 2025 were reviewed. These studies involved 1669 adult participants diagnosed with metabolic disorders and assessed changes in microbiota composition alongside metabolic outcomes including body weight, insulin sensitivity, blood glucose, lipid profiles, and inflammatory biomarkers. Findings across the studies demonstrated that dietary interventions frequently resulted in positive shifts in gut microbial communities. In particular, increased abundance of beneficial taxa such as *Bifidobacterium*, *Faecalibacterium prausnitzii*, and *Akkermansia muciniphila* was often associated with improved metabolic outcomes. These bacteria are known to produce short-chain fatty acids (SCFAs), especially butyrate, which support gut barrier function, reduce inflammation, enhance insulin sensitivity, and regulate lipid metabolism. Several studies reported significant reductions in body weight, visceral fat, and BMI, as well as improvements in fasting glucose, HbA1c, cholesterol levels, and inflammatory cytokines following dietary intervention. However, the review also identified variability in individual responses and outcomes across studies. Factors such as baseline gut microbiota composition, genetic predisposition, type and duration of dietary intervention, and adherence influenced results. Not all studies reported statistically significant improvements, and some control groups also experienced metabolic benefits, limiting the observed differences.

Subject Areas

Public Health

Keywords

Gastrointestinal Tract Harbors, Microorganism, Ecosystem

1. Introduction

The human gastrointestinal tract harbors a diverse array of microorganisms, collectively referred to as the gut microbiota [1]. This community includes bacteria, fungi, viruses, and other microbes residing in the gastrointestinal tract. These organisms form a complex ecosystem that plays a crucial role in maintaining homeostasis, facilitating food digestion, promoting nutrient absorption, supporting immune function, and regulating various metabolic processes [2] [3].

The gut microbiota contributes to host metabolism through multiple biochemical pathways. For example, gut microbes are involved in the breakdown of bile acids, biosynthesis of essential vitamins such as vitamins K and B12, and fermentation of dietary polysaccharides—particularly those in dietary fibers that humans cannot digest—into short-chain fatty acids (SCFAs), including butyrate, propionate, and acetate [4]. These SCFAs serve as an energy source for intestinal epithelial cells and exert beneficial effects such as modulating inflammation, regulating appetite, and influencing glucose and lipid metabolism [4]. Consequently, the composition of the gut microbiota has been recognized as a critical determinant of metabolic health, with mounting evidence linking dysbiosis to various metabolic disorders.

Metabolic disorders, characterized by disturbances in normal metabolic processes, often involve systemic dysfunction in the metabolism of glucose, lipids, and other substrates. Common examples include type 2 diabetes mellitus (T2DM), obesity, dyslipidemia, non-alcoholic fatty liver disease (NAFLD), and metabolic syndrome. Diet plays a central role in the etiology, progression, and management of these conditions. Nutritional interventions are widely utilized as therapeutic strategies [5]. For instance, excessive caloric intake contributes to obesity, while high-glycemic diets can elevate blood glucose levels, increase insulin demand, and promote insulin resistance. Similarly, diets rich in saturated and trans fats are associated with dyslipidemia, and the growing prevalence of metabolic syndrome has been linked to poor dietary habits [6]-[8].

Dietary interventions serve as an effective approach for the management and prevention of metabolic disorders by aiming to regulate body weight, blood glucose, lipid profiles, and inflammatory status. Caloric restriction has proven effective in managing obesity [9], while low-glycemic index diets aid in stabilizing blood glucose and insulin levels in T2DM [5]. Reducing the intake of saturated and trans fats can also improve lipid profiles. Such interventions may involve altering the nutrient composition of the diet, using supplements, or modulating the gut microbiota to produce favorable metabolic outcomes. Common strategies include the administration of probiotics, prebiotics, synbiotics, high-protein diets, vegan diets, low-fat diets, and low-carbohydrate diets.

Assessing metabolic health indicators is essential for monitoring disease progression and evaluating responses to dietary or pharmacologic interventions. These indicators include anthropometric measures (e.g., weight, body composition, body mass index [BMI]), biochemical markers (e.g., fasting blood glucose, glycated hemoglobin [HbA1c], lipid profiles including LDL, HDL, and triglycerides), and inflammatory biomarkers (e.g., interleukin-6 [IL-6], interleukin-8 [IL-8]). Monitoring these metrics allows clinicians and researchers to evaluate the effectiveness of interventions. Several studies have explored how dietary modifications targeting the gut microbiome affect metabolic outcomes in conditions such as obesity, T2DM, and NAFLD [10].

Over time, research has expanded the understanding of the role of gut microbiota in human health. Early studies in the 20th century identified gut microbes but lacked insights into their functional significance due to technological limitations. Recent advances, such as high-throughput sequencing and metagenomics, have elucidated the diversity and metabolic functions of the gut microbial ecosystem [11]. Some studies have reported associations between gut microbiota dysbiosis and metabolic disorders. For example, Turnbaugh *et al.* (2006) found differences in gut microbial composition between obese and lean individuals [12]. Ridaura *et al.* demonstrated that fecal microbiota transplantation from obese mice could induce obesity in germ-free mice, implicating microbiota in the pathogenesis of obesity [13]. Other studies have explored the mechanisms through which the microbiota influences metabolism, further emphasizing its potential as a therapeutic target [14].

Multiple dietary approaches have been investigated for their ability to modulate the gut microbiota and improve metabolic health. Probiotics—live microorganisms such as *Lactobacillus* spp. and *Bifidobacterium* spp., administered in adequate amounts—have been shown to enhance insulin sensitivity, reduce inflammation in T2DM, and improve lipid metabolism [15]. Prebiotics, such as inulin, stimulate the growth and activity of beneficial gut microbes, thereby increasing SCFA production [16] [17]. Synbiotics, which combine probiotics and prebiotics, have also been studied, although results are mixed; for example, Kazanawa *et al.* reported no significant changes in glycemic control following 24 weeks of synbiotic supplementation [18] [19].

The Mediterranean diet—rich in fruits, vegetables, whole grains, nuts, and olive oil—has been shown to enhance gut microbial diversity and improve glucose metabolism. Galie *et al.* observed increased insulin sensitivity following dietary intervention with the Mediterranean diet [20]-[22]. Similarly, ketogenic and low-carbohydrate diets have been associated with alterations in gut microbiota and improved metabolic outcomes. Deledda *et al.* reported enhanced insulin sensitivity and glycemic control following the introduction of a ketogenic diet [23] [24].

Recent studies have also considered individual variability in baseline gut microbiota composition and host genetics, which may influence responses to dietary interventions. For example, Zhang *et al.* (2021) found that individuals with higher baseline levels of *Bacteroides* experienced greater weight loss [25]. Comparative studies, such as randomized crossover trials, have examined the differential effects of dietary interventions; Deledda *et al.* reported greater weight loss with a ketogenic diet than with a Mediterranean diet [23].

Given the increasing global prevalence of T2DM and obesity, there is an urgent need for sustainable and effective interventions. Dietary strategies offer a promising non-pharmacologic approach that could reduce reliance on medication, lower healthcare costs, and enhance quality of life. Some studies suggest that these interventions may be tailored to individual needs based on microbiota profiles. However, translating these findings into clinical practice requires comprehensive and systematically synthesized evidence, which is currently lacking. Variability in study design, population characteristics, dietary interventions, and outcome measures has contributed to the heterogeneity of existing data.

These gaps in the literature limit the development of robust clinical guidelines. This systematic review seeks to address these gaps by critically appraising recent evidence on dietary interventions targeting the gut microbiome and their effects on metabolic health indicators in adults with metabolic disorders. Specifically, the objectives are to:

- Identify the effects of dietary interventions on gut microbiota composition and diversity.
- Assess the impact of each intervention on metabolic indicators such as body weight, glycemic control, lipid profiles, and inflammatory biomarkers.
- Compare the microbiota and metabolic effects of different dietary interventions in similar populations.

This review will enhance the understanding of the interactions among diet, gut microbiota, and metabolism, and inform clinical decision-making in the management of metabolic disorders. It will also provide recommendations based on the strengths and limitations of current research, thereby guiding future investigations and supporting evidence-based practice.

2. Methodology

This study followed the PRISMA guidelines, and the PICO framework was used to formulate the research question and study selection [26] [27]. The population (P) refers to adults with metabolic disorders, the intervention (I) includes dietary interventions that aim to modulate gut microbiota, such as the use of probiotics, specific diets and so on, the comparison (C) is a standard/conventional diet, and the outcomes (O) being assessed are metabolic health indicators. The purpose of this study is to address this research question: **In adults with metabolic disorders (P), how does modulation of gut microbiota through dietary interventions (I) compared to a standard diet (C) affect metabolic health indicators (O)?**

2.1. Inclusion and Exclusion Criteria

Original peer-reviewed studies on this topic were selected (Randomized controlled trials (RCTs), cohort studies, clinical trials). Studies investigating dietary interventions modulating gut microbiota were included (probiotics, prebiotics, fiber supplementation, Mediterranean diet, ketogenic diet). Studies that measure metabolic health indicators such as insulin sensitivity, blood glucose levels, lipid profiles, BMI, weight loss, and inflammation were included.

Studies on non-human populations (animal studies), and studies without a standard diet control group or clear metabolic health indicators. Studies published outside the 2010-2025 timeframe, non-peer-reviewed articles, and dissertations were not included. Studies not published in English or not available in full-text format were also excluded.

Animal studies were excluded in order to ensure that the findings of this review are applicable to human health due to various interspecies differences in gut microbiome composition, diet, and metabolism (See Table 1).

2.2. Search Strategy

A search was conducted in PubMed Google Scholar, and Cochrane library and the following search terms were used:

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Original studies	Systematic Reviews
Studies published between 2010-2025	Studies not published between 2010-2025
Studies with human subjects	Studies with animal subjects
Peer-reviewed publications	Dissertations, thesis, etc.
Studies published in English Language	Studies not in English Language
Articles accessible in full-text	Articles not accessible in full-text
Studies with clear metabolic indicators and diet control groups	Studies without clear metabolic indicators and control groups.

- **"dietary intervention" OR "probiotics" OR "prebiotics" OR "dietary fiber" OR "Mediterranean diet" OR "ketogenic diet"**
- **"gut microbiota" OR "gut microbiome" OR "microbiome"**
- **"metabolic health" OR "insulin sensitivity" OR "glucose metabolism" OR "lipid metabolism" OR "BMI" OR "weight loss" OR "inflammatory markers"**
- **"metabolic disorders" OR "obesity" OR "type 2 diabetes" OR "dyslipidemia"**
- **"clinical trial" OR "randomized controlled trial"**
- **"adult"**

Boolean operators "AND" and "OR" were used to combine the keywords into strings for advanced searches and the studies were filtered for publication in English and published within the last 15 years (2010-2025).

2.3. Study Selection and Screening

The initial search on PubMed, Google Scholar and Cochrane Library retrieved a total of 22,399 articles. The titles and abstracts of these articles were screened, and 22,328 were excluded for failing to meet the inclusion criteria. The remaining 71 articles were uploaded into Rayyan software for duplicate detection and were reviewed in full text [28]. Studies were included and excluded based on the inclusion and exclusion criteria.

Four individuals carried out the full-text screening and differences resolved through discussion. Data from the included studies were extracted into a data extraction matrix (See **Table 2**) that included study characteristics (authors, publication year, study design), Population (sample size, characteristics, metabolic disorder diagnosed), Intervention details (type of dietary intervention, duration), Outcome measures, Key findings and a Critical Appraisal of the findings. A CASP checklist (See **Appendix**) was also used to assess the quality of the studies [29].

2.4. Ethical Considerations

As this study involved a review of existing literature, no ethical approval was required. All data used in the review were from publicly available, peer-reviewed sources. The studies that involved primary data collection received ethical approval to be conducted and obtained informed consent from participants, the confidentiality of participants was maintained.

Table 2. Data extraction matrix.

	Authors	Year	Study Design	Sample Size	Population	Metabolic Disorder Diagnosed	Intervention	Duration	Outcome Measures	Key Findings	Critical Appraisal
1	Kahleova *et al.*	2020	Randomized Clinical Trial	168	Overweight individuals	Obesity, Insulin Sensitivity	Low-fat vegan diet	16 weeks	Body weight, body composition, insulin sensitivity, gut microbiota	Significant reduction in body weight (−5.9 kg), fat mass (−3.9 kg), and visceral fat (−240 cm^3) in the vegan diet group. Increased insulin sensitivity (+0.83). Increased relative abundance of *Faecalibacterium prausnitzii*, which correlated with weight and fat loss [33].	Well-designed study with a large sample size. However, the study only focused on a specific diet (low-fat vegan), limiting generalizability and the duration of the study was a short period.
2	Hiel *et al.*	2020	Randomized Placebo-Controlled Trial	150	Obese individuals	Obesity	Inulin supplement	3 months	Body composition, glucose, microbiome	Inulin supplementation resulted in greater weight loss (−2.2 kg) compared to placebo. Significant reductions in systolic blood pressure, serum AST, and insulin levels. Altered gut microbiota with a significant increase in *Bifidobacterium* [17].	The study's limitations are the relatively short duration. Potential confounding factors were not fully controlled (some of the individuals were being treated with metformin which may possibly alter gut microbiota and some individuals reported side effects)
3	Deledda *et al.*	2022	Randomized Controlled Trial	11	Type 2 diabetes, Obesity	Type 2 Diabetes	Ketogenic vs Mediterranean Diet	3 months	Weight, body composition, gut microbiota	The ketogenic diet group showed significantly better weight loss and reduction in fat mass compared to the Mediterranean diet group. Changes in gut microbiota showed a shift towards beneficial taxa like Akkermansia [23].	The sample size was small, and the small sample size (n = 11) limits the power and generalizability of the results. Both diets were well-designed, but the short follow-up period might not capture long-term effects.
4	Henning *et al.*	2019	Randomized Controlled Trial	51	Overweight individuals	Obesity	Avocado-based hypocaloric diet	12 weeks	Weight loss, biomarkers, gut microbiota	Both groups experienced weight loss, but the avocado group showed significant reductions in triglycerides and serum hepatic growth factor (HGF). There was a significant increase in the relative abundance of beneficial gut bacteria, particularly Bacteroides and Clostridium [37].	The participants were not blinded to what group they were assigned to and this could have affected compliance with the dietary plan. The duration of the study was short and the drop-out rate (12 participants) could have affected the results.

Continued

5	Galiè *et al.*	2021	Randomized Crossover Trial	44	Adults with Metabolic Syndrome	Metabolic Syndrome (MetS)	Mediterranean Diet vs. Nuts Supplementation	2 months per intervention, 1-month washout period	Plasma metabolites, glucose, insulin, HOMA-IR, gut microbiota composition	Mediterranean Diet resulted in significant improvements in plasma metabolites, insulin sensitivity (HOMA-IR), and metabolic profile (glucose, insulin). The gut microbiota composition shifted favorably with Mediterranean Diet compared to the nuts supplementation [22].	The crossover design minimizes intra-individual variability. The relatively small sample size and the lack of blinding are notable limitations and the study also did not identify species-level bacterial changes, limiting detailed microbiota analysis.
6	Sergeev *et al.*	2020	Randomized controlled trial	20	Obese individuals	Obesity	Synbiotic supplement	3 months	Weight loss, gut microbiota, blood biomarkers	Synbiotics (Lactobacillus and *Bifidobacterium* strains) showed an increase in beneficial gut bacteria, including *Bifidobacterium*. However, there were no statistically significant differences in body composition, including body fat mass or BMI [36].	The sample size was small and short duration of the trial (3 months) and lack of blinding of the study participants. The adherence to the dietary plan was also not adequately tracked.
7	Hasain *et al.*	2022	Randomized Clinical Trial	132	Post-GDM women	Gestational Diabetes Mellitus	Probiotics	12 weeks	Fasting glucose, HbA1c, cholesterol, triglycerides, microbiota	After the 12-week intervention, the probiotics group's fasting blood glucose level significantly decreased (mean difference −0.20 mmol/L; $p = 0.0021$). The HbA1c, total cholesterol, triglycerides, and high-sensitivity C-reactive protein levels were significantly different between the two groups ($p < 0.05$). Sequencing data also demonstrated a large rise in the *Bifidobacterium* adolescentis following probiotic supplementation [32].	The duration of the study was short and does not show long-term impacts. The exact probiotic strains used were well-chosen, but more research on account for dose-response relationships is needed.
8	Muralidharan *et al.*	2021	Randomized Controlled Trial	362	Overweight/obese adults	Metabolic Syndrome	Mediterranean diet + physical activity	1 year	Weight loss, BMI, glucose, cholesterol, microbiota	The Mediterranean diet with physical activity resulted in greater weight loss (−4.2 kg) and improvements in metabolic health (glucose, cholesterol, triglycerides). Significant changes in gut microbiota, including reductions in *Butyricicoccus* and *Ruminiclostridium* [30].	The study may have confounded the effects of exercise and diet. Further trials focusing on diet alone would be beneficial.

Continued

9	Zhang *et al.*	2021	Randomized Controlled Trial	60	Obese individuals	Obesity	Low-carbohydratediet (LCD)	12 weeks	Weight loss, gut microbiota, biomarkers	LCD significantly improved weight loss outcomes in participants with higher baseline Bacteroides abundance. Gut microbiota changes, including an increase in butyrate-producing bacteria like Porphyromonadaceae and Ruminococcaceae, were associated with weight loss [25].	The study was well-conducted with a clear hypothesis linking gut microbiota to diet outcomes. However, it focused on short-term outcomes (12 weeks).
10	Lauw *et al.*	2023	Randomized Trial	55	Overweight/obese individuals	Metabolic Syndrome	Synbiotic supplementation	8 weeks	Weight loss, insulin resistance, microbiota	The combination of increased dietary fiber and synbiotics resulted in significant improvements in weight loss and metabolic syndrome markers (glucose, insulin, triglycerides). There was a reduction in Megamonas abundance, which correlated with improved metabolic outcomes [44].	However, the sample size was relatively small, and the duration was short (8 weeks). The findings suggest that synbiotics can complement dietary fiber to improve metabolic syndrome, but larger studies are required to confirm these results.
11	Kanazawa *et al.*	2021	Randomized Controlled Trial	88	Obese patients with Type 2 Diabetes	Type 2 Diabetes	Synbiotic supplementation (*Lacticaseibacillus paracasei* & *Bifidobacterium breve* with Galactooligosaccharides)	24 weeks	Interleukin-6, gut microbiota, fecal organic acids	Synbiotics improved gut microbiota composition (increase in *Bifidobacterium* species), but did not significantly affect inflammation markers (IL-6, CRP) [19].	Longer duration or higher doses of synbiotics might show more effects.
12	Zikou *et al.*	2023	Randomized, Double-Blind, Placebo-Controlled Trial	91	People with Type 2 Diabetes in Greece	Type 2 Diabetes	Multi-strain probiotic supplement (*Lactobacillus acidophilus*, *Lactobacillus plantarum*, *Bifidobacterium lactis*, *Saccharomyces boulardii*)	6 months	HbA1c, fasting glucose, lipid levels, gut microbiome	Significant reductions in HbA1c, fasting glucose, and cholesterol, with improvements in body fat and waist circumference. No significant changes in microbiome diversity [34].	This study had a high drop-out rate (32.6%) there was also no adequate tracking of the diets of the participants and this could have affected results. The possible effects of antidiabetic medications such as Metformin on gut microbiota may have also affected results.
13	Zhang *et al.*	2023	Randomized Controlled Trial	55	Obese individuals with colorectal neoplasia history	Obesity, Metabolic Syndrome	Prebiotic food (beans) addition to diet	16 weeks	Gut microbiota diversity, circulating metabolites, inflammatory markers	Increased gut microbiota diversity, particularly *Faecalibacterium*, and reductions in pro-inflammatory markers. Parallel shifts in metabolites like pipecolic acid [34].	Promising evidence for prebiotic effects of beans on gut microbiota and metabolic health. There was no wash-out period between the crossovers.

Continued

14	Chooi *et al.*	2024	Randomized Controlled Trial	88	Chinese females with NAFLD	Non-alcoholic Fatty Liver disease	Mediterranean diet with or without C15:0 supplementation	12 weeks	Weight, liver fat, cholesterol, gut microbiota	Mediterranean diet led to weight loss, reduced liver fat (PDFF), and improved cholesterol. C15:0 supplementation reduced LDL-cholesterol and promoted beneficial gut microbiota shifts [30].	The study could be expanded for greater generalizability. Sample size can be larger.
15	Rinott *et al.*	2022	Randomized Controlled Trial	294	Individuals with abdominal obesity/dyslipidemia	Abdominal obesity, Dyslipidemia	Green-Mediterranean diet (green tea, Mankai aquatic plant, walnuts)	12 weeks	Weight, abdominal fat, cholesterol, gut microbiota	Green-MED diet led to more prominent microbiome changes, especially in non-core taxa. Reduced body weight and improved cardiometabolic markers [21].	The strengths of the study include the intense dietary instruction and multidisciplinary supervision, the simultaneous design, and the high retention rate.

3. Results

3.1. Study Characteristics

The studies selected for this review were published between 2019 and 2024, 15 in total- 13 randomized control trials and 2 crossover trials. They all studied the effects of dietary interventions that modulate gut microbiota on metabolic outcomes. The individual sample sizes ranged from (n = 11) in the study by Deledda *et al.* in 2022 [23], to (n = 362) in the study by Muralidharan *et al.* in 2022 [30] and a total of 1669 participants across all studies. The populations studied included Adults with metabolic disorders such as Obesity, Type 2 Diabetes Mellitus, Gestational Diabetes, Dyslipidemia, Metabolic syndrome and Non-alcoholic fatty liver disease. Most of the studies had a balanced gender distribution but 2 of the studies used an all-female population [31] [32].

The studies were conducted in various locations, 5 studies were conducted in Europe (Belgium, Spain, Italy and Greece), 7 studies were conducted in Asian countries such as Japan, China, Malaysia and Israel and 3 of the studies were conducted in the United States of America. The different dietary interventions included low-fat vegan diet, ketogenic diet, mediterranean diet, avocado-enriched hypocaloric diet, synbiotics, probiotics and prebiotics, and all studies had control groups.

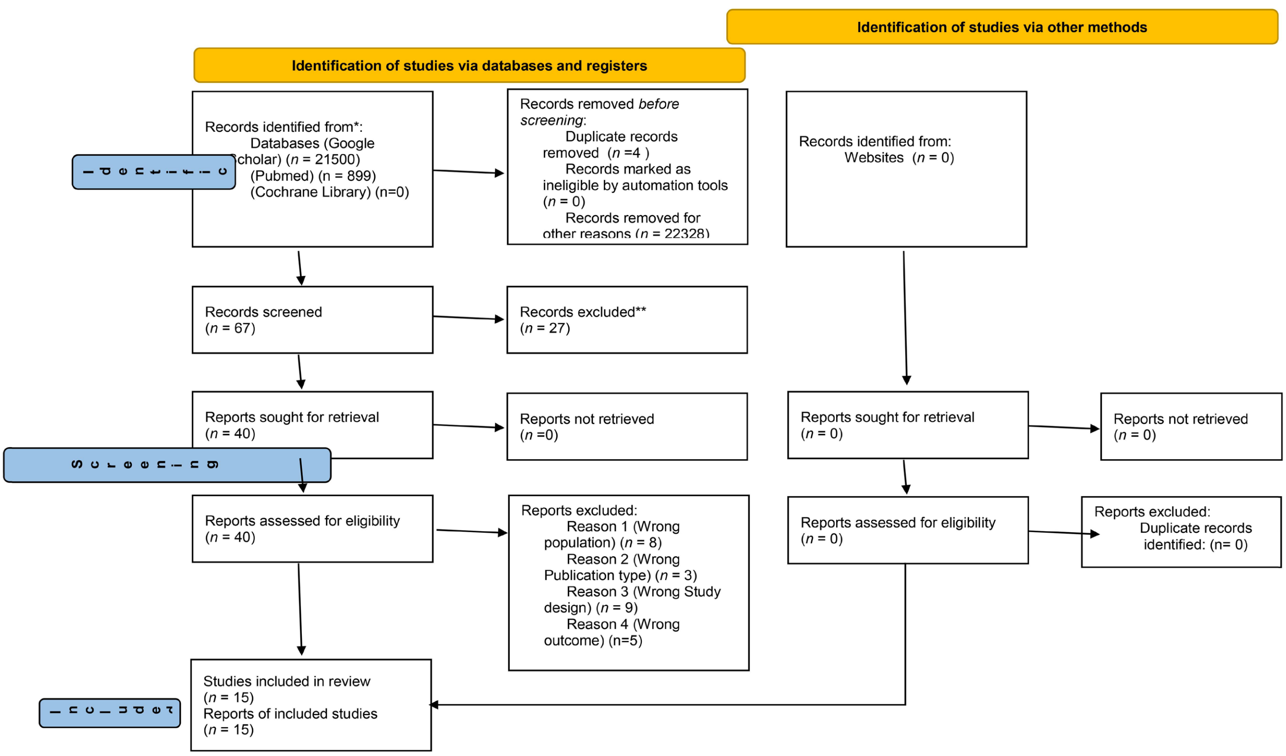

Figure 1. Prisma flowchart.

The search results presented in **Figure 1** above (the PRISMA flow chart) show the summary of the papers used in the study. The databases provided a total of

Twenty two thousand three hundred and ninety five (22,399) research papers, of which only fifteen met the inclusion criteria for this systematic review (See **Appendix**).

3.2. Changes in Gut Microbiota

Differences in the composition of gut microbiota were observed with most dietary interventions. Kahleová *et al.* (2020) reported an increase in the abundance of *Faecalibacterium prausnitzii* following the introduction of a low-fat vegan diet. Similarly, Hiel *et al.*, in a study on inulin supplementation in obese individuals, observed an increase in *Bifidobacterium*, which was associated with improvements in metabolic health [33]. Chooi *et al.* reported an increase in *Bifidobacterium adolescentis* resulting from C-15 (pentadecanoic acid) supplementation, and Kanazawa *et al.* also reported favorable changes in the abundance of *Bifidobacterium adolescentis* and *Bifidobacterium pseudocatenulatum* in their intervention group [31]. Another study by Hassain *et al.* (2022) also documented an increase in *Bifidobacterium adolescentis* following a dietary intervention [32].

Zikou *et al.* (2023) reported the effects of a probiotic supplement on gut microbiota, showing an increase in the genera *Akkermansia*, *Megamonas*, and *Flavonifractor*, while *Shigella* showed a significant decrease in relative abundance in the intervention group [34]. An intervention by Deledda *et al.* (2022) involving a ketogenic diet demonstrated a shift in the gut microbiome, with a significant increase in beneficial microbial taxa such as members of the phylum *Verrucomicrobiota*—including *Verrucomicrobiae*, *Verrucomicrobiales*, *Akkermansiaceae*, and *Akkermansia*—as well as *Christensenellaceae*, *Eubacterium* spp., and a reduction in microbial taxa previously associated with obesity, such as *Firmicutes* and *Actinobacteriota* [23].

In the BE-GONE trial, which utilized beans as a prebiotic, an increase in the abundance of *Bifidobacterium adolescentis*, *Eubacterium rectale*, and *Eubacterium* spp. was reported after the intervention, accompanied by reductions in pro-inflammatory markers [35].

In 2021, Zhang *et al.* investigated the effects of a low-carbohydrate diet and observed an increase in butyrate-producing bacteria such as *Ruminococcaceae* and *Porphyromonadaceae* [25]. Rinott *et al.* reported that the Green-Mediterranean diet led to an increase in *Prevotella* and a decrease in *Bifidobacterium* spp. [21]. Sergeev *et al.*, in a placebo-controlled study on a synbiotic intervention, reported an increase at the genus level in *Ruminococcus*, *Bifidobacterium*, *Sutterella*, *Tyzzerella*, *Eisenbergiella*, *Eubacterium*, *Eggerthella*, *Methanobrevibacter*, *Lachnospiraceae*, *Edwardsiella*, *Lactobacillus*, *Allobaculum*, *Enterococcus*, *Hydrogenoanaerobacterium*, *Coprococcus*, and *Butyricimonas*. Conversely, the relative abundance of *Ruminococcaceae*, *Prevotella*, *Gardnerella*, *Turicibacter*, and *Megasphaera* was lower in the synbiotic group compared to the placebo group [36].

3.3. Effect on Body Composition and Weight

Some studies reported no significant differences in weight or body composition following dietary interventions. For example, Henning *et al.* (2019) found that an avocado-based hypocaloric diet resulted in significant weight loss; however, weight loss was also observed in the control group, and no statistically significant differences were noted between the groups [37]. Similarly, Sergeev *et al.* reported no significant changes in body composition or body fat percentage following their intervention [36].

Conversely, several studies reported positive changes, including reductions in body weight and composition, as a result of dietary interventions. In a randomized controlled trial conducted by Kahleová *et al.* (2020), a low-fat vegan diet led to a significant reduction in body weight, fat mass, and visceral fat volume (treatment effect: −5.9 kg, −3.9 kg, and −240 cm^3, respectively) [33]. Hiel *et al.* also reported greater weight loss and a reduction in body mass index (BMI) following inulin supplementation [17]. Similarly, Deledda *et al.* (2022) documented reductions in body weight and BMI after the introduction of ketogenic and Mediterranean diets [23]. In another study, Muralidharan *et al.* (2021) found that adherence to a Mediterranean diet combined with physical activity resulted in greater weight loss (−4.2 kg) [30]. Zhang *et al.* (2021) also observed significant weight loss following a low-carbohydrate dietary intervention [25].

3.4. Effect on Insulin Sensitivity and Glucose Control

Some studies reported improvements in blood glucose control and insulin sensitivity following dietary interventions. For example, Galié *et al.* observed an improvement in HOMA-IR, a measure of insulin sensitivity, after an intervention with the Mediterranean diet [22]. Hasain *et al.* and Zikou *et al.* reported that probiotic supplementation significantly reduced fasting blood glucose and glycated hemoglobin (HbA1c) levels in study participants [32]-[34]. Deledda *et al.* (2022) also found that a ketogenic diet led to improvements in insulin sensitivity and glucose control [23].

However, Kanazawa *et al.* (2021) reported no significant differences in glycemic control between the two groups at 24 weeks. Notably, the symbiotic group exhibited significantly higher fasting blood glucose and HbA1c levels at 12 weeks compared to the control group [19].

3.5. Lipid Profile and Other Biomarkers

Positive changes in lipid profiles were reported in several studies. For example, Galié *et al.* reported a reduction in total cholesterol and an improvement in HDL cholesterol levels following a Mediterranean dietary intervention, while Zikou *et al.* observed reductions in LDL cholesterol and triglycerides with probiotic supplementation [22] [34]. Chooi *et al.* (2024) also reported a reduction in LDL cholesterol as a result of C15 (pentadecanoic acid) supplementation [31]. Similarly, Hasain *et al.* observed a decrease in mean total cholesterol levels following probiotic supplementation [32]. Henning *et al.* reported a reduction in serum hepatic growth factor following the introduction of an avocado-based hypocaloric diet [37].

Some studies also assessed the effects of these interventions on inflammatory biomarkers. Hasain *et al.* (2022) reported higher levels of interleukin-6 (IL-6) and interleukin-8 (IL-8) in the control group, while Kanazawa *et al.* noted no significant differences in IL-6 levels between groups [132]. The BE-GONE trial by Zhang *et al.* (2023) reported an increase in fibroblast growth factor 19 (FGF-19), while levels of interleukin-10 receptor alpha (IL10RA) and other cytokines—including tumor necrosis factor-related activation-induced cytokine (TRANCE), T-cell surface glycoprotein CD8 alpha chain (CD8A), programmed cell death 1 ligand 1 (PD-L1), C-X-C motif chemokine ligand 1 (CXCL1), and urokinase-type plasminogen activator (uPA)—decreased in response to an 8-week bean-based dietary intervention [35].

3.6. Comparison of Dietary Interventions

A comparison of the Mediterranean diet and ketogenic diet by Deledda *et al.* (2022) reported greater weight loss in the ketogenic diet group than in the Mediterranean diet group, although both diets led to an increase in beneficial gut microbiota, such as *Akkermansia* [23]. Galié *et al.* also compared the Mediterranean diet to nut supplementation and reported a general increase in circulating plasma amino acids; specifically, phenylalanine, histidine, cystathionine, and threonine levels were higher in the Mediterranean diet group, while cysteine was higher in the nut supplementation group. Additionally, they reported higher succinate levels and increased testosterone in the Mediterranean diet group, whereas androsterone sulfate levels were elevated in the nut supplementation group [22].

4. Discussion

Certain gut microbial taxa may be responsible for the positive metabolic changes observed following dietary interventions. *Bifidobacterium*, *Akkermansia*, and *Faecalibacterium* were reported in several of the studies reviewed. These studies documented increases in these microbial groups, accompanied by improvements in metabolic indicators. For instance, Hiel *et al.* (2020) found that inulin supplementation increased *Bifidobacterium* abundance, which was associated with enhanced weight loss and insulin sensitivity. Several other studies similarly reported an increase in *Bifidobacterium* [17]. Zikou *et al.* and Deledda *et al.* observed increased levels of *Akkermansia* following their respective interventions, along with improvements in weight loss and glycemic control [34]. Kahleova *et al.* reported that *Faecalibacterium prausnitzii* increased among participants following a vegan diet intervention, with corresponding weight reduction [33].

Short-chain fatty acids (SCFAs), which are produced by these bacterial taxa, serve as energy sources for gastrointestinal cells and perform various metabolic functions, including appetite regulation, inflammation reduction, improved insulin sensitivity, and maintenance of intestinal barrier integrity [4]. These effects may underlie the metabolic benefits observed with increased abundance of these taxa. However, not all studies reported a consistent relationship between increased abundance of these organisms and improved metabolic parameters. For example, Zhang *et al.* (2021) suggested that baseline gut microbiota composition influenced individual responses to dietary interventions; participants with higher baseline levels of *Bacteroides* experienced more pronounced weight loss [25]. Furthermore, sample sizes in many of these studies were small, and the duration of interventions relatively short. A subsequent study by Zhang *et al.* (2023) found no significant improvement in insulin resistance in some participants, despite increased *Faecalibacterium prausnitzii* abundance [35].

Although *Bifidobacterium*, *Akkermansia*, and *Faecalibacterium* are important gut taxa implicated in metabolic benefits from dietary interventions, findings suggest that their increase alone does not universally lead to clinical improvements. Other factors, such as host genetics and baseline microbiota composition, may also play significant roles.

Dietary interventions targeting the gut microbiome have shown potential to promote weight loss and improve body composition in adults with metabolic disorders. Several studies reported significant reductions in body weight and other anthropometric measurements. For example, Kahleova *et al.* (2020) observed weight and fat mass reduction following a low-fat vegan diet. Similarly, Hiel *et al.* reported weight loss and BMI reduction with inulin supplementation [33]. Zhang *et al.* (2021) noted weight loss among participants on a low-carbohydrate diet, while Deledda *et al.* reported similar outcomes with ketogenic and Mediterranean diets [25]. Muralidharan *et al.* found that combining a Mediterranean diet with physical activity further enhanced weight loss [30]. However, not all studies demonstrated statistically significant differences; Henning *et al.* and Sergeev *et al.* observed no significant differences between intervention and control groups [36] [37].

Several mechanisms have been proposed to explain these effects, including increased SCFA production by gut microbiota. Butyrate, for example, may regulate appetite by promoting satiety and improve energy expenditure and fat metabolism [4]. Contradictory results in some studies may be attributed to short intervention durations or to control diets that also conferred metabolic benefits—for instance, a hypocaloric diet (Henning *et al.*) and a low-carbohydrate high-protein diet (Sergeev *et al.*) [36] [37]. Nevertheless, dietary modifications targeting the gut microbiota remain a promising strategy for achieving weight loss and improving body composition in individuals with metabolic disorders.

Dietary interventions may also enhance glycemic control in individuals with type 2 diabetes mellitus (T2DM) by modulating the gut microbiome and increasing insulin sensitivity. Galie *et al.* linked increased SCFA-producing bacteria, induced by adherence to a Mediterranean diet, to improved insulin sensitivity (measured by HOMA-IR), HbA1c, and fasting blood glucose levels [22]. Deledda *et al.* similarly reported improved insulin sensitivity and glycemic regulation following a ketogenic diet intervention [23]. Zikou *et al.* and Hasain *et al.* observed reductions in fasting blood glucose and HbA1c after probiotic supplementation [32] [34]. In contrast, Kanazawa *et al.* (2021) found no significant differences in glycemic control following synbiotic supplementation at 24 weeks [19].

It is postulated that these improvements arise from reduced gut permeability and systemic inflammation, mediated by SCFAs [38]. However, confounding factors, such as the use of hypoglycemic agents like metformin, which also influence gut microbiota composition, may affect responses to dietary interventions. Despite individual variability, the evidence supports the efficacy of microbiota-targeting dietary interventions in improving glycemic control in T2DM patients [34].

Lipid metabolism also appears to benefit from dietary interventions that alter the gut microbiota. Several studies reported favorable changes in lipid profiles. For example, Zikou *et al.* and Hasain *et al.* observed reductions in LDL cholesterol and triglycerides following probiotic supplementation. Chooi *et al.* reported lowered LDL cholesterol with C15 supplementation, and Galie *et al.* noted reductions in total cholesterol and improvements in HDL cholesterol after adherence to a Mediterranean diet [31] [32] [34].

SCFAs are known to influence bile acid metabolism and lipid synthesis. Butyrate, in particular, plays a critical role in regulating lipid storage and synthesis pathways [39]. SCFAs also activate GPR43 receptors, which regulate cholesterol metabolism and triglyceride storage in tissues [40]. Thus, dietary interventions that enhance SCFA production via gut microbiota modulation may contribute to improved lipid metabolism.

Furthermore, some dietary interventions reduce systemic inflammation by lowering levels of inflammatory biomarkers in individuals with metabolic disorders. Several studies reported decreases in pro-inflammatory cytokines following intervention. For instance, Hasain *et al.* found higher levels of interleukin-6 and interleukin-8 in the control group compared to the intervention group, whereas Kanazawa *et al.* found no significant differences in interleukin-6 levels [32]. The anti-inflammatory effects are believed to be mediated by SCFAs, which act as signaling molecules that activate receptors promoting the release of anti-inflammatory cytokines and suppressing pro-inflammatory mediators. SCFA-producing bacteria may also modulate immune responses through T-cell regulation [41]. Thus, the anti-inflammatory benefits of dietary interventions targeting the gut microbiota are likely mediated by microbial metabolites such as SCFAs.

The effectiveness of dietary interventions in modulating the gut microbiome and improving metabolic outcomes varies depending on the specific dietary approach. The studies included in this review utilized various diets, including vegan, ketogenic, low-carbohydrate, and Mediterranean diets, as well as probiotic and synbiotic supplementation, each demonstrating differing degrees of impact on metabolic parameters. For instance, one study comparing ketogenic and Mediterranean diets found greater weight loss in the ketogenic group [23]. Galie *et al.* also reported distinct metabolomic profiles when comparing Mediterranean diets to nut supplementation, with differences in plasma amino acid and hormone levels [22].

These differences may be attributed to variations in macronutrient composition, fiber content, and bioactive compounds, which influence gut microbial communities in unique ways. Ketogenic diets, typically low in fermentable fiber, promote the growth of specific bacteria [42], whereas Mediterranean diets, rich in fiber and polyphenols, support the proliferation of SCFA-producing taxa [43]. These findings suggest that dietary interventions should be individualized based on the patient's needs and baseline gut microbiota composition to optimize metabolic outcomes, as further supported by evidence from Lauw *et al.*, who demonstrated that synbiotic supplementation tailored to dietary patterns improved metabolic parameters and modulated gut microbiota in overweight individuals [44].

5. Conclusions

This systematic review synthesizes current evidence on the impact of dietary interventions that modulate the gut microbiota on metabolic health indicators in adults with metabolic disorders. The findings affirm the significant role of gut microbiota in influencing metabolic outcomes such as body weight, glycemic control, lipid profiles, and inflammation. Across a diverse range of dietary approaches—including Mediterranean, vegan, ketogenic, low-carbohydrate diets, as well as probiotic, prebiotic, and synbiotic supplementation—there is a consistent association between beneficial shifts in gut microbial composition and improvements in metabolic health.

Notably, certain bacterial taxa such as *Bifidobacterium*, *Faecalibacterium prausnitzii*, and *Akkermansia muciniphila* were frequently associated with favorable changes in metabolic indicators. Their presence often coincided with enhanced short-chain fatty acid (SCFA) production, which in turn contributed to reduced systemic inflammation, improved insulin sensitivity, and better lipid metabolism. However, the review also highlights the complexity of the gut microbiome's interaction with diet; not all interventions led to statistically significant improvements, and individual variability in response—potentially due to baseline microbiota composition and host genetics—was evident.

Weight reduction and improvements in body composition were consistently observed in several studies, especially those involving vegan, ketogenic, and Mediterranean diets. These effects appear to be mediated through both caloric restriction and microbial shifts. Similarly, interventions improved glycemic control in individuals with type 2 diabetes, as reflected by reductions in HbA1c and fasting glucose levels. Lipid profiles also showed notable improvements, particularly reductions in LDL cholesterol and triglycerides, as well as increases in HDL cholesterol in some cases.

Despite promising results, the heterogeneity in study design, intervention duration, sample size, and participant characteristics presents challenges in generalizing these findings. Additionally, confounding factors such as medication use and dietary adherence further complicate the interpretation of outcomes. While the reviewed studies support the therapeutic potential of targeting gut microbiota through diet, robust, long-term randomized controlled trials with standardized methodologies are needed to establish causality and inform clinical guidelines.

In conclusion, modulating the gut microbiota through tailored dietary interventions represents a promising, non-pharmacological strategy for managing metabolic disorders. Integrating microbiome profiling into personalized nutrition plans may enhance intervention efficacy and optimize health outcomes. Future research should prioritize longitudinal designs, mechanistic studies, and the development of individualized treatment frameworks to fully harness the gut microbiota's therapeutic potential.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix: Casp Checklist

Paper for appraisal and reference: Effect of modulation of gut microbiota through dietary interventions on metabolic health indicators

Section A: Are the results of the review valid?			
1) Did the review address a clearly focused question?	Yes Can't Tell No	✓	HINT: An issue can be 'focused' In terms of • the population studied • the intervention given • the outcome considered
Comments: The research question was focused clearly using the PICO framework: In adults with metabolic disorders (P), how does modulation of gut microbiota through dietary interventions (I) compared to a standard diet (C) affect metabolic health indicators (O)?			
2) Did the authors look for the right type of papers?	Yes Can't Tell No	✓	HINT: 'The best sort of studies' would • address the review's question • have an appropriate study design (usually RCTs for papers evaluating interventions)
Comments: A search was conducted in PubMed and Google Scholar and the following search terms were used: "dietary intervention" OR "probiotics" OR "prebiotics" OR "dietary fiber" OR "Mediterranean diet" OR "ketogenic diet" "gut microbiota" OR "gut microbiome" OR "microbiome" "metabolic health" OR "insulin sensitivity" OR "glucose metabolism" OR "lipid metabolism" OR "BMI" OR "weight loss" OR "inflammatory markers" "metabolic disorders" OR "obesity" OR "type 2 diabetes" OR "dyslipidemia" "clinical trial" OR "randomized controlled trial" "adult" Boolean operators "AND" and "OR" were used to combine the keywords into strings for advanced searches and the studies were filtered for publication in English and published within the last 15 years (2010-2025).			
Is it worth continuing?			
3) Do you think all the important, relevant studies were included?	Yes Can't Tell No	✓	HINT: Look for • which bibliographic databases were used • follow up from reference lists • personal contact with experts • unpublished as well as published studies • non-English language studies
Comments: The initial search on PubMed, Google Scholar and Cochrane Library retrieved a total of 22,399 articles. The titles and abstracts of these articles were screened, and 22,328 were excluded for failing to meet the inclusion criteria. The remaining 71 articles were uploaded into Rayyan software for duplicate detection and were reviewed in full text 28. Studies were included and excluded based on the inclusion and exclusion criteria.			
4) Did the review's authors do enough to assess quality of the included studies?	Yes Can't Tell No	✓	HINT: The authors need to consider the rigour of the studies they have identified. Lack of rigour may affect the studies' results ("All that glisters is not gold" Merchant of Venice – Act II Scene 7)
Comments: A critical appraisal was performed on individual studies, noting sample size limitations, intervention durations, potential confounders (e.g., metformin use), blinding issues, and adherence challenges.			

Continued

5) If the results of the review have been combined, was it reasonable to do so?	Yes Can't Tell No	✓ (Yes)	HINT: Consider whether • results were similar from study to study • results of all the included studies are clearly displayed • results of different studies are similar • reasons for any variations in results are discussed
Comments: While some results were similar across some studies, there was some heterogeneity with some results. The variability in the characteristics of the selected studies also necessitated a qualitative format for the results.			
Section B: What are the results?			
6) What are the overall results of the review?			HINT: Consider • If you are clear about the review's 'bottom line' results • what these are (numerically if appropriate) • how were the results expressed (NNT, odds ratio etc.)
Comments: The review concludes that dietary modulation of the gut microbiota is an effective adjunctive approach to improving metabolic health in adults with metabolic disorders, although the magnitude of effect varies depending on the specific intervention and individual factors			
7) How precise are the results?			HINT: Look at the confidence intervals, if given
Comments: Most of the studies provided p-values but confidence intervals were not provided by some studies.			
Section C: Will the results help locally?			
8) Can the results be applied to the local population?	Yes Can't Tell No	✓ (Can't Tell)	HINT: Consider whether • the patients covered by the review could be sufficiently different to your population to cause concern • your local setting is likely to differ much from that of the review
Comments: The studies spanned numerous geographic locations and populations with different metabolic disorders. The dietary patterns were also different so individual patient needs should always be considered.			
9) Were all important outcomes considered?	Yes Can't Tell No	✓ (No)	HINT: Consider whether • there is other information you would like to have seen
Comments: Long-term outcomes were not reported in some cases.			
10) Are the benefits worth the harms and costs?	Yes Can't Tell No	✓ (Can't Tell)	HINT: Consider • even if this is not addressed by the review, what do **you** think?