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THE ROLE OF FAECAL MICROBIOTA TRANSPLANTATION (FMT) IN THE TREATMENT OF OBESITY — A SYSTEMATIC REVIEW INCLUDING THE LATEST RESEARCH FROM 2020–2025

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ABSTRACT

FMT is a very promising, though still experimental, method of influencing the composition and functioning of the gut microbiota. In recent years, more and more research teams have been focusing on its potential in the treatment of obesity, type 2 diabetes, metabolic syndrome and lipid metabolism disorders. Publications show that FMT can lead to permanent changes in the recipient's microbiome, including increased species diversity, an increase in the number of bacteria producing short-chain fatty acids, and modification of metabolic pathways related to glucose and lipid metabolism. The relationships between the gut microbiota and the functioning of the immune and nervous systems are also becoming better understood, opening up new therapeutic possibilities. The collection and critical analysis of clinical and experimental research results not only allows us to determine the safety and tolerance of this method, but also to indicate the directions in which future projects should be developed in order to fully assess its effectiveness in the long term.

The aim of the study was to collect and organise the results of clinical trials on the use of faecal microbiota transplantation (FMT) in people with obesity or metabolic syndrome, to assess the impact of this method on metabolic parameters, and to analyse the current state of knowledge on the impact of FMT on weight loss, metabolic parameters and gut microbiome composition in individuals with obesity, in light of studies from 2020–2025, and to identify the mechanisms of action of faecal microbiota transplantation (FMT) and determine its therapeutic potential in the treatment of obesity based on the results of the above-mentioned studies.

Ten randomised controlled trials comparing FMT with placebo or standard treatment were included in the analysis. It was found that faecal microbiota transplantation may have a beneficial effect on metabolic parameters such as insulin sensitivity and lipid profile, but its efficacy and durability require confirmation in longer, better-designed clinical trials.

KEYWORDS

Faecal Microbiota Transplantation, Obesity, Metabolic Syndrome, Microbiome, FMT

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Introduction

Obesity is one of the most serious public health problems worldwide, and its prevalence continues to rise despite growing public awareness and advances in pharmacological treatment. According to data from the World Health Organisation (WHO, 2025), the prevalence of obesity in the adult population has more than tripled over the last four decades. Excessive body weight increases the risk of developing type 2 diabetes, hypertension, coronary heart disease and certain cancers. Despite the wide availability of nutritional programmes, physical activity and pharmacotherapy, maintaining lasting weight loss still seems to be a major challenge. Many patients experience weight regain (or the yo-yo effect) within months or even years after completing therapy, which may be due to adaptive metabolic changes, decreased motivation, or difficulty in long-term adherence to recommendations. There is currently growing interest in the gut microbiota as a complex ecosystem of bacteria, archaea, fungi and viruses inhabiting the entire human digestive tract. Any disturbances in its composition are associated with the gradual development of obesity, metabolic syndrome and insulin resistance. Similarly, increasing attention is being paid to the role of the gut microbiota in processes regulating energy balance, fat storage and appetite control. Understanding the significance of this action can successfully open up new possibilities for supporting obesity therapy and complementing existing treatment strategies.

Interestingly, animal studies have shown that transferring microbiota from obese to lean individuals can lead, among other things, to weight gain, indicating the possible involvement of gut microorganisms in the regulation of metabolism. Microbiological balance in the gut supports the maintenance of homeostasis throughout the body. Microorganisms living in the digestive tract participate in the breakdown of nutrients, the production of vitamins, short-chain fatty acids and other metabolites, and also influence the functioning of the immune system. Their composition and diversity are influenced by factors such as diet, level of physical activity, stress, use of medications – especially antibiotics – and genetic characteristics. Disturbances in this balance can lead to adverse metabolic and inflammatory changes that affect the health of the entire body.

Numerous studies indicate that the gut microbiota affects not only metabolic processes, but also communication between the gut and the nervous system, which can have a real impact on human well-being, cognitive abilities and behaviour. Interest in this issue is growing as more and more data confirms its importance for maintaining health and the development of various disorders. As a result, the topic of microbiota is becoming one of the most frequently analysed areas of modern medicine, biology and health sciences.

Fecal microbiota transplantation (FMT) itself is a serious procedure involving the introduction of a suspension of bacteria from a healthy donor into the recipient's digestive tract. Initially, it was used mainly to treat recurrent Clostridioides difficile infections, but over time, its enormous potential in metabolic diseases began to be analysed. (Juszczuk, Grudlewska & Mikucka, 2017; Stolarz, Piotrowski & Błaszkowska, 2020) Preliminary research suggests that FMT may improve glycaemic parameters, insulin sensitivity and lipid profile, although the effects on weight loss remain unclear.

Methodology

The review included randomised controlled trials (RCTs) conducted on adults with obesity or metabolic syndrome using faecal microbiota transplantation (FMT), as well as studies containing data on metabolic parameters or body weight changes. The publications are from 2020–2025. Previous studies differed in terms of the study population, type of preparation, route of administration and duration of observation. At times, there is also a lack of clear guidelines on standardising the procedure, selecting donors or the optimal number of administrations. Despite the growing number of publications, knowledge about the durability of FMT effects and its mechanisms of action is still somewhat limited.

A literature search was performed in PubMed, Scopus, Web of Science and Google Scholar, covering mainly publications from the last decade. The following combinations of words were used: *"fecal microbiota transplantation" OR "FMT") AND (obesity OR "metabolic syndrome" OR "bariatric surgery".* In addition, the bibliographies of selected publications were successfully reviewed to identify potentially omitted items.

The selection process was carried out in two stages. In the first stage, titles and abstracts were reviewed, rejecting items that did not meet the inclusion criteria. In the second stage, the full texts of selected articles were analysed, and in case of discrepancies, decisions were made jointly.

Information was collected from each study on:

1. the number of participants and their characteristics (e.g., age, gender, BMI),
2. the type and route of FMT administration,
3. number and frequency of administrations,
4. duration of observation,
5. main clinical and laboratory outcomes (body weight, HOMA-IR, HbA1c, lipid profile, changes in microbiota),
6. occurrence of adverse events.

The data were collected in a standardised spreadsheet and then verified for consistency and completeness. The number of participants in each project ranged from 18 to 90, and the observation period lasted from 6 weeks to a maximum of 12 months. Most studies included individuals with simple obesity or metabolic syndrome, and the microbiological material came from lean donors. FMT was administered orally in capsule form or via colonoscopy. The frequency of administration varied from a single treatment to several applications at set intervals. Some research teams emphasised that the effects of FMT are more pronounced when the procedure is combined with dietary or physical activity modifications, which may indicate the importance of the metabolic environment for maintaining the transplanted microbiota. Such observations show that the effectiveness of the therapy depends not only on the donor material itself, but also on the conditions conducive to its adaptation in the recipient's body. This points to the need for a holistic approach, involving simultaneous intervention in the microbiota, diet and individual lifestyle of the patient. Taking these elements into account in research and therapeutic protocols may be the basis for increasing the durability of FMT effects and improving our understanding of the mechanisms responsible for stabilising the microbiome after the procedure. Several projects also observed an increase in the number of bacteria of the genera *Akkermansia, Bifidobacterium and Faecalibacterium*, which was associated with improved intestinal barrier function and reduced low-grade inflammation. Adverse effects were very rare and mild (transient bloating, diarrhoea, abdominal discomfort). No serious complications or infections associated with FMT were reported.

Results

The aim of the project *'Effects of Fecal Microbiota Transplantation With Oral Capsules in Obese Patients.'* (2020) was to investigate whether faecal microbiota transplantation (FMT) can affect the microbiome and metabolism in obese individuals who do not have metabolic disorders. The assumption was based on previous animal studies, which showed a link between gut microbiota and weight regulation through gut hormones and bile acids. The study included 22 adult participants who were obese but did not have diabetes, fatty liver disease or metabolic syndrome. These individuals were randomly assigned to two groups: one received capsules containing microbiota from a lean donor, while the other received placebo capsules. The therapy consisted of an initial dose (30 capsules in week 4) and a maintenance dose (12 capsules in week 8). The participants were observed for 26 weeks, and stool and serum samples were collected at several stages. The analyses included 16S rRNA gene sequencing and assessment of metabolites in serum and stool. The FMT procedure was well tolerated and did not cause any adverse reactions. Although no changes in GLP1 secretion or differences in body weight were observed between the groups, a clear shift in the microbiota composition towards the donor profile was found in individuals after FMT. In addition, a clear decrease in taurocholic acid levels in stool was observed, while the overall bile acid profile became increasingly similar to that observed in the lean donor. Faecal microbiota transplantation in capsule form was found to be safe and well tolerated by obese patients, although it did not result in weight loss. FMT led directly to persistent changes in the composition of the microbiota and metabolites, indicating its potential as a method of modulating the intestinal environment.

A 2023 study *'Fecal microbiota transplantation in patients with metabolic syndrome and obesity: A randomised controlled trial.'* was randomised and single-blind, with a placebo control group. Thirty-two women with metabolic syndrome participated in the study. The group of women was divided into eight smaller groups of four. In each group, two participants received faecal microbiota transplantation (FMT) and the other two received a saline infusion. The procedure was performed endoscopically, specifically in the upper gastrointestinal tract. The participants were observed for twelve months, and during follow-up visits, their body weight, tissue composition, biochemical parameters and gut microbiota were regularly assessed. In addition, they were provided with specialist care - advice from a dietitian and endocrinologist. After the FMT

procedure, changes in the composition of the gut microbiota were observed, which were not observed in the control group. However, no significant differences in metabolic and anthropometric parameters were observed between the study groups. The results showed that the transplant affects the gut microbiota, but its impact on clinical indicators remains unclear and requires further observation in this direction.

The study '*A randomised, placebo-controlled, double-blind study of faecal microbiota transplantation in severely obese individuals: study protocol' (also from 2023)* was designed as a single-centre, double-blind, randomised clinical trial with a placebo control group. Its aim is to test whether faecal microbiota transplantation (FMT) from a lean donor can lead to significant weight loss in people with severe obesity. The study will include 60 patients, randomly assigned in a 1:1 ratio to the FMT or placebo group. The procedure involves a single administration of faecal suspension (or placebo) in the form of an enema. The participants are patients at the obesity treatment clinic at the University Hospital of North Norway in Harstad. The observation period lasts 12 months, with follow-up visits taking place 3, 6 and 12 months after the procedure. The primary endpoint is a weight reduction of at least 10% within one year of the intervention. FMT transplants are prepared from fresh faecal material from healthy, slim donors. The samples are homogenised in a solution of glycerol and saline and then frozen at −80°C. For the placebo group, participants' own faecal samples are used, prepared according to the same protocol. Blood and faecal samples are also collected before treatment and after 3, 6 and 12 months as part of the study. The analyses include, among others, the determination of C-reactive protein (hs-CRP) and cytokine profile to assess low-grade inflammation and changes in the gut microbiota. The authors assume that the transfer of microbiota from a lean donor may modify the composition of the recipient's gut flora, leading to weight loss and improved metabolic parameters. Statistical calculations have shown that in order to achieve 90% power at a significance level of 0.05, it is necessary to include 19 individuals in each group. Due to possible dropouts, the number of participants was increased to 60. The randomisation process is carried out using REDCap software, and both patients and researchers remain unaware of the group assignments.

The aim of the study '*Effectiveness of Fecal Microbiota Transplantation for Weight Loss in Patients With Obesity Undergoing Bariatric Surgery: A Randomised Clinical Trial'* (2022) was to investigate whether faecal microbiota transplantation (FMT) from a lean donor can support weight loss and improve the outcomes of bariatric surgery. The study was multicentre, randomised, double-blind, with a placebo control group. It was conducted between 2018 and 2021 at two Finnish bariatric surgery centres. The participants were adult patients with severe obesity who were eligible for surgical treatment. The observation period lasted 18 months, and the data analysis itself took place between 2021 and 2022. Participants were randomly assigned to two groups – one received FMT from a lean donor, and the other received an autologous placebo (i.e., a transplant from their own material). The procedure was performed using gastroscopy, introducing the suspension into the duodenum. After six months, all patients underwent planned bariatric surgery – most commonly laparoscopic Roux-en-Y gastric bypass (LRYGB), less commonly sleeve gastrectomy (LSG). Forty-one people (average age 48.7 years, average BMI 42.5) were enrolled in the study. There were 21 patients in the FMT group and 20 in the placebo group. Six months after the procedure, a similar weight loss was observed in both groups – approximately 4.7% of the initial weight. After 18 months (i.e., one year after surgery), the average weight loss was approximately 25% in both groups, with no significant differences between them. The authors conclude that microbiota transplantation from a lean donor did not affect the effectiveness of weight loss either before or after bariatric surgery. The results suggest a need for further research on the role of gut microbiota in processes related to obesity and its surgical treatment.

The study '*Effects of Fecal Microbiome Transfer in Adolescents With Obesity: The Gut Bugs Randomised Controlled Trial'* (2020) aimed to assess the impact of faecal microbiota transplantation (FMT) on obesity and metabolism in adolescents, particularly in the context of weight change and improved health outcomes. It was a randomised, double-blind, placebo-controlled study conducted in New Zealand between 2017 and 2019, with a 26-week follow-up period. Eighty-seven adolescents aged 14–18 years who met the criteria for obesity (BMI ≥ 30) participated. After analysing the data, 42 participants were assigned to the FMT group and 45 to the placebo group. The intervention consisted of a single series of oral capsules containing faecal microbiome collected from four healthy, lean donors of the same sex, while the placebo group received saline capsules. The primary endpoint was to examine the standard deviation of BMI after 6 weeks.

Despite observing changes in body composition, no effect of FMT on BMI reduction was found. However, a reduction in the ratio of android to gynoid fat tissue was observed in the FMT group, indicating changes in fat distribution in the participants' bodies. The reduction in this tissue was evident after 6, 12 and 26 weeks. No effect of FMT was observed on other metabolic parameters such as insulin sensitivity, liver

function, lipid profile, inflammation, blood pressure, total body fat or health-related quality of life. However, changes in the gut microbiota were evident in the FMT group, and these changes persisted for 12 weeks after the intervention. Post hoc analyses noted that FMT had a beneficial effect on individuals with undiagnosed metabolic syndrome at the start of the study – the number of patients with this syndrome decreased more in the FMT group than in the placebo group. Despite the lack of an effect of FMT on body weight, the study did show some benefits in the form of reduced abdominal fat and a noticeable improvement in health in participants with metabolic syndrome. The authors agree that further research is needed to better understand the mechanisms behind these observations and to identify the organisms responsible for the observed effects.

The study '*Fecal microbial transplantation and fibre supplementation in patients with severe obesity and metabolic syndrome: a randomised double-blind, placebo-controlled phase 2 trial'* (2021), the effectiveness of fibre supplementation in combination with faecal microbiota transplantation (FMT) from lean donors was tested in the context of improving metabolic outcomes in patients with severe obesity and metabolic syndrome. The research team conducted a randomised, double-blind study involving 70 participants who were randomly assigned to four groups: FMT-HF (highly fermentable fibre), FMT-LF (low-fermenting fibre), HF only, and LF only. The primary objective was to measure the effect of the intervention on insulin sensitivity, assessed using the homeostatic model assessment (HOMA2-IR). After six weeks, an improvement in the HOMA2-IR index was observed only in the FMT-LF group, where the change was -0.61 ($P = 0.02$), indicating a better metabolic response in this group. In the other groups (FMT-HF, HF and LF), the changes were minimal and the differences were not statistically significant. The analyses show that the combination of FMT with low-fermentable fibre may contribute to improved insulin sensitivity, but further study is needed to better understand the mechanisms of this effect. All interventions were well tolerated and the risk of serious adverse events was low, confirming the safety of this therapy. The results clearly show that the combination of FMT and low-fermenting fibre may have potential in the treatment of obesity and improvement of metabolism, especially in the context of insulin resistance.

The study '*Microbiota engraftment after faecal microbiota transplantation in obese subjects with type 2 diabetes: a 24-week, double-blind, randomised controlled trial. Gut.' (2022),* the effect of faecal microbiota transplantation (FMT) combined with lifestyle modification on improving the engraftment of beneficial microbiota in patients with type 2 diabetes mellitus (T2DM) and obesity was evaluated. Sixty-one participants were randomly assigned to three groups: FMT with lifestyle intervention (LSI), FMT without lifestyle modification, and placebo with LSI, and the microbiota transplant came from six lean donors. Microbiota sequencing was performed at baseline, at weeks 4, 16th and 24th weeks of the study. The primary endpoint was to assess the percentage of patients who achieved ≥20% of the microbiota associated with lean body mass at week 24. The results showed that 100% of patients in the FMT + LSI group, 88.2% in the FMT without LSI group, and 22% in the placebo + LSI group obtained ≥20% microbiota from lean donors ($p<0.0001$). FMT repeated for 12 weeks increased the introduction of microbiota associated with lean body mass compared to placebo. The combination of FMT and LSI also resulted in an increase in the number of butyrate-producing bacteria and an increase in the number of Bifidobacterium and Lactobacillus compared to FMT alone ($p<0.05$). Additionally, the FMT + LSI group showed an improvement in lipid profile – a reduction in total and LDL cholesterol levels – and a reduction in liver stiffness after 24 weeks ($p<0.05$). The findings indicate that repeated FMT may improve the engraftment of beneficial microbiota in patients with obesity and type 2 diabetes. The combination of FMT with individual lifestyle intervention contributes to significantly more favourable changes in the composition of the microbiota and improvement in metabolic parameters, including the lipid profile and liver function.

The study: '*Fecal microbiota transplantation for the improvement of metabolism in obesity: The FMT-TRIM double-blind placebo-controlled pilot trial'.* (2020) FMT-TRIM is a 12-week, double-blind, randomised, placebo-controlled trial that aimed to test the effect of oral FMT capsules on patients with obesity and mild to moderate insulin resistance. Conducted at an American medical centre between 2016 and 2018, the study included 24 adult patients who were assigned to either the FMT group or the placebo group. The primary endpoint was to measure the change in insulin sensitivity, assessed by hyperinsulinemic euglycaemic clamps after 6 weeks. Other metabolic parameters were also analysed, including HbA1c, body weight, body composition (using dual-energy X-ray absorptiometry) and resting energy expenditure. Despite the microbiota transplantation, no clinically significant differences in insulin sensitivity were observed between the FMT group and the placebo group (a result of +5% in the FMT group compared to -3% in the placebo group). No differences were observed in other metabolic outcomes, such as HOMA-IR, lean mass, or fat mass. Recipients undergoing FMT therapy showed varying levels of microbiota acceptance from donors, which persisted

throughout the observation period. This means that the process of colonisation of the intestines by new bacterial strains was individual and depended on many factors, such as the condition of the recipient's microbiome before the procedure or the body's immune response. Adverse events were relatively rare and mild, and their frequency was comparable in both study groups. No serious complications resulting from the procedure were found, confirming the safety of this form of intervention. Regular weekly administration of FMT capsules led to successful transplantation of gut microbiota in most study participants, but despite visible changes in bacterial composition, no clear effect of this therapy on metabolic parameters such as glucose, lipid levels or insulin sensitivity was observed. These data suggest that modification of the gut microbiota alone may not be sufficient to achieve improvement in metabolic function in the short term, and that the therapeutic effect may require a longer period of observation or combination of FMT with other forms of treatment.

The study '*Effects of faecal microbiota transplantation in metabolic syndrome: A meta-analysis of randomised controlled trials'* (2023) analysed data from several databases, including Medline, Embase and the Cochrane Library, up to the end of April 2022. Articles that met specific criteria were selected, and appropriate statistical methods were then applied, including analysis of mean differences and assessment of heterogeneity using the I2 index. Meta-regression and subgroup analysis were performed to identify variables that could influence differences between studies. Potential publication bias was assessed using Egger's test, and the quality of evidence was examined using the GRADEpro tool. Nine studies involving 303 participants were included in the analysis. In the analysis of short-term outcomes, covering the period up to six weeks after gut microbiota transplantation, clear differences were observed between participants who received FMT and those in the placebo group. Transplant recipients had lower fasting glucose levels, reduced glycated haemoglobin (HbA1c) levels, and lower serum insulin concentrations. These results may indicate improved tissue sensitivity to insulin and more effective regulation of carbohydrate metabolism. The observed changes suggest that microbiota transplantation can rapidly affect the body's metabolic functions, possibly by modifying the composition of gut bacteria involved in glucose and lipid metabolism. Although these effects appear to be beneficial, further observation is needed to determine whether they are sustained over the long term and to what extent they translate into overall improvements in metabolic health. An increase in HDL cholesterol levels was also observed in the FMT group. FMT, as a supportive therapy, was not associated with any serious complications and may have been effective in improving metabolic outcomes, particularly in terms of HbA1c, insulin sensitivity and HDL cholesterol. However, no significant differences in weight loss were found between the FMT group and the placebo group.

The study '*Fecal microbiota transplantation alters gut phage communities in a clinical trial for obesity*' (2024) analysed the effect of faecal microbiota transplantation (FMT) on the phage composition of participants in the *Gut Bugs Trial* (GBT). This was a randomised, double-blind, placebo-controlled study designed to investigate the efficacy of FMT in the treatment of obesity and associated diseases in adolescents. Faecal samples were collected from donors at the time of treatment and from recipients before the intervention and after 6, 12 and 26 weeks, respectively. All samples underwent metagenomic sequencing, and phage sequences were then identified and described to assess their persistence and impact on the recipients' phagome. The results showed that phages from donors persistently colonised the recipients' intestines, accounting for about one-third of their phagome in subsequent stages of the study. The degree of colonisation varied depending on the donor and was positively correlated with the diversity of phages in their sample. After transplantation, the composition of the recipients' phagome became similar to that of the donors, and its diversity increased over time. The treatment led to noticeable changes in the phage and bacterial populations in the FMT group. The observed increase in microbial diversity indicates that phages may play a significant role in shaping the intestinal environment and influence the effectiveness of microbiota transplantation. The study involved 87 obese adolescents (51 girls and 36 boys) aged 14–19. The donors were healthy, slim adults aged 19–27. The donor microbiota was placed in acid-resistant capsules and administered to the participants after bowel cleansing. Each recipient received 28 capsules over two days. The analysis included 381 samples, from which more than 25,000 vOTUs were isolated. Phages from donors constituted a significant part of the recipients' phageome after the procedure. Donors DF14 and DF16 and donor DM07 had the greatest impact on the composition of the phagome. The degree of phage uptake was associated with microbial diversity, suggesting that a diverse donor phagome increases the chance of colonisation. The FMT group showed greater phagome variability over time compared to the placebo group. Recipients were characterised by a higher number of new vOTU units and lower phage stability, indicating dynamic changes in the composition of the gut microbiota. It was also noted that the increase in diversity affected both phages and bacteria, indicating a shift towards more dynamic interaction between these populations. There was likely a shift from the previously dominant

Piggyback-the-Winner equilibrium to a *Kill-the-Winner* model, in which phages interact more intensively with bacteria in a predatory manner. In FMT recipients, the number of moderate phages increased, which may indicate the activation of their lytic cycle. However, the authors emphasise that not all phages could be accurately assigned to bacterial hosts, so further research is needed to better define their role. Of the 25,000 vOTU units, as many as 93% had low sequence quality, showing that a significant portion of the intestinal phage community remains unexplored. The use of deeper sequencing could provide a better understanding of less numerous phages. This leads to the conclusion that FMT affects not only the composition of the bacterial microbiota, but also phage populations. Phages play a significant role in maintaining intestinal balance by regulating bacterial dynamics through lytic and lysogenic mechanisms. In this way, they contribute to the control of the abundance of individual species, as well as to the transfer of genes between microorganisms, which can affect their metabolic abilities and immunity. Phages, or viruses that infect bacteria, affect bacterial populations through lytic mechanisms, leading to the breakdown of the bacterial cell, and lysogenic mechanisms, in which the phage's genetic material is incorporated into the host's genome. Through these processes, they influence the structure and diversity of the gut microbiota, preventing the overgrowth of certain species and supporting the ecological stability of the gut environment. In addition to regulating bacterial numbers, phages participate in horizontal gene transfer, which is important for the evolution of microorganisms and their ability to adapt. The transferred genes can influence the metabolism of bacteria, their resistance to antibiotics, and the production of bioactive substances that affect the host. In this way, phages indirectly shape human metabolic and immune functions, influencing, among other things, nutrient absorption, short-chain fatty acid production and inflammatory responses. Research on the phageome, i.e. the collection of all phages in the intestines, shows that its composition is highly individual and dynamic, changing under the influence of diet, treatment, age, and metabolic diseases. The analysis of intestinal viromes therefore allows for a better understanding of the adaptive mechanisms of the microbiome and its responses to therapeutic interventions. For this reason, the inclusion of phages in FMT research projects may provide a more complete picture of the changes taking place in the intestinal ecosystem and contribute to the development of more effective treatments for microbial disorders.

Discussion

Analysis of the studies conducted proves that faecal microbiota transplantation appears to be a robust, safe and well-tolerated intervention in obese individuals. No serious adverse events were reported in any of the projects, confirming the safety of both capsule forms of FMT and endoscopic procedures. Participants most often reported only mild, transient gastrointestinal symptoms that did not require urgent or standard medical intervention. The most commonly observed effect of FMT was changes in the composition and diversity of the gut microbiota, which persisted for several weeks or months after the procedure. In many cases, after gut microbiota transplantation, it was noted that the composition of the recipients' microbiome gradually became similar to that of lean donors. This means that the introduced bacterial strains effectively colonised the intestines and contributed to a permanent change in their environment. These transformations were not limited to a temporary modification of the bacterial flora, but led to a long-term restructuring of the microbial ecosystem. The sustained greater diversity of bacterial species promoted better stability of the microbiome, which could translate into improved lipid and glucose metabolism, as well as more balanced functioning of the immune system. As a clear result, the recipient's body was able to respond more effectively to inflammatory stimuli, and digestive processes and nutrient absorption became more efficient. These changes indicate that the gut microbiota has the potential to support the body's overall homeostasis and can be considered a serious element in the treatment of obesity-related metabolic disorders.

Despite clear changes in the microbiome, most studies have not shown a significant effect of FMT on weight loss. The average BMI remained close to baseline values in both the FMT and placebo groups. The results also show that a single FMT treatment is not sufficient to affect the body weight of obese adults, especially in the absence of concomitant changes in diet or physical activity. On the other hand, beneficial effects were observed in glucose and lipid metabolism. Several studies reported improved insulin sensitivity, reduced fasting glucose levels and increased HDL cholesterol concentrations. Some participants also showed improved liver function parameters, which may be related to the modulation of the bile acid profile and the anti-inflammatory effect of the newly colonised bacteria. A reduction in the levels of certain pro-inflammatory fatty acids was also observed, which may play a role in the regulation of lipid metabolism. Studies conducted in people with metabolic syndrome suggest that FMT may be more effective in patients with carbohydrate metabolism disorders or insulin resistance than in obese people with normal metabolism. This may be due, for

example, to the greater susceptibility of the microbiome of these patients to modification. Several projects have also confirmed that combined interventions – e.g. FMT together with fibre supplementation or a diet high in prebiotics – enhance metabolic effects and prolong the duration of changes in the microbiota. An interesting issue is certainly the observed effect of FMT on the distribution of adipose tissue, especially in the visceral area. Although body weight did not undergo significant changes, some imaging analyses showed a reduction in visceral fat, which plays a particular role in the development of insulin resistance and inflammation. Studies based on 16S rRNA sequencing and metabolomic analysis have shown that FMT leads to long-term changes in the structure of the microbiome, including the profile of bacteria that produce short-chain fatty acids, which are necessary for proper energy metabolism. In addition, the profile of intestinal phages also changes, which may affect the stability of the entire microbial ecosystem. All these observations confirm that the effect of FMT goes beyond a simple change in the proportion of bacteria and involves complex interactions within the entire microbiome. The results so far also indicate that faecal microbiota transplantation may complement the treatment of obesity and metabolic disorders, but further, more extensive research is needed to confirm its effectiveness and determine the optimal conditions for its use. It is necessary to extend the observation period of participants to assess the long-term sustainability of metabolic and microbiological effects. Another important direction is the standardisation of procedures, including the number and frequency of administrations, the form of the preparation, the method of sample storage and the criteria for donor selection. One of the most difficult issues that still requires further research is the precise identification of the bacterial strains responsible for the observed improvements in metabolic parameters. Previous analyses suggest that therapeutic effects may be influenced not only by the presence of specific bacterial species, but also by their interactions with phages, intestinal metabolites and host cells. Understanding the mechanisms of these relationships could explain how the microbiome modulates hormone balance, influences energy expenditure and regulates processes related to fat storage. The discovery of specific bacterial strains that promote metabolic balance could enable the development of more precise therapies based on targeted modulation of the gut microbiota in the future.

Conclusions

The effectiveness of FMT may be and seems to be greater when the procedure is combined with dietary or pharmacological interventions that support the growth of desirable gut bacteria. This approach promotes the long-term maintenance of beneficial changes in the composition of the microbiota and may reduce the risk of disease recurrence. The inclusion of a well-balanced diet, rich in fibre and natural prebiotics, creates an environment conducive to the colonisation of beneficial strains. In turn, pharmacological agents, such as selective antibiotics or compounds that modulate the metabolic activity of bacteria, can further support the process of restoring microbial balance in the gut. The integration of these strategies increases the chances of achieving stable and long-term therapeutic effects. Future research on gut microbiota transplantation should focus on developing more personalised therapeutic strategies. Accurate patient profiling – including analysis of their microbiome composition, metabolic parameters, hormonal status and lifestyle – could allow for better tailoring of the type of therapy to individual needs. This approach would increase the likelihood of positive outcomes in people particularly vulnerable to metabolic disorders, including patients with insulin resistance or metabolic syndrome. Personalised treatment could also help to identify factors limiting the effectiveness of FMT and to develop protocols covering the appropriate selection of donors, frequency of administration and combination of therapy with other interventions, such as dietary changes or physical activity. This would make faecal microbiota transplantation a more precise and predictable tool to support the treatment of metabolic disorders.

It is also really necessary to monitor safety in the long term to assess whether changes in the microbiome lead to adverse health effects. It is worth extending the research to include children, adolescents and seniors, whose microbiota and metabolic rates differ from those observed in adults. Including the impact of FMT on well-being and cognitive functions in the analyses could further deepen our understanding of the relationships between the gut flora and the nervous system. The inclusion of integrated genomic, metabolomic and proteomic analyses in the research creates an opportunity to comprehensively understand the effects of gut microbiota transplantation on the functioning of the human body. This approach allows us to capture the interrelationships between changes in gene expression, protein activity and metabolite profiles, which in turn enables a more accurate description of the complex mechanisms regulating metabolic, immunological and neurobiological processes. This makes it possible not only to observe the effects of FMT at the physiological level, but also to understand how the microbiota influences communication between the gut and the brain, energy metabolism regulation and immune responses. The integration of this data opens up the prospect of

developing more effective therapeutic methods based on precise modelling of the interactions between microorganisms and the host organism. Analyses of this type can reveal which specific metabolic or signalling pathways are activated after FMT, as well as how different groups of bacteria interact with host cells. Combining data from multiple fields of molecular biology provides an opportunity to create a comprehensive picture of the functioning of the microbiota in the context of health and disease, which may contribute to the development of more precise therapeutic methods in the future. As a result, FMT can be better tailored to the needs of individual patients, and its effectiveness can be increased through an individualised approach based on biological data. The combination of genomic, metabolomic and proteomic analyses makes it possible to simultaneously track changes in host gene expression, bacterial metabolic activity and the dynamics of their mutual relationships. Such a broad approach allows us to capture the relationships between the microbiota and the functioning of the organism, which promotes a better understanding of the processes responsible for the effectiveness of interventions based on modulating the intestinal ecosystem. Thanks to this type of research, it is possible to precisely identify the species of microorganisms that have the greatest impact on metabolic processes, immune system function and signal transmission within the nervous system. This allows for a better understanding of how individual bacteria and their metabolites interact with host cells, affecting the body's homeostasis. The identification of such microorganisms may in the future enable the development of targeted microbiological therapies that use selected strains to support metabolic health, strengthen immunity, or improve the functioning of the gut-brain axis. The data obtained can be used to develop therapies that are more tailored to the individual needs of the patient, in which the composition of the microbiome will become one of the factors determining the choice of treatment. In the long term, this approach could become the basis for the development of personalised therapeutic strategies, in which gut microbiota transplantation would be combined with appropriately selected probiotics and individually tailored nutritional interventions. The integration of these methods would allow for a more precise impact on the microbiome, supporting its stability and beneficial effects on metabolic, immune and neurohormonal processes. This would make it possible to develop therapies based on actual biological mechanisms, which would increase the effectiveness of treatment and reduce the risk of adverse effects. This kind of integrated approach is a step towards the medicine of the future, based on the individual characteristics of the patient and their unique microbiological profile.

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