

## Review Article

# Healthier gut, stronger kids: harnessing prebiotics for childhood obesity-a narrative review

Poornema Umasankar<sup>1\*</sup>, Narayanasamy K.<sup>2</sup>, Srinivas Govindarajulu<sup>1</sup>, Jasmine S. Sundar<sup>1</sup>, Valarmathi Srinivasan<sup>1</sup>, Kalpana Ramachandran<sup>1</sup>, Neela Chandran<sup>1</sup>, Dharshini Prem<sup>1</sup>

<sup>1</sup>Department of Epidemiology, The Tamilnadu Dr. M. G. R Medical University, Guindy, Chennai, India

<sup>2</sup>The Tamilnadu Dr. M. G. R Medical University, Guindy, Chennai, India

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### \*Correspondence:

Dr. Poornema Umasankar,

E-mail: [upoornema@gmail.com](mailto:upoornema@gmail.com)

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## ABSTRACT

Childhood obesity has become a significant global public health concern. The prevalence of obesity among children is rising, with over 390 million affected worldwide, including 160 million living with obesity. Obesity in childhood increases both immediate and long-term risks for various non-communicable diseases such as diabetes, cardiovascular disease, and non-alcoholic fatty liver disease (NAFLD). In recent years, attention has turned to the role of gut microbiota in obesity management. Prebiotics influence gut microbiota by selectively fermenting and modulating microbial activity, particularly through carbohydrates like oligosaccharides and fibers. This fermentation produces short-chain fatty acids (SCFAs) like acetate, propionate, and butyrate, which support gut health, reduce inflammation, and promote beneficial bacteria like *Bifidobacterium* and *Lactobacillus*. Clinical Studies suggest that prebiotics may reduce adiposity, improve metabolic makers, enhance satiety and reduce calorie intake. This review aims to provide an overview of the current evidence on the effectiveness of prebiotics in obesity management among children.

**Keywords:** Prebiotics, Childhood obesity, Gut microbiota

## INTRODUCTION

Childhood obesity is a growing public health concern worldwide, with significant implications for both immediate and long-term health outcomes. The prevalence of obesity among children has increased dramatically over the past few decades. Over 390 million children and adolescents aged 5–19 years were overweight in 2022, including 160 million who were living with obesity.<sup>1</sup> In India, the national family health survey (NFHS-5) indicated a significant increase in overweight children under five years old, reaching 3.4% in 2019-2021, up from 2.1% in 2015-2016.<sup>2</sup> More than 14.4 million children are obese in India, the second-highest rate globally, behind China.<sup>2</sup> About three-quarters of children who are overweight or obese continue to be so in adulthood, which increases both

immediate and imminent risks for a number of non-communicable diseases like diabetes, cardiovascular diseases, cancer, non-alcoholic fatty liver disease (NAFLD), and certain immune-related disorders.<sup>3</sup> In recent years, there has been increasing interest in the role of gut microbiota in weight management, particularly the potential benefits of prebiotic supplementation. Prebiotics are non-digestible food ingredients that selectively stimulate the growth and activity of beneficial bacteria in the gut.<sup>4</sup> These compounds, commonly found in foods such as garlic, onions, bananas, and whole grains, have been shown to improve gut health by promoting the growth of beneficial bacteria like *Bifidobacteria* and *Lactobacilli*.<sup>5</sup> The modulation of gut microbiota through prebiotic supplementation is believed to influence various metabolic processes, including energy homeostasis, fat storage, and appetite regulation, which are critical factors in weight management.<sup>6</sup> Researches have indicated that

prebiotics can reduce adiposity by enhancing the production of short-chain fatty acids (SCFAs), which play a crucial role in regulating energy metabolism and fat storage.<sup>7</sup> Additionally, prebiotics have been found to improve satiety and reduce overall calorie intake, thereby contributing to weight management.<sup>8</sup> These findings suggest that prebiotics could be an effective solution for preventing and managing childhood obesity. However, the evidence on the effectiveness of prebiotics in weight management among children is still emerging, and more research is needed to establish definitive conclusion. Therefore, this review aims to provide a comprehensive overview of the current evidence on the effectiveness of prebiotics in obesity management among children.

## IMPACT OF PREBIOTICS ON GUT MICROBIOTA

Prebiotics primarily influence the gut microbiota through selective fermentation and modulation of microbial activity.<sup>9</sup> They are primarily carbohydrate compounds, such as oligosaccharides or fibre that are resistant to digestion by human enzymes but are fermentable by gut microbes.<sup>10</sup> The fermentation process leads to the production of short-chain fatty acids (SCFAs), such as acetate, propionate, and butyrate, which have various health benefits.<sup>11</sup> These SCFAs are crucial for maintaining gut homeostasis and influencing microbiota composition.<sup>11</sup>

### Acetate

Acetate serves as a major energy source for colonocytes and promotes the growth of beneficial bacteria like *Bifidobacterium* and *Lactobacillus*.<sup>12</sup>

### Propionate

Propionate is known for its role in reducing inflammation and improving gut barrier integrity. It is primarily produced by Firmicutes.<sup>13,14</sup>

### Butyrate

Plays a significant role in maintaining gut health by promoting epithelial cell health, acting as a fuel for colonocytes, and regulating immune responses.<sup>15,16</sup>

Prebiotics select for specific microbial species that possess the enzymatic machinery to metabolize these complex carbohydrates.<sup>17</sup> For example, *Bifidobacteria* and *Lactobacilli* are known to thrive on specific prebiotic fibres like inulin or FOS (fructo-oligosaccharides).<sup>18</sup>

### Bifidobacteria

These are often considered one of the first microbes to colonize the infant gut, they can efficiently ferment oligosaccharides and produce lactic acid and SCFAs, fostering a favourable environment for beneficial species.<sup>19,20</sup>

### Lactobacilli

Similar to *Bifidobacteria*, these microbes thrive on fermentable fibre and produce organic acids like lactic acid that lower gut pH and prevent the growth of pathogenic organisms.<sup>21,22</sup>

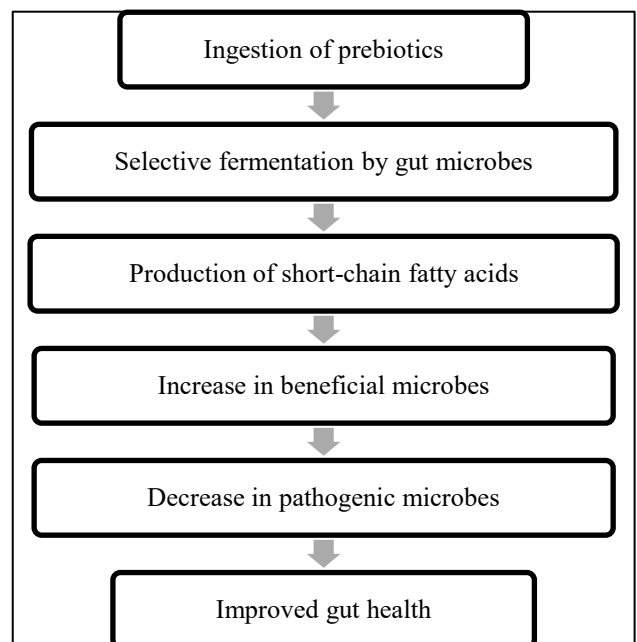
The intake of prebiotics leads to an increase in the populations of beneficial microorganisms while reducing the abundance of potential pathogenic bacteria like *Clostridia* or *Enterobacteriaceae*. The beneficial bacteria outcompete pathogenic species for available nutrients, leading to improved gut health and a balanced microbiome.<sup>23,24</sup>

### Diversity enhancement

Prebiotics increase the diversity of gut microbiota, which is often associated with better health outcomes, such as a reduced risk of gastrointestinal diseases.<sup>25</sup>

### Reduction in pathogen load

The competitive exclusion of pathogens occurs due to the increase in beneficial bacteria that lower the pH and outcompete pathogens for nutrients (Figure 1).<sup>24</sup>

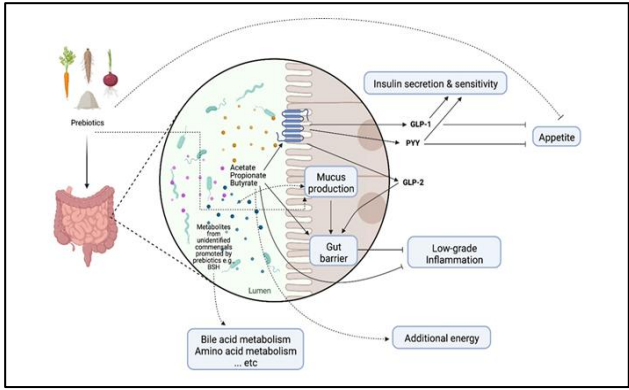


**Figure 1: Impact of prebiotics on gut microbiota.**

## MECHANISMS OF PREBIOTICS IN IMPROVING METABOLIC FUNCTION

The primary mechanism for the systemic effects on glucose and lipid homeostasis, as well as satiety control, is frequently attributed to the modification of enteroendocrine function by prebiotics and their fermentation products.<sup>26</sup> It has been demonstrated that SCFAs increase the levels of circulating glucagon-like

peptide-1 (GLP-1) and anorexigenic peptide YY (PYY) in both mice and humans after prebiotic intervention.<sup>26</sup> Furthermore, preliminary research on mice indicates that the mucosal architecture was changed by the commensal bacterial growth produced by prebiotics.<sup>27</sup> In the setting of obesity, the changed mucus composition and/or regular turnover of mucin glycoproteins may assist preserve the integrity of the mucosal barrier and reduce inflammation.<sup>28,29</sup>



**Figure 2: Mechanism of action through which prebiotics may influence host metabolism.<sup>5</sup>**

Certain prebiotics may directly interact with the host to enhance glucose metabolism and improve barrier function.<sup>30</sup> Increased endogenous synthesis of intestinal glucagon-like peptide-2 (GLP-2), which is known to strengthen gut barrier function by upregulating important tight junction proteins in the epithelium, may further amplify the prebiotic impact.<sup>31</sup> The health-promoting effects of prebiotics have been mostly attributed to faecal bifidobacteria, as the changes listed above were accompanied by an increase in this bacterial population.

However, few studies have questioned how bifidobacteria mediate prebiotic-induced metabolic benefits.<sup>32</sup> It is noteworthy that the definition of a healthy gut microbial community frequently varies by age and population prebiotic effects are now known to go beyond bifidobacteria and would probably necessitate a consortium of gut microbes involved in the trophic interactions.<sup>33,34</sup> Along with the microbiota-dependent processes, prebiotics can help to improve dietary fibre consumption and reduce calorie intake, which has been linked to lowering the risk of visceral obesity (Figure 2).<sup>35</sup>

**EFFECTS OF PREBIOTICS ON OBESITY MANAGEMENT IN CHILDREN**

The gut contains the greatest population of microorganisms in the human microbiota, which work in symbiotic relationships with the host to support metabolic balance and overall health, including the synthesis of a wide range of metabolites. Dysbiosis is associated with the promotion or aggravation of chronic metabolic diseases, including obesity and type 2 diabetes.<sup>36</sup>

One cause of metabolic disease is the gut microbiota's function in regulating inflammation, whereby high levels of lipopolysaccharide (LPS), which are made worse by a high-fat diet or high-fructose diet, cause metabolic endotoxemia, a low-grade inflammatory condition.<sup>37</sup> Dysbiosis also leads to change in metabolite synthesis. Consumption of prebiotics can modulate the gut microbiota, reduce systemic inflammation, improve the metabolic health and become a viable strategy to manage obesity.<sup>38</sup> Studies indicate that prebiotic supplementation, often combined with probiotics (synbiotics), can positively influence weight and other obesity indicators.<sup>39</sup> Table 1 summarizes the clinical studies focused on the effects of prebiotics on overweight/obese children.

**Table 1: Clinical studies on the effects of prebiotics on overweight/obese children.**

| Author                        | Study design                                           | Study population                                         | Intervention and duration                               | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------|--------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Nicolucci et al <sup>37</sup> | Single-centre, double-blind, placebo-controlled trial. | 42 children, 7–12 years old, with overweight or obesity. | Oligofructose-enriched inulin (OI). Duration -16 weeks. | Children who consumed OI had significant decreases in body weight z-score (decrease of 3.1%), percent body fat (decrease of 2.4%), and percent trunk fat (decrease of 3.8%) compared with children given placebo. Children who consumed OI also had a significant reduction in level of interleukin 6 from baseline (decrease of 15%) compared with the placebo group. There was a significant decrease in serum triglycerides (decrease of 19%) in the OI group. Increase in <i>Bifidobacterium</i> spp. in the OI group compared with controls. 16S rRNA sequencing revealed significant increases in species of the genus <i>Bifidobacterium</i> and decreases |

Continued.

| Author                            | Study design                                         | Study population                                                                 | Intervention and duration                                                                                     | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------------------------|------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                   |                                                      |                                                                                  |                                                                                                               | in <i>Bacteroides vulgatus</i> within the group who consumed OI. In faecal samples, levels of primary bile acids increased in the placebo group but not in the OI group.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Zhang et al <sup>40</sup>         | In vitro study                                       | 14 obese children, aged 9 years were recruited and their faecal sample was used. | Lactacaseibacillus paracasei (K56), xylooligosaccharide (XOS), galactooligosaccharide (GOS), polyglucose (PG) | Regulated gut microbiota and metabolites in children with obesity. GOS and XOS had higher degradation rates than PG + K56 symbiotics in the gut microbiota of children with obesity. Treatment with XOS, GOS, and their symbiotic combinations, (XOS + K56) and (GOS + K56), significantly reduced the production of gas, propionic acid, and butyric acid compared with PG + K56 treatment. Treatments with GOS + K56 and XOS + K56 altered the composition of the gut microbiota, improved the abundance of Bifidobacteria and Lactobacilli, and reduced the abundance of Escherichia/Shigella.                                                                                                                                               |
| Visuthranukul et al <sup>41</sup> | Randomized, double-blinded placebo-controlled study. | 155 obese children, aged 7-15 years.                                             | Inulin supplement<br>Duration – 6 months.                                                                     | Fat-free mass index significantly increased. There were no significant differences in the metabolic profiles between groups.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Visuthranukul et al <sup>42</sup> | Randomized, double-blinded placebo-controlled study. | 143 obese children, aged 7-15 years.                                             | Inulin supplement<br>Duration – 6 months.                                                                     | Increase in alpha-diversity was observed in the inulin group. Increased Bifidobacterium, Blautia, Megasphaera, and several butyrate-producing bacteria, including Agathobacter, Eubacterium coprostanoligenes, and Subdoligranulum, compared to the other groups. Significant difference in functional pathways of proteasome and riboflavin metabolism.                                                                                                                                                                                                                                                                                                                                                                                        |
| Hume et al <sup>8</sup>           | randomized, double-blind, placebo-controlled trial.  | 42 children, 7–12 years old, with overweight or obesity.                         | Oligofructose - enriched inulin.<br>Duration – 16 weeks.                                                      | Compared with placebo, prebiotic intake resulted in significantly higher feelings of fullness (p=0.04) and lower prospective food consumption (p=0.03) at the breakfast buffet at 16 weeks compared with baseline. Compared with placebo, prebiotic supplementation significantly reduced energy intake at the week 16 breakfast buffet in 11- and 12-y-olds (p=0.04) but not in 7- to 10-y-olds. Fasting adiponectin (P = 0.04) and ghrelin (P = 0.03) increased at 16 weeks with the prebiotic compared with placebo. In intent-to-treat analysis, there was a trend for prebiotic supplementation to reduce BMI z score to a greater extent than placebo (-3.4%;p=0.09) and a significant -3.8% reduction in per-protocol analysis (p=0.043) |

Continued.

| Author                               | Study design                                       | Study population                                                                      | Intervention and duration                                                                                                                                                                        | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------------|----------------------------------------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Czarnowski et al<sup>43</sup></b> | Animal and human trial.                            | 100 overweight/obese children, aged 5-10 years.                                       | Starch degradation products (SDexF).                                                                                                                                                             | SDexF slowed weight gain in female mice on both diets but only tempo rarely in males. It altered bacterial diversity and specific taxa abundances in mouse feces. In humans, SDexF did not influence weight loss or gut microbiota composition, showing minimal changes in individual taxa. The anti-obesity effect observed in mice with West Diet-induced obesity was not replicated in children undergoing a weight-loss program.                                                                                        |
| <b>Atazadegan et al<sup>44</sup></b> | Randomize double-blind, placebo-controlled trial   | 60 overweight /obese children, aged 8-18 years.                                       | synbiotic capsule containing $6 \times 10^9$ colony forming units (CFU) Lactobacillus coagulans SC-208, $6 \times 10^9$ CFU Lactobacillus indicus HU36 and fructooligosaccharide as a prebiotic. | The mean (standard deviation, SD) age was 11.07 (2.00) years and 11.23 (2.37) years for the placebo and synbiotic groups, respectively ( $p=0.770$ ). The waist-height ratio decreased significantly at the end of the intervention in comparison with baseline in the synbiotic group ( $0.54 \pm 0.05$ vs. $0.55 \pm 0.05$ , $p=0.05$ ). No significant changes were demonstrated in other anthropometric indices or body composition between groups.                                                                     |
| <b>Liber et al<sup>45</sup></b>      | Randomize double-blind, placebo-controlled trial   | 97 overweight /obese children, aged 7-18 years.                                       | Oligofructose. Duration-12 weeks.                                                                                                                                                                | At 12 weeks, the BMI-for-age z-score difference did not differ between the experimental (n 40) and control (n 39) groups. There were also no significant differences between the groups with regard to any of the secondary outcomes, such as the mean BMI-for-age z-score, percentage of body weight reduction and the difference in total body fat. Adverse effects were similar in both groups. In conclusion, oligofructose supplementation for 12 weeks has no effect on body weight in overweight and obese children. |
| <b>Zhang et al<sup>46</sup></b>      | Hospitalized intervention trial                    | 38 children, aged 3-16 years with simple obesity (SO) or Prader-Willi Syndrome (PWS). | Mixed prebiotics. Duration-4 weeks (SO), 12 weeks (PWS).                                                                                                                                         | Increased bifidobacterium spp. And enhanced carbohydrate metabolism. Reduced inflammation. Reduced leptin and increased adiponectin. Reduced BMI, improved liver condition, lipid and glucose metabolism.                                                                                                                                                                                                                                                                                                                   |
| <b>Zalewski et al<sup>47</sup></b>   | Randomized, double-blind, placebo-controlled trial | 96 overweight/obese children, aged 6-17 years.                                        | Glucomannan. Duration-12 weeks.                                                                                                                                                                  | No effect on weight reduction. Compared with the placebo, the glucomannan group had lower total and low-density lipoprotein cholesterol concentrations.                                                                                                                                                                                                                                                                                                                                                                     |

## CONCLUSION

Prebiotic supplementation may emerge as a promising strategy for managing childhood obesity by modulating the gut microbiota, enhancing the production of beneficial

metabolites like short-chain fatty acids, and potentially influencing metabolic processes such as fat storage, energy homeostasis, and appetite regulation. The studies reviewed indicate that prebiotics can have a positive impact on gut health, reduce adiposity, improve satiety,

and decrease overall calorie intake in children with obesity. However, while there is growing evidence supporting their effectiveness, the results remain inconsistent, suggesting that more research is necessary to identify the most effective prebiotics, dosages, treatment durations and long-term effects on childhood obesity. The influence of individual differences in gut microbiota composition also needs to be considered when assessing prebiotic interventions. As the body of evidence continues to grow, prebiotics may hold potential as a complementary approach to traditional obesity interventions in childhood, offering a novel pathway for addressing this pressing public health issue.

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