



Role of Probiotics in Enhancing the Effects of Physiotherapy in Patients with Metabolic Syndrome

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Abstract: Metabolic syndrome (MetS) refers to a constellation of metabolic disturbances such as central obesity, insulin resistance, dyslipidemia, and hypertension that together heighten the risk of developing cardiovascular disease and type 2 diabetes. Physiotherapy, particularly exercise-based interventions, is pivotal in improving metabolic health and physical function in MetS patients. Recent evidence suggests that gut microbiota modulation through probiotics may complement physiotherapeutic approaches by improving metabolic control, inflammation, and muscle function. Probiotic bacteria are live microorganisms incorporated into foods that confer health benefits to the host. They are commonly present in fermented products such as yogurt, kefir, sauerkraut, kimchi, and soybean-based foods like miso and natto. Probiotics exert a wide range of beneficial effects, including the modulation of gastrointestinal function and related disorders, enhancement of immune responses, and improvement of conditions such as hyperlipidemia, hypertension, and allergies. This article reviews the mechanisms through which probiotics enhance the outcomes of physiotherapy in metabolic syndrome, emphasizing their role in systemic inflammation reduction, insulin sensitivity improvement, and overall success of the interventions.

Keywords: Health, Metabolic Syndrome, Probiotics, Immunity, Muscle function

Introduction: The word *probiotic* originates from the Latin term “pro,” meaning “for,” and the Greek word “biotic,” meaning “life.” These microorganisms are generally recognized as beneficial to human health. The World Gastroenterology Organization (WGO) notes that different substances may act as probiotics, prebiotics, or symbiotics. Furthermore, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) define probiotics as “live microorganisms which, when consumed in sufficient quantities, provide health benefits to the host” (Hill et al., 2014).

According to the International Olympic Committee (IOC), “Probiotics are live micro-organisms that when administered orally for several weeks can increase the number of beneficial bacteria in the gut. These have been associated with a range of potential benefits to gut health, as well as modulation of immune function” (Maughan et al., 2018). What makes probiotics unique compared to other supplements is that they include living microorganisms, supplied in adequate amounts that support health (Rowland et al., 2010). Gavrilova et al. (2020) review on athletic nutrition showed that most research tailors diets to specific sports, training loads, or related health issues. It highlights the growing importance of biotechnological approaches to create specialized foods for athletes and physically active people. The study described the development of a probiotic-enriched curd product containing at least 1×10^8 CFU immobilized probiotics, was designed to improve digestibility and support gastrointestinal stability in athletes. Technological parameters and a production scheme for this specialized dairy product were established.

According to Jäger et al. (2020), probiotics may influence health outcomes in athletes and those engaged in regular physical activity. It was reported that specific probiotic strains support energy metabolism, reduce fatigue, alleviate exercise-induced gastrointestinal issues, enhance immune function, and improve nutrient absorption and recovery. The effects were strain- and dose-dependent, highlighting probiotics’ potential to



enhance performance and overall health. The authors reiterated that standardized protocols are required to confirm probiotics efficacy across different sport and training conditions.

Nutrition is crucial for athletic performance and recovery, but the role of gut microbiota has been largely overlooked. Emerging evidence links gut microbial composition to physical performance, with probiotics offering a way to beneficially modulate gut function and overall health. This review summarized studies on the interplay between physical activity and the gut microbiota, emphasizing the influence of probiotics on performance, recovery, and cognition. Beneficial microbes may enhance exercise capacity and an athlete's health, though more robust clinical trials are needed to clarify underlying mechanisms and confirm these effects (Marttinen et al., 2020).

Pugh et al.(2020) study tested whether four weeks of probiotic supplementation (PRO) could enhance maltodextrin absorption and oxidation during endurance cycling, thus preserving glycogen stored in the muscles for a later time. Seven male cyclists completed PRO and placebo trials in a crossover design. PRO slightly increased carbohydrate oxidation and plasma glucose and insulin levels while reducing fat oxidation, but had no effect on gastrointestinal integrity or time-trial performance. Overall, probiotics produced minor metabolic changes without improving endurance outcomes.

Humans host diverse microbial communities across body sites, with the gut microbiota playing key roles in immunity, metabolism, and overall health. Exercise intensity affects gut physiology, and 20–60% of athletes experience stress from overtraining and poor recovery. Supplementing with probiotics or prebiotics can enhance metabolic, immune, and barrier functions. It was reported that *Bifidobacterium breve* BR03 and *Streptococcus thermophilus* FP4 improved muscle performance, reduced inflammation, and aided recovery after strenuous exercise. Overall, specific probiotics may support performance and recovery in athletes under intense training (Pane et al., 2018).

Ibrahim et al.(2018) investigated the combined properties of probiotic supplements and circuit training on muscle strength, power, and cytokine responses in young men. In this study, forty-eight sedentary males were randomly assigned to four groups: control, probiotics (P), circuit training (CT), and circuit training with probiotics (CTP). After 12 weeks, both CT and CTP groups showed significant gains in knee strength and power. Overall, circuit training improved muscular performance and probiotics alone or with training enhanced anti-inflammatory responses.

Shaw et al. (2016) study completed a survey on usage of supplements in pre-event camp on thirty-nine elite Australian swimmers, compared with statistics from 11 years earlier. While overall supplement use remained high (97–100%), the 2009 swimmers used more total supplements, particularly those with stronger scientific support (sports foods and ergogenics) and use of less reputable supplements declined significantly. Australian Institute of Sport (AIS) swimmers reported greater use of ergogenic aids and fewer lower-quality supplements indicating that supplement practices have shifted more towards evidence-based products.

Gleeson et al.(2011) study investigated the effects of *Lactobacillus casei* Shirota (LcS) supplementation during 16 weeks of winter endurance training on upper respiratory tract infections (URTIs) and immune markers in 84 athletes. Compared with placebo, the probiotic group had 36% fewer weeks with URTI symptoms and significantly fewer total episodes (1.2 ± 1.0 vs. 2.1 ± 1.2 ; $p < 0.01$). Symptom severity and duration were similar between groups. Salivary IgA levels were higher in the probiotic group after 8 and 16 weeks. Regular LcS intake reduced URTI frequency, likely by supporting mucosal immunity during intense training.

Metabolic syndrome is a serious health problem that affects millions of adults worldwide. It occurs when several risk factors such as excess belly fat, high blood pressure, abnormal cholesterol levels, and high blood sugar happen together. Doctors diagnose metabolic syndrome when at least three of these issues are present: large waist size, high triglycerides, low HDL cholesterol, high blood pressure, or high fasting blood sugar (Grundy et



al., 2005). Physical activity and nutrition play a critical role in treating obesity and metabolic syndrome. Exercise reduces fat accumulation and increases energy expenditure, depending on its duration, intensity, and type (Morales et al., 2016).

Physiotherapy, particularly exercise training, is a cornerstone of non-pharmacological management for improving insulin sensitivity, cardiorespiratory fitness, and musculoskeletal health. Zeman and Valášková (2017) observed that a structured three-month physiotherapeutic program produced measurable reductions in waist circumference and related anthropometric parameters among subjects with metabolic syndrome. These improvements occurred despite the lack of concurrent dietary interventions. Patients with MetS often exhibit chronic low-grade inflammation and gut dysbiosis, which could impair exercise tolerance, tissue recovery, and overall rehabilitation outcomes. Nutritional strategies targeting gut microbiota especially supplementation with probiotics (live beneficial microorganisms) and prebiotics (non-digestible fibers that promote beneficial bacteria growth) are emerging as powerful adjuncts to physiotherapeutic care. Integrating microbiome modulation with physiotherapy could potentially optimize metabolic health, enhance exercise responsiveness, and accelerate physical rehabilitation in MetS patients (Zeman & Valášková, 2017).

Gut Microbiota and Metabolic Health: (Pane et al., 2018)

The gut microbiome exerts a fundamental influence on host physiology, particularly through its involvement in energy metabolism, modulation of inflammatory pathways, and maintenance of immune equilibrium. In metabolic syndrome, dysbiosis leads to:

- Increase in the permeability of gut (“leaky gut”) and translocation of lipopolysaccharides (LPS).
- Chronic systemic inflammation and insulin resistance.
- Altered short-chain fatty acid (SCFA) production, impacting muscle and liver metabolism.

Physiotherapy promotes beneficial shifts in microbiota through physical activity, while probiotics further reinforce gut health, creating a bidirectional relationship between microbiome modulation and exercise performance.

Mechanisms Linking Probiotics and Prebiotics to Health Outcomes:

The combination of microbiota-targeted nutrition and physiotherapy enhances rehabilitation outcomes via multiple mechanisms:

1. Improved Insulin Sensitivity and Glucose Control: (Torres et al., 2019)

Probiotics such as *Lactobacillus rhamnosus*, *Bifidobacterium lactis*, and *Akkermansia muciniphila* improve insulin sensitivity by reducing systemic inflammation and enhancing gut barrier integrity.

- SCFAs produced by prebiotic fermentation (e.g., butyrate, propionate) enhance glucose uptake in skeletal muscle.
- Improved glycemic control supports better endurance and energy utilization during physiotherapy exercises.

2. Anti-inflammatory and Antioxidant Effects: (Torres et al., 2019)

Probiotics modulate cytokine production, reducing pro-inflammatory mediators (TNF- α , IL-6) and increase anti-inflammatory cytokines (IL-10). As a result there would be less muscle soreness, faster recovery, and improved tolerance to exercise.



3. Muscle Function and Fatigue Resistance: (Ibrahim et al., 2018)

Research indicates that probiotic supplementation may increase mitochondrial biogenesis and oxidative capacity in muscle tissue. Enhanced muscle metabolism contributes to improved strength gains, endurance, and rehabilitation outcomes.

4. Weight Regulation and Body Composition: (Torres et al., 2019)

Prebiotic fibers (inulin, fructooligosaccharides) promote satiety hormones (GLP-1, PYY), reducing calorie intake and central adiposity. Coupled with physiotherapy-guided exercise, this combination aids in restoring metabolic balance.

Physiotherapy in Metabolic Syndrome: The Role of Gut Health (Zeman & Valášková, 2017)

Physiotherapists aim to improve cardiovascular fitness, flexibility, and musculoskeletal strength in MetS patients. However, metabolic dysfunction and inflammation can limit the physiological adaptation to exercise. A gut–muscle axis has been proposed, linking microbial metabolites to muscle performance. SCFAs such as butyrate and acetate produced by probiotics and prebiotics enhance: muscle glucose uptake, mitochondrial energy production and anti-inflammatory signalling during post-exercise recovery. Therefore, integrating microbiota-targeted nutrition can magnify the effects of physiotherapy by optimizing both metabolic and muscular adaptations.

Integration Strategy: Combining Physiotherapy with Microbiome Support

A multidisciplinary approach combining physical rehabilitation and gut microbiota optimization could be implemented as follows: (Ibrahim et al., 2018)

1. Baseline Assessment: Evaluate metabolic markers (fasting glucose, HOMA-IR), body composition, and gut health indicators.
2. Probiotic Supplementation: Daily intake of multi-strain probiotics (e.g., *Lactobacillus*, *Bifidobacterium*) for 8–12 weeks.
3. Physiotherapy Protocol: Progressive aerobic and resistance training tailored to individual metabolic capacity.
4. Outcome Monitoring: Assess muscle strength, inflammatory markers, and metabolic improvements using biochemical tools such as LC–MS/MS for metabolite profiling.

Implications for Clinical Practice (Zeman & Valášková, 2017; Ibrahim et al., 2018; Marttinen et al., 2020).

For physiotherapists and clinical nutritionists, understanding the gut–metabolism connection is crucial for comprehensive care. Probiotic supplementation may:

- Improve exercise tolerance and fatigue recovery.
- Enhance metabolic flexibility and insulin sensitivity.
- Reduce systemic inflammation, supporting musculoskeletal healing.
- Complement physiotherapy interventions for sustainable lifestyle modification.

This integration aligns with the holistic rehabilitation model, addressing both metabolic and functional dimensions of recovery.



Future Research Directions: Future studies should aim to:

- Identify strain-specific probiotic effects on physiotherapy outcomes.
- Determine optimal dosages and intervention durations.
- Utilize metabolomic and microbiome profiling (via LC–MS/MS and next-generation sequencing) to correlate gut-derived metabolites with rehabilitation markers.
- Evaluate long-term adherence and improvement in life quality in MetS subjects receiving combined interventions.

Such evidence would engrave the path for clinical guidelines integrating nutritional microbiome modulation into physiotherapy practice.

Conclusion: Probiotics represent promising adjunct therapies for enhancing physiotherapy outcomes in patients with metabolic syndrome. By modulating gut microbiota, reducing inflammation, and improving metabolic efficiency, these nutritional interventions complement the physiological adaptations induced by exercise and rehabilitation. The integration of gut-targeted nutrition with physiotherapeutic care may redefine recovery models for metabolic syndrome, fostering faster, more sustainable improvements in health and functionality.

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