

METABOLIC SYNDROME: SECRETS AND CURRENT MANAGEMENT APPROACHES**Symak Z.**

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<https://doi.org/10.5281/zenodo.21411825>**Abstract**

Metabolic syndrome (MS) remains one of the key global public health challenges due to its increasing prevalence and close association with obesity, insulin resistance, type 2 diabetes, and cardiovascular diseases. The aim of this review is to systematize current approaches to managing MS—including lifestyle modifications, pharmacological strategies, nutraceuticals, and innovative methods of personalized therapy.

An analysis of current evidence regarding the effectiveness of dietary models, physical activity, medications (in particular, GLP-1 agonists and SGLT2 inhibitors), and dietary supplements has been prepared.

Main conclusion: Comprehensive approaches that combine lifestyle changes with individualized therapy focused on component-specific correction remain the most effective. Further research should focus on integrating biomarkers, the microbiome, and digital technologies to personalize treatment.

Keywords: metabolic syndrome, insulin resistance, obesity, dietary therapy, physical activity, nutraceuticals, personalized therapy.

INTRODUCTION

Metabolic syndrome (MS) is defined as a cluster of interrelated metabolic disorders: central (visceral) obesity, hypertension, dyslipidemia (elevated triglycerides, low HDL cholesterol), impaired glucose tolerance, or insulin resistance [1].

According to recent studies, the prevalence of MS among adults is approximately 12.5–31.4%, depending on the diagnostic criteria. It correlates with an increased risk of cardiovascular disease, diabetes, cancer, and all-cause mortality in a dose-dependent manner [2].

The pathogenesis involves insulin resistance, excessive visceral adipose tissue, chronic systemic inflammation, oxidative stress, and endothelial dysfunction [3].

Due to the significant risk of developing cardiovascular disease (CVD), nonalcoholic fatty liver disease (NAFLD), type 2 diabetes (T2D), and overall mortality, managing metabolic syndrome is a priority in preventive cardiology and endocrinology [4].

Today, medicine is moving away from simply treating symptoms toward deeper levels of intervention. Modern approaches to managing metabolic syndrome (MS) are based on the concept of "4P medicine": personalization, prediction, prevention, and patient participation.

A detailed description of the key strategies that define the current standard of care for MS is provided in Table 1.

Table 1

Modern Directions of Pathogenetic Correction of Metabolic Syndrome

Approach	Components / What it includes
Lifestyle Modification	Dietary modification (LCHF, intermittent fasting), personalized exercise programs.
Pharmacotherapy	Use of GLP-1 receptor agonists, SGLT2 inhibitors, and insulin sensitizers.
Microbiome	Targeting the gut microbiota to regulate glucose metabolism.
Psychosomatics	Stress management and correction of circadian rhythms (sleep).

This review aims to summarize modern approaches to the prevention and treatment of MS, assess the evidence for the effectiveness of different strategies, and define avenues for further research.

RESULTS AND DISCUSSION

The main trend in recent years has been the shift from treating isolated symptoms (such as blood pressure or blood glucose) to targeting the fundamental mechanisms of obesity and insulin resistance.

Etiology and Pathogenesis of Metabolic Syndrome

MS is a multifactorial condition. Genetic and epigenetic factors play a significant role: studies demonstrate that (epi)genetic modifications, particularly those affecting the functional parameters of the hypothalamus and neuropeptides (such as BDNF), can be pivotal in the development of MS [5].

Adipose tissue localization plays a crucial role: visceral obesity stimulates the release of free fatty acids and pro-inflammatory cytokines (TNF- α , IL-6), along with a reduction in adiponectin levels, which drives the development of insulin resistance [1].

Dyslipidemia, hypertension, insulin resistance, and endothelial dysfunction form a detrimental metabolic profile that leads to atherosclerosis and T2D [6].

Modern research emphasizes that MS should be viewed not merely as a cluster of risk factors, but as a complex systemic disease that affects the liver, kidneys, heart, blood vessels, and nervous system [6].

Nutritional Therapy in the Management of Metabolic Syndrome

Dietary modification is a fundamental component of MS treatment. Caloric restriction and subsequent weight loss (a reduction of $\geq 5\%$ is recommended) are associated with improvements in insulin resistance and lipid profiles [4].

The Mediterranean diet has accumulated the strongest body of evidence. Characterized by a high intake of vegetables, fruits, whole grains, olive oil, and fish, alongside moderate consumption of red meat, it is associated with a reduced risk of developing MS and improved metabolic parameters.

Furthermore, low-glycemic index (Low-GI) diets, carbohydrate restriction, low-carbohydrate (Low-Carb) diets, and intermittent fasting demonstrate significant potential for MS management [7]. The role of micronutrients and antioxidants is also notable: magnesium, chromium, polyphenols, and omega-3 PUFAs are currently being investigated as adjunct options to improve the metabolic profile [8].

According to recent meta-analyses and randomized controlled trials (RCTs), a Mediterranean dietary pattern significantly reduces triglyceride levels and insulin resistance indices (HOMA-IR) within 6–12 months of intervention in patients with metabolic syndrome and NAFLD [9].

A systematic review and meta-analysis titled "*The impact of the Mediterranean diet on cardiovascular risk factors in patients with non-alcoholic fatty liver disease*" demonstrated that, compared to control groups, the Mediterranean diet:

- significantly lowers triglycerides;
- reduces HOMA-IR (insulin resistance) [10].

Physical Activity

Physical activity plays a pivotal role in the management of MS: aerobic training (e.g., 150 minutes/week of moderate intensity) and resistance exercises contribute to enhanced insulin sensitivity, reduction of visceral adipose tissue, and improvement of both lipid profiles and blood pressure [2].

Consistency, moderate-to-high intensity, long-term adherence, and tracking are all factors that influence the outcome. The authors emphasize that rather than a one-time intervention, the sustainability of lifestyle changes is what remains paramount [2].

Pharmacological Therapy

Although data directly addressing the treatment of metabolic syndrome as a single, unified diagnosis remain limited, the targeted therapy of its individual components demonstrates substantial efficacy.

• **Insulin Resistance and Metabolic Control:** Metformin and thiazolidinediones are widely utilized to address insulin resistance.

• **Cardiovascular and Lipids Management:** Statins, omega-3 fatty acids, and antihypertensive

agents are employed to correct dyslipidemia and blood pressure [2].

• **Next-Generation Agents:** GLP-1 receptor agonists (such as semaglutide and tirzepatide) and SGLT2 inhibitors demonstrate profound outcomes. Beyond lowering blood glucose, they induce radical weight reduction and mitigate cardiovascular risk [2]. Specifically, SGLT2 inhibitors provide potent cardio-protection and nephroprotection by promoting osmotic diuresis and excreting excess glucose via urine.

• **Combination Therapy:** Modern protocols increasingly advocate for the early combination of these two drug classes to achieve a synergistic therapeutic effect.

It is crucial to emphasize that pharmacotherapy must always be accompanied by lifestyle modifications. According to a recent review, while treating individual components of MS successfully reduces cardiovascular disease (CVD) risk, there is still insufficient evidence that directly treating MS as a holistic syndrome lowers hard adverse clinical outcomes [2].

The Role of Nutraceuticals and Dietary Supplements

Adjunct therapies are gaining popularity in the management of MS. For instance, a systematic analysis of 37 studies on the effects of resveratrol demonstrated that this supplement can lower systolic and diastolic blood pressure, as well as blood glucose levels [8]. Other supplements—including magnesium, chromium, polyphenols, and probiotics—are currently being investigated as potential agents to improve the metabolic profile.

Certain essential trace elements, particularly iron (Fe), copper (Cu), and manganese (Mn), play vital roles in biochemical and physiological functions at low concentrations but can exert toxic effects on the gut microbiota at higher levels. Some potentially essential trace elements, such as chromium (Cr), silicon (Si), and nickel (Ni), which are considered intermediate in terms of essentiality and toxicity, have shown varied effects on the gut microbiota and its metabolites. Furthermore, bidirectional relationships have been identified between heavy metals and the gut microbiota [12].

At the same time, it is crucial to emphasize that current data remain insufficient to support broad clinical application, and such interventions must be accompanied by proper monitoring and medical supervision.

Innovative and Personalized Approaches

• **Gut Microbiome-Targeted Therapy:** Substantial evidence underscores the profound impact of the gut microbiota on the development of obesity and insulin resistance.

• **Genetic and Epigenetic Testing:** This includes assessing the role of BDNF and other neurotrophic factors in the pathogenesis of MS, as well as identifying genetic predispositions to specific lipid or carbohydrate metabolic pathways [5].

• **Digital Technologies:** Mobile applications and wearable devices that track physical activity, sleep, and nutrition enable the creation of highly personalized intervention programs. This includes the use of continuous sensors even in non-diabetic individuals to identify which specific foods trigger sharp insulin spikes.

- **Digital Twins and Metabolic Modeling:** Simulating a patient's metabolic processes within software programs to predict treatment outcomes.
- **Chrononutrition and Circadian Rhythms:** Aligning dietary intake and exercise schedules with circadian biology is rapidly gaining popularity as a component of future therapeutic strategies.
- **Chronic Stress Management:** Utilizing psychometabolic correction techniques and cognitive behavioral therapy (CBT) to combat emotional eating and elevated cortisol levels.

- **Social Support Systems:** Shifting toward multidisciplinary teams (consisting of a physician, nutritionist, health coach, and psychologist) rather than relying on a single general practitioner.

While these approaches open new horizons in metabolic health, they require further robust clinical research [11]. The key trends of modern approaches compared to traditional ones are summarized in Table 2.

Table 2

Comparative Analysis of Traditional and Modern Approaches to Metabolic Health Correction

Parameter	Traditional Approach (2010s)	Modern Approach (2025–2026)
Primary Goal	Weight loss and glucose reduction	Metabolic health and quality of life
Methods	"Eat less, move more"	Hormonal regulation and biohacking
Nutrition	Standardized diets (e.g., Diet No. 9, Diet No. 10)	Personalized nutrition driven by GLP-1 therapy
Monitoring / Control	Periodic blood tests	Continuous monitoring (wearables + CGM)
Medications	Metformin, statins	GLP-1/GIP receptor agonists, SGLT2 inhibitors

Analyzing the data in Table 2, a clear conclusion can be drawn regarding a fundamental paradigm shift in metabolic health management over the past 15 years. Medicine and the wellness industry have transitioned from the standardized, often grueling restrictions of the 'previous generation' toward high-tech, personalized biohacking, where hormonal correction, digital technologies, and intelligent management of the body's biological processes have become the primary tools.

CONCLUSION

Metabolic syndrome is a multifactorial pathology that requires comprehensive management. The most effective strategies are those that combine lifestyle modifications (diet and physical activity) with individualized therapy targeting the specific components of the syndrome. Pharmacological and nutraceutical interventions can serve as powerful adjuncts but do not replace the foundation, which is lifestyle change. Promising avenues include the integration of genetics, microbiota, and digital solutions to personalize the approach. Further research should focus on the efficacy rates of full metabolic syndrome correction as a unified diagnosis, rather than just treating its individual components.

Perspectives for Further Research

There is a need to conduct randomized controlled trials aimed specifically at reducing risk through the management of metabolic syndrome as a holistic condition. This includes investigating the impact of nutraceuticals in large cohorts, as well as developing algorithms for personalized nutritional therapy that account for genetic, microbiome, and behavioral characteristics. Additionally, the implementation of digital technologies and mobile solutions is crucial for the long-term support of patients with metabolic syndrome.

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