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THE RELATIONSHIP BETWEEN INSULIN RESISTANCE AND INFLAMMATORY MARKERS IN DIFFERENT DIET TYPES

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Abstract
This article summarizes current data on the impact of various dietary patterns on inflammatory markers and their relationship with insulin resistance. The effects of the Mediterranean, low-carbohydrate, high-fiber, and anti-inflammatory diets are examined. Diets high in fiber, antioxidants, and monounsaturated fats have been shown to reduce levels of TNF-α, IL-6, and CRP, contributing to improved insulin sensitivity. Limiting saturated fats and sugars further reduces inflammation and lowers the risk of insulin resistance progression.

Keywords: Insulin resistance, inflammatory markers, diet, Mediterranean diet, low-carbohydrate diet, fiber, anti-inflammatory diet, type 2 diabetes.

Introduction

The scientific novelty of this study lies in its first systematic comparison of different dietary patterns with the dynamics of inflammatory markers (TNF-α, IL-6, CRP) and their impact on insulin resistance in adult patients. Combining clinical and molecular data allows us to identify mechanistic links between diet, inflammation, and metabolic profile, as well as formulate practical recommendations for the prevention and treatment of type 2 diabetes.

Insulin resistance is a central pathophysiological factor in the development of type 2 diabetes mellitus and metabolic syndrome, and is an independent risk factor for cardiovascular complications. Insulin resistance is characterized by a reduced response of peripheral tissues to insulin, leading to compensatory hyperinsulinemia, disturbance of glycemic homeostasis and dyslipidemia [1].

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One of the main mechanisms underlying the development and progression of insulin resistance is chronic low-grade inflammation. Elevated levels of proinflammatory cytokines (such as TNF-α and IL-6) and an imbalance of adipokines (such as leptin and resistin) disrupt normal insulin signaling. These mediators induce serine phosphorylation of IRS (insulin receptor substrates) and suppress the key intracellular PI3K-AKT pathway. This, in turn, leads to decreased translocation and activity of the GLUT4 glucose transporter on the cell surface and, consequently, impaired glucose utilization.

Diet is a key modifiable factor that can influence both insulin resistance and systemic inflammation. The Mediterranean diet, rich in monounsaturated fats, fiber, and antioxidants, has been consistently associated with improved insulin sensitivity and reduced inflammatory markers (e.g., CRP and IL-6) [2]. Low-carbohydrate, high-fiber diets also demonstrate a positive effect on inflammatory markers and improved metabolic profiles in patients with type 2 diabetes.

Despite the existence of isolated studies, there is a pressing need for a comprehensive data analysis focusing on the relationship between insulin resistance and inflammatory markers across different dietary patterns. Such analysis will identify specific mechanistic pathways through which diet modulates inflammation and, consequently, insulin sensitivity, which is important for developing evidence-based recommendations for the prevention and treatment of type 2 diabetes.

The aim of this study was to summarize current clinical and mechanistic data on the effects of different dietary patterns on inflammatory markers and their direct relationship with insulin resistance in adult patients with type 2 diabetes mellitus, identify key pathophysiological relationships, and propose evidence-based dietary recommendations.

Chronic low-grade inflammation is a key factor in the development of insulin resistance (IR). The key cellular and molecular mechanisms are:

1. Increased levels of proinflammatory cytokines. TNF-α, IL-6, and IL-1β are produced by adipose tissue, macrophages, and the liver. These cytokines activate serine / threonine kinases (e.g., JNK, IKKβ) that phosphorylate insulin receptor

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substrate (IRS) at serine residues, disrupting the normal PI3K–AKT pathway and reducing GLUT4 transporter activity [3].

2. Activation of adipokines. Adipokines such as resistin and leptin enhance inflammatory signaling pathways and worsen the metabolic profile of tissues, reducing insulin sensitivity [4].

3. Oxidative stress and mitochondrial damage. Excessive lipid accumulation in skeletal muscle and liver increases the production of reactive oxygen species, damages mitochondria, and increases inflammation, which further disrupts insulin signaling [1].

4. Endotokinemia and intestinal dysbiosis. Increased levels of lipopolysaccharides (LPS) in the blood due to intestinal microbiota imbalance activates Toll-like receptors and NF- κB, which leads to systemic inflammation and decreased insulin sensitivity [5].

5. The effect of diet on inflammation. Dietary factors such as high intake of saturated fat and sugar increase inflammation, while diets high in fiber, antioxidants, and omega-3 fatty acids reduce levels of TNF-α, IL-6, and CRP [2].

Table 1 - The main mechanisms of inflammation that influence insulin resistance

Mechanism	**Key molecules/ effects**	**Effect on insulin resistance**
Proinflammatory cytokines	TNF-α, IL-6, IL-1β	Serine phosphorylation of IRS, ↓ GLUT4
Adipokines	Resistin, leptin	Increased inflammatory signals, ↓ insulin sensitivity
Oxidative stress	ROS, mitochondrial damage	Insulin signaling disorder, ↑ IR
Endotokinemia and intestinal dysbiosis	κB activation	Systemic inflammation, decreased insulin sensitivity
Dietary factors	Saturated fat, sugar, fiber, antioxidants	Increase or decrease in inflammation, correction of IR

Various dietary patterns demonstrate significant modulating effects on key inflammatory markers TNF-α, IL-6, and CRP, which directly correlates with improved insulin resistance.

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1. The Mediterranean diet, characterized by a high intake of monounsaturated fats (olive oil), vegetables, fruits, nuts, and fish, has a pronounced anti-inflammatory effect. Adherence to the Mediterranean diet in overweight patients with type 2 diabetes leads to a significant reduction in CRP, IL-6, and TNF-α levels, reflecting a reduction in systemic inflammation and improved metabolic health [2].
2. Carbohydrate-restricted diets are effective in reducing body weight, insulin levels, and, consequently, inflammatory markers, especially in individuals with obesity and type 2 diabetes. Although these diets demonstrate rapid improvement in metabolic parameters, their long-term adherence may be associated with the risk of vitamin and micronutrient deficiencies, which requires individual selection and nutritional support [6].
3. Increased dietary fiber intake promotes improved metabolic control and a reduction in systemic inflammation via the gut-metabolism axis. Fiber stimulates the formation of favorable intestinal microbiota and increases the production of short-chain fatty acids (SCFA). SCFA, as key metabolites, help reduce systemic inflammation by positively influencing insulin sensitivity [7].
4. A general strategy that includes limiting saturated fat and added sugar, combined with high intake of antioxidants and omega-3 fatty acids, specifically targets chronic inflammation. These diets promote a reduction in inflammatory markers, which is directly associated with improved insulin sensitivity and restoration of normal insulin signaling [1].

Table 2 - Effect of different dietary patterns on key inflammatory markers

Power supply type	**Main components**	**Effect on inflammatory markers (TNF-α, IL-6, CRP)**	**Effect on insulin resistance**
Mediterranean diet	Olive oil, vegetables, fruits, fish, nuts	↓ CRP, ↓ IL-6, ↓ TNF-α	Improves insulin sensitivity
Low-carb diet	Limit carbohydrates, proteins, fats	↓ CRP, ↓ IL-6 (short term)	Reduces IR, requires nutrient control
High-fiber diet	Whole grains , vegetables, fruits	↓ IL-6, ↓ CRP, ↑ SCFA	Improves IR through gut microbiota
Anti-inflammatory diet	Antioxidants, omega-3, low in sugar and saturated fat	↓ TNF-α, ↓ IL-6, ↓ CRP	Improves IR

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Based on an analysis of modern clinical studies and meta-analyses, a number of evidence-based dietary recommendations can be formulated for patients with type 2 diabetes and prediabetes aimed at reducing chronic inflammation and improving insulin sensitivity:

1. Mediterranean diet.
The essence of the recommendation: actively include olive oil (as the main source of fat) in the diet, as well as vegetables, fruits, nuts and fatty fish.
Metabolic effect: a reduction in the levels of CRP, IL-6 and TNF-α was observed, which directly correlates with an improvement in systemic insulin sensitivity [2].

2. High fiber diet.
The essence of the recommendation: a significant increase in the consumption of whole grain products, legumes, vegetables and fruits (up to 30–40 g per day).
Metabolic effect: stimulation of intestinal microbiota to produce short-chain fatty acids (SCFA), which helps to reduce systemic inflammation and improve the metabolic profile [4].

3. Limitation of pro-inflammatory components.
The essence of the recommendation: a sharp reduction in the consumption of saturated fats (red and processed meat) and added sugars (sweet drinks, processed foods, confectionery).
Metabolic effect: reduction of systemic inflammation, reduction of lipotoxicity and improvement of lipid profile, which has a positive effect on insulin signaling function [6].

4. Enrichment with anti-inflammatory and functional components.
The essence of the recommendation: regular consumption of Omega-3 fatty acids (fatty fish, flax seeds, walnuts) and foods rich in antioxidants (berries, green tea).
Metabolic effect: direct suppression of the activity of proinflammatory cytokines and restoration of tissue sensitivity to insulin [1].

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5. Individual approach and laboratory monitoring.

The essence of the recommendation: the selection of the optimal dietary model should be strictly individualized, taking into account body weight, concomitant diseases, lifestyle, and personal preferences.

Monitoring: To assess the effectiveness of the intervention and ensure safety, regular monitoring of biochemical markers (glucose, HbA1c, CRP, IL-6) is necessary [5].

Table 3 - Practical Dietary Recommendations for Reducing Inflammation and Improving Insulin Sensitivity

Recommendation	**Key components**	**Effect on inflammatory markers**	**Effect on insulin resistance**
Mediterranean diet	Olive oil, vegetables, fruits, fish, nuts	↓ CRP, ↓ IL-6, ↓ TNF-α	Improves insulin sensitivity
High fiber diet	Whole grains , legumes, vegetables, fruits	↓ IL-6, ↓ CRP, ↑ SCFA	Improves IR through microbiota
Limit saturated fat and sugar	Red meat, sweet drinks, processed foods	↓ TNF-α, ↓ CRP	Reduces IR
Anti-inflammatory components	Omega-3, antioxidants (berries, green tea)	↓ TNF-α, ↓ IL-6	Increases insulin sensitivity
Individual approach	Personalized diet, marker monitoring	Stabilization of biochemical parameters	Improving metabolic profile

Chronic low-grade inflammation is a key mechanism in the development of insulin resistance and the progression of type 2 diabetes. Proinflammatory cytokines (TNF-α, IL-6), adipokines (leptin, resistin), oxidative stress, and intestinal dysbiosis disrupt insulin signaling, reducing glucose utilization and increasing the risk of metabolic disorders.

Different diets have a significant impact on inflammatory markers and insulin sensitivity. The Mediterranean diet, high-fiber diets, and anti-inflammatory strategies reduce levels of CRP, TNF-α, and IL-6, helping to improve insulin sensitivity. Conversely, excess consumption of saturated fats and refined

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carbohydrates increases inflammation and promotes the progression of insulin resistance.

The practical significance of this study is that dietary intervention is an effective tool for modulating inflammation and improving the metabolic profile in patients with prediabetes and type 2 diabetes. A personalized approach, taking into account preferences, comorbidities, and monitoring biochemical markers, maximizes the effectiveness of dietary therapy.

Thus, systemic dietary modification aimed at reducing inflammatory processes is a key component of the comprehensive treatment of insulin resistance and the prevention of diabetes complications.

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