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The Role of Lifestyle in the Prevention and Treatment of Insulin Resistance: A Review of Clinical and Intervention Studies

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Abstract

Introduction

Insulin resistance (IR) is a metabolic disorder characterized by reduced tissue sensitivity to insulin, resulting in impaired glucose homeostasis. IR plays a pivotal role in the development of type 2 diabetes, metabolic syndrome, and associated cardiovascular complications. Effective strategies for the prevention and treatment of IR focus on lifestyle modification, including physical activity and stress management.

Aim of the Study

The aim of this study is to evaluate the role of lifestyle factors in the prevention and treatment of insulin resistance (IR) based on the analysis of clinical and interventional studies, with a particular focus on dietary interventions, physical activity programs, stress reduction techniques, and sleep quality improvement recommendations.

Materials and Methods

A review of clinical and interventional studies was conducted using databases such as PubMed. The analysis included studies evaluating the impact of specific lifestyle interventions on markers of insulin resistance (IR), such as fasting insulin levels, HOMA-IR indices and glucose tolerance. Particular attention was paid to randomized controlled trials (RCTs) and meta-analyses published between 2020 and 2024.

Summary

Studies have shown that diets such as the Mediterranean and DASH, combined with regular aerobic and resistance exercises, significantly improve insulin sensitivity. Additionally, stress-reduction techniques like mindfulness and yoga, along with adequate sleep quality, enhance positive metabolic effects. These findings highlight the need for a multifaceted approach to treating insulin resistance, incorporating dietary and behavioral changes. The review also points out research gaps and emphasizes the necessity of long-term studies to refine lifestyle recommendations for diverse populations.

Keywords: insulin resistance (IR), metabolic syndrome, type 2 diabetes, insulin sensitivity, diet, physical activity.

Literature Review

Insulin resistance is a key pathogenic factor in many metabolic diseases, including type 2 diabetes. It is defined as a state of reduced tissue response to insulin, leading to impaired glucose metabolism. Mechanisms of its development include, among others, lipid accumulation in the liver and muscles. [1]

In insulin resistance, there is also a chronic inflammatory state that negatively affects insulin sensitivity. Pro-inflammatory cytokines, such as TNF-alpha and interleukin-6, play a key role in this process. Interleukin-6 particularly affects insulin resistance in the liver, disrupting insulin signaling and reducing its effectiveness, leading to impaired glucose metabolism. Studies have shown that interleukin-6 inhibits early insulin receptor signaling and further insulin actions, such as glycogen synthesis, worsening glucose control. Chronic elevation of these cytokines contributes to the development and maintenance of insulin resistance, potentially leading to type 2 diabetes and other metabolic complications. [20]

Excess fat in atypical areas such as the liver, kidneys, or heart leads to serious health issues related to obesity, including obesity-related glomerulopathy, non-alcoholic fatty liver disease (NAFLD), and cardiomyopathy. In insulin resistance, lipotoxicity contributes to dysfunction of pancreatic beta cells and affects the development of polycystic ovary syndrome (PCOS). [2]

The role of lifestyle factors.

Analysis of the Mediterranean and DASH diets as examples of effective interventions.

The Mediterranean diet, based on healthy fats such as olive oil, fish, vegetables, and fruits, is considered beneficial for insulin resistance and also reduces the risk of cardiovascular diseases. In one study, patients with type 2 diabetes following this diet had lower HbA1c levels (a marker of long-term blood glucose) and better glycemic control compared to those on traditional low-fat diets. [3,18,19]

A cross-sectional analysis was conducted among 901 diabetes patients visiting a diabetic clinic in Southern Italy. The study found that adherence to the Mediterranean diet was inversely correlated with postprandial glucose levels and HbA1c. Patients with high adherence to this diet had significantly lower HbA1c and post-meal glucose levels. Another study, although not statistically significant, showed a trend towards an inverse relationship between diet adherence and HbA1c levels, accounting for other variables like physical activity and BMI. [3,18,19]

The DASH diet (Dietary Approaches to Stop Hypertension) is a popular dietary model that shows numerous health benefits. [4] The diet emphasizes consuming lean proteins, a large amount of fruits, whole grains or complex carbohydrates, low-fat dairy products, and foods low in saturated fats. [5] It helps not only in maintaining a healthy body weight but also influences the composition of various components in the body, liver function, and reduces levels of inflammatory biomarkers. Furthermore, this diet improves overall health, particularly in the prevention of cardiovascular and metabolic diseases such as insulin resistance and type 2 diabetes. [4]

The DASH diet (Dietary Approaches to Stop Hypertension) shows significant benefits in glucose metabolism and insulin resistance, particularly in reducing fasting insulin levels and the HOMA (Homeostasis Model Assessment) index, which assesses insulin sensitivity. Studies have shown that the DASH diet leads to a significant reduction in these parameters in both patients with metabolic syndrome and those without, with minimal differences between the two groups. Additionally, the DASH diet may improve HbA1c levels in patients with an HbA1c of 5.7% or higher, which is an important long-term indicator of glycemic control in individuals with diabetes and insulin resistance. [5,6,7]

Physical Activity: A Review of the Benefits of Aerobic and Strength Training.

Aerobic training, also known as endurance training, includes activities such as running, cycling, dancing, and swimming. It is a form of exercise that engages large muscle groups and requires a constant supply of oxygen.

Strength training, also known as resistance training, includes physical activities such as weightlifting, bodyweight exercises like push-ups and squats, as well as using resistance machines. The goal of this training is to build muscle mass, improve strength, and enhance endurance. [23]

A randomized controlled trial was conducted on a group of 160 obese older adults, comparing aerobic exercise (AEX), resistance exercise (REX), or combined exercise (COMB). Results were analyzed after 6 months, focusing on changes in intramuscular adipose tissue (IMAT) and visceral adipose tissue (VAT) using MRI, insulin sensitivity (ISI) through an oral glucose tolerance test, physical function via a modified physical performance test (PPT), peak VO2, walking speed, and knee strength using dynamometry. [9]

The analysis of the results showed an improvement in insulin sensitivity index (ISI) across all interventions, as measured by the oral glucose tolerance test. Improvement in ISI is a key indicator of reduced insulin resistance. [9] Additionally, other studies comparing differences in exercise intensity and duration found that despite significant variations in intensity and duration, 12 weeks of HIIT (High-Intensity Interval Training) and MICT (Moderate-Intensity Continuous Training) led to similar short-term improvements in peripheral insulin sensitivity (measured the day after exercise) and comparable long-term metabolic adaptations in skeletal muscles in individuals with obesity. These results suggest that the improvement in insulin sensitivity from both types of exercise primarily arises from the most recent training sessions, rather than long-term accumulated adaptations. [8]

In subsequent studies conducted by Lee et al., it was shown that resistance exercises are a better method for reducing body fat, while aerobic and combined exercises demonstrated similar benefits in improving insulin sensitivity [21,22].

Stress management: The impact of mindfulness, yoga, and other stress reduction techniques.

Yoga, as a form of activity that connects the body and mind, has been effectively used to improve insulin sensitivity in individuals at risk of developing type 2 diabetes. Yoga-based interventions have contributed to better glycemic control, reduced stress levels, and decreased overall metabolic risk factors. These changes are attributed to a reduction in stress hormones such as cortisol, which supports glucose metabolism and insulin function. [10,11]

Studies suggest that mindfulness-based interventions, such as Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT), can positively impact glycemic control and insulin resistance in individuals with type 2 diabetes. Meta-analyses of these techniques have shown significant reductions in HbA1c levels (average difference ~0.25–0.35%), indicating improved fasting glucose and potentially better insulin sensitivity. These effects are attributed to reductions in cortisol levels and improvements in the autonomic nervous system function, which indirectly influence glucose metabolism and insulin function. [12,13,14]

Sleep Quality: The Importance of Regular and Sufficient Sleep.

Sleep quality has a significant impact on insulin sensitivity, and sleep disorders can increase the risk of developing insulin resistance. Insufficient sleep or disrupted circadian rhythms can disrupt hormonal balance, leading to poorer glucose utilization and reduced insulin sensitivity. Sleep is crucial for maintaining metabolic health as it allows for the body to regenerate and the hormonal system, including insulin, to function properly. [15,16,17]

Deep sleep, especially during the REM phase, is particularly important as it helps repair cells and improves insulin signaling. Therefore, enhancing sleep quality can positively impact insulin sensitivity and assist in managing risk factors related to diabetes and obesity. [15]

To improve sleep quality and insulin sensitivity, it is important to maintain a regular sleep schedule, reduce exposure to blue light before bed, ensure a comfortable temperature and darkness in the bedroom, and avoid caffeine and alcohol in the evening. Therefore, enhancing insulin sensitivity and reducing the risk of insulin resistance requires not only increasing sleep duration but also ensuring its quality by maintaining a regular circadian rhythm and avoiding disruptions, such as night shifts. [16,17]

Conclusion

Studies show that lifestyle changes, such as a proper diet, physical activity, stress reduction techniques, and improving sleep quality, have a significant impact on insulin sensitivity and can prevent or alleviate insulin resistance (IR). The Mediterranean diet and the DASH diet, combined with regular aerobic and resistance exercises, demonstrate significant improvements in insulin sensitivity and glucose control.

In particular, diets rich in healthy fats (e.g., olive oil, fish), vegetables, and fruits, as well as the reduction of saturated fats, show beneficial effects in lowering HbA1c levels and improving glucose metabolism. The DASH diet, which focuses on consuming lean proteins, fruits, vegetables, and whole grains, also demonstrates a significant reduction in fasting insulin levels and an improvement in insulin sensitivity markers, which is especially beneficial for individuals with metabolic syndrome and type 2 diabetes.

Regular physical activity, both aerobic and resistance, also contributes to improved insulin sensitivity. Studies show that both high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) lead to similar short-term improvements in insulin sensitivity. Resistance training, on the other hand, may be more effective in reducing fat tissue, while aerobic exercises and a combination of both types of activity contribute to overall metabolic improvement.

Stress management techniques, such as yoga and mindfulness meditation, help lower cortisol levels, which positively impacts glucose metabolism and insulin function. Mindfulness interventions have shown a reduction in HbA1c levels, indicating improved glycemic control.

Sleep quality, particularly regular and deep sleep, plays a crucial role in maintaining optimal insulin sensitivity. Sleep disturbances, such as short sleep duration or irregular circadian rhythms, can lead to reduced insulin sensitivity. Therefore, improving sleep quality, including adhering to a regular sleep schedule and avoiding disruptive factors such as blue light or caffeine in the evening, is important in preventing insulin resistance

In summary, effective treatment and prevention of insulin resistance require a multifaceted approach that combines dietary changes, regular physical activity, stress reduction techniques, and improvement in sleep quality. Further research, particularly long-term studies, is needed to better tailor these interventions to different population groups and optimize therapeutic strategies for the prevention and treatment of insulin resistance.

Disclosure

Conceptualization: Daria Rybak; Methodology: Bartosz Omasta; Software: Katarzyna Kamińska-Omasta; Check: Kuba Borys Romańczuk and Olga Krupa; Formal analysis: Kinga Furtak and Magdalena Agata Czerska; Investigation: Paulina Dorota Pietrukaniec and Szymon Przemysław Stolarczyk; Resources: Magdalena Agata Czerska and Zofia Martyna Wójcik; Data curation: Bartosz Omasta; Writing -through preparation: Daria Rybak; Writing -review and editing: Katarzyna Kamińska-Omasta and Kuba Borys Romańczuk; Visualization: Szymon Przemysław Stolarczyk and Zofia Martyna Wójcik; Supervision: Paulina Dorota Pietrukaniec; Project administration: Olga Krupa and Kinga Furtak

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The authors deny any conflict of interest.

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