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Current Research Status on the Effects of Exercise Intervention on Metabolic Conditions in Patients with Glucose Metabolism Disorders

Nan Zhu

Beijing Sport University, Beijing, China
happykishi@163.com

Abstract. As a non-pharmacological strategy, exercise intervention has demonstrated significant health benefits in the prevention and treatment of disorders related to glucose metabolism disorders. By enhancing insulin sensitivity, optimizing lipoprotein metabolism, lowering blood lipid levels, improving dyslipidemia, and aiding in weight management, exercise provides effective support for managing type 2 diabetes and metabolic syndrome. This study presents a comprehensive analysis of various forms of exercise interventions—including aerobic exercise, resistance training, traditional Chinese exercises, and high-intensity interval training (HIIT)—and their effects on glucose metabolism abnormalities. It finds that all forms of exercise can improve glucose and lipid metabolism to varying extents. Moreover, the suitability and metabolic focus of each exercise type vary according to population characteristics and exercise intensity. Despite the widely recognized positive effects of exercise intervention, challenges such as individual differences, exercise habits, and economic conditions persist during implementation. Future research should focus on the personalized design of exercise programs, motivational mechanisms for long-term adherence, and the integration of exercise with other healthy lifestyle practices. As a key component of public health strategies, exercise intervention should be promoted through policy guidance, financial support, and public education to encourage widespread participation in healthy living.

Keywords: Glucose Metabolism Disorders, Exercise therapy, Type 2 diabetes, Glucose-lipid metabolism

1. Introduction

In recent years, due to changes in lifestyle and an aging population, the prevalence of glucose metabolism disorders and its impact on health have garnered increasing attention. This condition is characterized by its high incidence rate and widespread influence. According to statistics, diseases associated with glucose metabolism disorders, such as type 2 diabetes, are prevalent worldwide. The Guidelines for the Prevention and Treatment of Type 2 Diabetes in China (2017 Edition) clearly point out the significant increase in the prevalence of type 2 diabetes in China, particularly among individuals who are overweight or obese[1]. Furthermore, glucose metabolism disorders is closely

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linked to the onset and progression of various diseases and is commonly found as a comorbid condition in multiple health disorders. Given the widespread nature of glucose metabolism disorders and their extensive health implications, it is imperative that these issues receive adequate attention and that effective preventive and therapeutic strategies be developed.

2. Research on diseases related to glucose metabolism disorders

Glucose metabolism disorders serves as an important pathological basis for various diseases, exerting wide-ranging and profound clinical impacts. Studies have shown that it is closely associated with cardiovascular disease, kidney disease, and neurological disorders. Glucose metabolism disorders involves the processes of glucose intake, storage, utilization, and conversion, which, when disrupted, may lead to elevated blood glucose levels and an increased risk of developing diabetes [2]. Type 2 diabetes is the most typical manifestation of glucose metabolism disorders. With changes in modern lifestyle—particularly the rise in sedentary behavior and unhealthy eating habits—the incidence of glucose metabolism disorders has been steadily increasing, especially among the elderly.

Effective management of glucose metabolism disorders is crucial for preventing diabetes and reducing its complications. Early intervention measures, such as dietary adjustments, increased physical activity, and weight management, can significantly reduce the risk of progression from glucose metabolism disorders to full-blown diabetes. Among comprehensive management strategies, exercise has been proven to be an effective intervention. It functions by increasing muscle mass, enhancing insulin sensitivity, and promoting the normalization of glucose metabolism.

3. Research on the effects of exercise intervention on metabolic conditions in patients with glucose metabolism disorders

During the process of literature review, it was found that type 2 diabetes is the most extensively studied and documented condition among diseases related to glucose metabolism disorders. Therefore, this section focuses on type 2 diabetes, a representative and prevalent condition within this category.

Conventional treatment primarily relies on blood glucose control, including oral medications and insulin injections. However, these approaches have limitations in improving patients' overall quality of life. As a non-pharmacological treatment, exercise intervention improves metabolic status by increasing physical activity, enhancing insulin sensitivity, lowering blood glucose and lipid levels, controlling weight, and reducing the risk of complications [3]. In addition, it improves cardiopulmonary function and contributes to overall health and well-being. Nevertheless, the practical application of exercise intervention faces numerous challenges. Factors such as individual differences, exercise habits, physical conditions, and treatment adherence can all affect its effectiveness. Issues including the development of personalized exercise programs, improvement of patient compliance, and integration of community resources and policy support are urgent problems that need to be addressed.

3.1. Current research status on the effects of aerobic exercise on metabolic conditions in patients with glucose metabolism disorders

Existing studies have shown that aerobic exercise can improve glucose metabolism in patients with type 2 diabetes by increasing metabolic rate and promoting more efficient glucose utilization. A

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2012 study demonstrated that aerobic exercise significantly improved glucose metabolism and physical fitness in elderly patients with type 2 diabetes—particularly by reducing glycated serum protein and fasting blood glucose levels and improving lung function and body composition [4]. These findings indicate that aerobic exercise not only helps regulate blood glucose levels but also improves physical health indicators related to diabetes, thereby contributing to better quality of life.

3.1.1. Effects of aerobic exercise on blood glucose in patients with glucose metabolism disorders

Aerobic exercise lowers blood glucose in patients with type 2 diabetes through multiple mechanisms: increasing insulin sensitivity, promoting direct glucose uptake by muscles, enhancing insulin secretion, and reducing insulin resistance [5]. Studies have shown that regular aerobic exercise significantly reduces fasting blood glucose, 2-hour postprandial blood glucose, and HbA1c levels in type 2 diabetes patients, outperforming dietary control or oral medications alone. This underscores the positive impact of aerobic exercise on improving insulin sensitivity and alleviating insulin resistance, thereby reducing the risk of hyperglycemia [6]. Research also indicates that aerobic exercise is effective in managing blood glucose regardless of whether patients are obese or non-obese. Thus, aerobic exercise is a vital component of comprehensive treatment strategies for type 2 diabetes, helping to improve both glycemic control and quality of life. In further exploration of this topic, a 2016 study found that postprandial aerobic exercise more effectively improved glucose and lipid metabolism and reduced insulin resistance in type 2 diabetes patients than regular aerobic exercise [7].

3.1.2. Effects of aerobic exercise on BMI and body composition in patients with glucose metabolism disorders

Research shows that aerobic exercise significantly reduces BMI and improves metabolic status in patients with glucose metabolism disorders. By promoting fat burning and increasing energy expenditure, aerobic exercise achieves weight loss and improves fat quality and body fat percentage—factors crucial for this patient population. Studies reveal that aerobic exercise enhances both glucose and lipid metabolism, reduces insulin resistance, optimizes pancreatic function, and supports body weight reduction. Compared to pharmacological treatment, aerobic exercise demonstrates better outcomes in improving BMI [8]. For instance, studies on middle-aged and elderly obese patients with type 2 diabetes show that aerobic exercise reduces visceral fat and its correlation with HbA1c, improves fat distribution, and lowers disease incidence [9]. A 2015 study further confirmed that postprandial aerobic exercise significantly enhances glucose and lipid metabolism in newly diagnosed obese patients, reduces insulin resistance and leptin levels, and decreases BMI—demonstrating promising therapeutic efficacy [10]. However, exercise plans must be tailored to individual patients to maximize their positive effects on BMI and body composition.

3.1.3. Current research status on different forms of aerobic exercise for patients with glucose metabolism disorders

For patients with glucose metabolism disorders—particularly those with type 2 diabetes—traditional aerobic exercise regimens are often difficult to sustain due to time constraints and limited access to exercise facilities. In recent years, high-intensity interval training (HIIT) has gained widespread attention as an efficient form of exercise with proven benefits in improving glucose

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metabolism. A 2017 study found that HIIT effectively improved glucose and lipid metabolism in prediabetic patients over a short period and showed superior fat-reduction effects compared to moderate-intensity continuous training (MICT). The study also indicated that HIIT has better safety, tolerance, and adherence among patients, providing strong clinical evidence for its use in prediabetic exercise interventions [11].

Additionally, some researchers suggest that exercising in cold environments can trigger physiological responses that normalize glucose metabolism. A 2023 study showed that aerobic exercise performed in low-temperature environments more effectively lowered blood glucose, improved kidney morphology and function in mice with diabetic nephropathy, and outperformed both room-temperature aerobic exercise and cold exposure alone. Clinically, performing aerobic exercise at least twice a week in cold environments significantly reduced the short-term risk of adverse outcomes in patients with diabetic nephropathy. This provides a novel clinical strategy for treating diabetes through aerobic exercise and has important practical implications [12].

3.2. Research on the effects of resistance training on metabolic conditions in patients with glucose metabolism disorders

In recent years, as awareness of healthy lifestyles continues to grow, resistance training has emerged as an important component in the management of type 2 diabetes. It can improve lipid profiles—particularly by reducing triglycerides and increasing high-density lipoprotein (HDL) levels—and also has regulatory effects on total cholesterol and low-density lipoprotein (LDL).

3.2.1. Regulation and improvement of glucose and lipid metabolism by resistance training in patients with glucose metabolism disorders

Research shows that resistance training—such as weightlifting or using resistance bands—effectively increases muscle mass and improves muscular strength and endurance. It promotes energy expenditure through oxidative metabolism in muscle tissue, thereby helping to regulate blood glucose and lipid levels [13]. Analyses of various aspects of resistance training have revealed that frequency, intensity, and duration can all affect its effectiveness. Furthermore, resistance training can improve insulin sensitivity and reduce the risk of insulin resistance, which is particularly important for patients with type 2 diabetes [14]. For example, high-frequency, moderate-intensity resistance training has been shown to significantly reduce triglyceride and total cholesterol levels and markedly improve insulin resistance. Resistance training also has potential benefits in regulating HDL and LDL levels and may reduce fat accumulation by enhancing fat breakdown, thus further improving glucose and lipid metabolism.

3.2.2. Effects of resistance training on BMI and quality of life in patients with glucose metabolism disorders

In addition to its impact on blood glucose and lipid levels, research on resistance training in patients with type 2 diabetes also emphasizes its effects on BMI and quality of life [2]. Improvements in quality of life are key indicators for evaluating diabetes management outcomes. Changes in BMI reflect not only weight loss but also changes in muscle and fat mass, which have important clinical implications in managing type 2 diabetes.

Clinically, resistance training improves metabolism by strengthening muscles and increasing basal metabolic rate, thereby assisting type 2 diabetes patients in achieving better blood glucose

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control [15]. It can also lead to healthier dietary habits and lifestyle improvements, which together enhance quality of life. Therefore, resistance training contributes positively both physiologically, by improving glucose and lipid metabolism, and psychologically, by enhancing overall well-being—thus offering strong scientific support for its use in diabetes management. Future studies should further investigate the long-term effects of resistance training on BMI and quality of life, and explore how best to integrate it with other forms of exercise and dietary interventions to optimize treatment outcomes.

3.2.3. Types and selection of resistance training

Resistance training comes in various forms, including free weights, resistance machines, and bodyweight exercises. When designing a resistance training regimen, factors such as training intensity, frequency, and duration must be considered based on individual patient conditions [16]. Studies have shown that high-frequency, moderate-intensity training may be most effective in improving glucose and lipid metabolism in patients with type 2 diabetes. When developing exercise programs for T2DM patients, it is important to customize intervention cycles, sets, and repetitions to suit individual needs. Research has also shown that resistance training is superior to traditional aerobic exercise in improving blood glucose and lipid profiles [17]. When combined with individualized dietary interventions, resistance training can comprehensively enhance metabolic status and improve quality of life in type 2 diabetes patients. Therefore, future research should continue to explore the effects of different resistance training protocols and develop personalized training plans to maximize therapeutic outcomes.

3.3. Current research on other exercise-related therapeutic approaches

3.3.1. Innovative studies on the combination of aerobic exercise and non-exercise treatments

Some studies have confirmed the positive effects of aerobic exercise in improving blood glucose levels, enhancing insulin sensitivity, and reducing insulin resistance [18]. However, certain researchers have pointed out that for patients with glucose metabolism disorders—particularly the elderly—sole reliance on aerobic exercise may not achieve optimal therapeutic outcomes. Instead, they recommend combining it with other interventions such as dietary adjustments and pharmacological treatments [19].

A 2023 study investigated the effects of combining red light therapy with aerobic exercise in obese patients with type 2 diabetes. Red light therapy promotes cell regeneration and immune function through exposure to specific wavelengths of light. The study found that this combination significantly improved glucose and lipid metabolism in obese type 2 diabetes patients, with better outcomes than traditional aerobic exercise alone [20]. This finding offers a new clinical perspective: employing multimodal treatment strategies to optimize therapeutic outcomes and mitigate the limitations of single-modality interventions.

3.3.2. Effects of different exercise intensities on metabolic conditions in patients with glucose metabolism disorders

Exercise of varying intensities may lead to different metabolic improvements in patients with glucose metabolism disorders. Appropriate intensity helps optimize glucose metabolism, while inappropriate intensity may exacerbate metabolic issues or trigger hypoglycemia and other risks

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[21]. Understanding these mechanisms is crucial for the development of personalized exercise intervention plans and for enhancing both the safety and effectiveness of such interventions.

Research shows that low-intensity exercise is suitable for individuals with limited exercise capacity or mild metabolic syndrome, although its impact on improving blood glucose, lipid levels, and blood pressure is relatively limited [22]. Moderate-intensity exercise, on the other hand, effectively enhances insulin sensitivity, improves glucose utilization, corrects lipid abnormalities, and helps lower blood pressure [23]. High-intensity exercise produces the most pronounced improvements in metabolic parameters but requires careful assessment of a patient's health and physical condition to ensure safety and feasibility [24]. Thus, choosing the appropriate intensity and type of exercise tailored to each patient is key to achieving metabolic improvement.

3.3.3. Research on the effects of traditional chinese exercises on metabolic conditions in patients with glucose metabolism disorders

Traditional Chinese exercises, such as Baduanjin, Tai Chi, and Wuqinxi, emphasize not only physical movement but also the coordination of breathing, intention, and body posture. These exercises have demonstrated unique advantages in regulating bodily functions and improving metabolic disorders [25]. Studies indicate that traditional Chinese exercises significantly improve glucose metabolism in patients with diabetes and prediabetes. They reduce blood glucose levels, improve obesity-related indicators such as waist-to-hip ratio and BMI, and regulate blood lipids to reduce the risk of cardiovascular diseases [26]. Furthermore, these exercises can alleviate emotional distress, reduce symptoms of depression and anxiety, and enhance overall quality of life.

In clinical practice, combining aerobic exercise with the traditional Chinese herbal formula Shenling Baizhu San has been shown to improve clinical outcomes and glucose metabolism indicators in obese type 2 diabetes patients [27]. Similarly, high-quality nursing care combined with Baduanjin has been successfully applied in elderly diabetes care, improving blood glucose and lipid levels and enhancing patient satisfaction and well-being [28]. In addition, the combination of simplified Tai Chi and resistance training has demonstrated favorable effects in improving metabolic disorders among prediabetic individuals [29]. Future studies should further explore the mechanisms of action, refine exercise protocols, and expand clinical applications to better serve the prevention and treatment of diabetes and its early stages.

4. The role of the national health concept in exercise intervention for glucose metabolism disorders

4.1. Application of exercise intervention in the national health management system

Within the framework of national health management, exercise intervention has gradually emerged from the confines of pharmacological treatment to become a critical tool in the prevention and management of disorders related to glucose metabolism disorders. As research has progressed, the scientific basis, efficacy, and individualized nature of exercise interventions have been increasingly validated. These interventions have been shown to significantly improve patients' glucose metabolism indicators and overall quality of life. With the advancement of public health awareness and improved access to health resources, exercise intervention has become a cornerstone of national health strategies. Its validated effectiveness has made it a crucial reference point in the formulation of public health policies, contributing to a shift in chronic disease management from single-mode treatment to a more comprehensive intervention model.

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4.2. The unique value of traditional chinese exercise in national health

Under the guiding principle of nationwide fitness, traditional Chinese exercises—representing a core component of Chinese cultural heritage—have played a unique role in the prevention and treatment of diabetes. Modern medical research has confirmed the scientific validity and clinical efficacy of these practices, particularly in diabetes management. Traditional Chinese exercises are characterized by low risk and ease of implementation, making them especially suitable for elderly individuals and patients with chronic conditions. As a practical embodiment of the nationwide fitness campaign, these exercises offer deep cultural resonance and scientific value. They not only provide modern medicine with new perspectives and treatment strategies but also inject new vitality into the preservation and development of traditional Chinese culture.

5. Conclusion

As an effective non-pharmacological treatment, exercise intervention plays a crucial role in the prevention and management of glucose metabolism disorders. By increasing physical activity, enhancing insulin sensitivity, lowering blood glucose levels, regulating lipid metabolism, and promoting weight control, exercise helps alleviate metabolic stress and effectively control or reverse glucose metabolism disorders. Moreover, exercise therapy reduces the burden of treatment, improves patients' psychological well-being and quality of life, and contributes to the sustainability of chronic disease management. In addition to its clinical benefits, exercise intervention reduces public healthcare costs and alleviates the financial burden on patients.

In recent years, numerous clinical trials and long-term follow-up studies have confirmed the significant positive effects of exercise interventions on improving glucose metabolism. Strategies for exercise intervention are continuously being refined to accommodate individualized needs and achieve better therapeutic outcomes. From a national health perspective, the optimization and future development of exercise intervention strategies should include the precise formulation of exercise prescriptions, personalized exercise plans, and scientifically managed intervention protocols. Future research should continue to explore the optimal modes of exercise intervention—including various exercise types, frequencies, durations, and intensities—to maximize their impact on glucose metabolism disorders. At the same time, it is essential to consider the safety and cost-effectiveness of these interventions to ensure their viability as a sustainable public health strategy.

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