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Research Progress of Exercise Therapy in Lipid Metabolism

Wu Yuwei[1]

Abstract

Persistent elevation of blood lipids promotes the accumulation of cholesterol in the vascular walls, leading to atherosclerosis, which is a key risk factor for serious cardiovascular and cerebrovascular diseases such as coronary heart disease and stroke. Hyperlipidemia is mainly classified into two subtypes: primary and secondary. Its occurrence is influenced by multiple factors, including genetic predisposition, dietary habits, liver metabolism abnormalities, insulin resistance, and oxidative stress. Aerobic exercise has a significant positive impact on hyperlipidemia by promoting fat oxidation and reducing lipid parameters. Resistance training effectively improves lipid metabolism by increasing muscle mass and enhancing basal metabolic rate. Although several sports medicine organizations worldwide have advocated the use of exercise prescriptions to prevent and treat chronic diseases, this approach has not been widely and effectively applied in the prevention and treatment of hyperlipidemia. This paper aims to review the pathogenesis of hyperlipidemia and explore the role of exercise in lipid regulation, advocating for the achievement of fat reduction goals through physical activity to provide a scientific basis for the treatment of hyperlipidemia.

Keywords: *Hyperlipidemia, Aerobic Exercise, Resistance Training, Lipid Metabolism, Non-Pharmacological Interventions*

A. Introduction

Hyperlipidemia is a condition characterized by elevated levels of cholesterol or triglycerides in the blood due to lipid metabolism disorders in the body. The direct consequence of prolonged elevated blood lipids is the infiltration, deposition, and accumulation of lipids, particularly cholesterol, into the vascular walls. This process promotes the proliferation of smooth muscle cells and fibroblasts in the arterial intima, leading to atherosclerosis, which is a critical pathological basis for high mortality and high disability diseases such as coronary heart disease and stroke.

With the improvement in living standards, people's dietary patterns have gradually shifted towards high-fat, high-sugar, and high-calorie diets, resulting in an increase in hyperlipidemia and other diseases. Hyperlipidemia has become a common pathological condition that widely affects human health, especially prevalent among the elderly population(Karr et al., 2017). Additionally, unhealthy lifestyles and dietary habits have increasingly affected younger populations with hyperlipidemia(Navar et al., 2015). Currently, the clinical treatment of hyperlipidemia mainly relies on dietary control, smoking cessation, alcohol abstinence, and the use of lipid-lowering drugs. However, these methods may cause side effects such as myolysis, gastrointestinal reactions, and hepatotoxicity(Bragg et al., 2015). With the development of sports medicine, physical activity has been widely used as a non-pharmacological treatment for various

[1]College of Physical Education, Southwest University, China, wuyuwei1224@163.com

chronic diseases. Exercise improves lipid metabolism and regulates blood lipid levels, providing an effective treatment option for patients with hyperlipidemia. This paper will explore the pathogenesis of hyperlipidemia and summarize the regulatory effects of exercise on blood lipids to promote fat reduction through physical activity and provide a scientific basis for the treatment of hyperlipidemia.

This study is crucial because persistent elevation of blood lipids promotes the accumulation of cholesterol in the vascular walls, leading to atherosclerosis, a key risk factor for serious cardiovascular and cerebrovascular diseases such as coronary heart disease and stroke. Hyperlipidemia, classified into primary and secondary subtypes, is influenced by multiple factors including genetic predisposition, dietary habits, liver metabolism abnormalities, insulin resistance, and oxidative stress. Given the complex etiology of hyperlipidemia, addressing it requires a multifaceted approach. Aerobic exercise significantly benefits hyperlipidemia by promoting fat oxidation and reducing lipid parameters, while resistance training improves lipid metabolism by increasing muscle mass and enhancing basal metabolic rate. Despite the global advocacy by sports medicine organizations for using exercise prescriptions to prevent and treat chronic diseases, this approach has not been widely and effectively applied to hyperlipidemia. Therefore, this paper reviews the pathogenesis of hyperlipidemia and explores the role of exercise in lipid regulation. It advocates achieving fat reduction through physical activity to provide a scientific basis for the treatment of hyperlipidemia, underscoring the need for integrating exercise-based interventions more effectively into clinical practice.

B. Methods

This study employs a qualitative research design to gain an in-depth understanding of the factors influencing the implementation of exercise prescriptions in the prevention and treatment of hyperlipidemia, as well as participants' perceptions of the impact of exercise on their condition. The initial stage involves a literature review to comprehend the pathogenesis of hyperlipidemia and the role of exercise in lipid regulation, alongside the development of research instruments such as semi-structured interview guides. Participants diagnosed with hyperlipidemia, aged between 18-65 years, and without medical contraindications to exercise will be recruited through announcements at health clinics, social media, and local communities. Participants will be divided into two groups: the aerobic group, which will follow an aerobic exercise program (such as brisk walking, jogging, or cycling), and the resistance training group, which will follow a weight training program. Each program will last for 12 weeks, with a frequency of 3-5 times per week.

Qualitative data will be collected through in-depth interviews with participants before and after the exercise program to explore their experiences during the intervention, their perceptions of exercise, and the barriers and supports they encountered. Observations during the exercise sessions will also be conducted to record compliance levels and participants' responses to the exercise program. Qualitative data analysis will use thematic analysis to identify key themes from the interviews, such as participants' perceptions of the effectiveness of exercise, motivation, challenges, and the support they received. Data coding will be assisted by qualitative analysis software such as NVivo to ensure systematic and thorough analysis.

Through this qualitative approach, the study aims to provide rich insights into how participants respond to the exercise program in the context of hyperlipidemia treatment and what factors influence the implementation of exercise prescriptions. The study also aims to offer more

targeted recommendations to enhance the application of exercise prescriptions in clinical practice.

C. Findings and Discussion

1. Pathogenesis of Hyperlipidemia

Hyperlipidemia can be divided into primary and secondary subtypes. Primary hyperlipidemia is caused by genetic defects and environmental factors or unknown mechanisms, while secondary hyperlipidemia is associated with metabolic disorders such as diabetes, liver disease, thyroid disease, and kidney disease. Dietary imbalances and genetic defects are the main pathological bases of primary hyperlipidemia. Genes related to lipid metabolism include lipoproteins ApoA, ApoB, ApoC, ApoE, etc.(et al., 2021), the low-density lipoprotein receptor (LDL-R) gene, the lipoprotein lipase (LPL) gene, and the ATP-binding cassette transporter genes(Schulze et al., 2016). Individuals with genetic defects in single or multiple genes may be predisposed to primary hyperlipidemia. ATP-binding cassette transporter A1 is an important protein located on the cell membrane that regulates cholesterol efflux, mediating the transport of intracellular cholesterol to the extracellular space(Li et al., 2022). Transferred cholesterol is transported in reverse to the liver via high-density lipoprotein (HDL), metabolized into bile acids, and eventually excreted as feces. Therefore, defects or mutations in one or more of the aforementioned genes may lead to the occurrence of hyperlipidemia.

Metabolic disorders are key pathogenic factors of secondary hyperlipidemia. Metabolic diseases such as diabetes, hypothyroidism, liver disease, kidney disease, hypertension, and obesity are often accompanied by hyperlipidemia(Bragg et al., 2015). Besides regulating blood glucose, insulin is also an important factor in regulating fat metabolism. It reduces lipase activity and HDL metabolic activity, leading to issues with triglyceride (TG) clearance(Yang et al., 2016). In the early stages of diabetes, plasma insulin levels are very high, leading to excessive fat synthesis in the body, causing elevated endogenous cholesterol (TC) and TG. In the late stages of primary biliary cirrhosis, LDL increases, and HDL decreases, possibly due to the inhibition of total cholesterol esterification. Nephrotic syndrome is a common kidney disease accompanied by hyperlipidemia. Studies have shown that chronic proteinuria can reduce the activity of the rate-limiting enzyme 7-hydroxylase in cholesterol catabolism and increase the activity of the rate-limiting enzyme 3-hydroxy-3-methylglutaryl-coenzyme A in cholesterol biosynthesis, leading to hyperlipidemia(Zhao et al., 2019). Hyperlipidemia caused by metabolic disorders has always received significant attention from medical researchers, but its specific mechanisms require further study to better guide clinical treatment.

2. Regulation of blood lipids by exercise

Recent studies have shown that regular exercise can effectively improve lipid metabolism disorders, promote the mobilization and utilization of body fat, benefit cardiovascular health, and serve as a method for preventing cardiovascular diseases and diabetes. Exercise can improve high-density lipoprotein cholesterol (HDL-C) and TG lipoproteins, which is considered an important mechanism beneficial to coronary cardiovascular disease(Zhao et al., 2021). Additionally, exercise can achieve fat reduction and weight loss. However, the success rate of exercise in fat reduction or improving lipid metabolism has not reached ideal levels. Factors such as exercise intensity, duration, and type significantly influence the outcomes of weight loss and fat reduction through exercise(Kessler et al., 2012).

Effects of Aerobic Exercise on Hyperlipidemia

Aerobic exercise is considered an effective means to reduce weight and body fat percentage(Mcneilly et al., 2012), especially for obese individuals with hyperlipidemia. It not only helps prevent lipid abnormalities but also improves health by enhancing fat catabolism. Current research on exercise and fat reduction mainly focuses on maximizing the degree of fat oxidation, increasing the proportion of energy derived from fat oxidation, and oxidation rates.

Studies have shown that aerobic exercise can exert anti-atherosclerotic effects by reducing the expression levels of serum ICAM-1 and LFA-1, improving intimal thickening, and endothelial damage induced by a high-fat diet. Additionally, it can significantly lower plasma viscosity and whole blood viscosity, enhancing the body's ability to resist oxidative damage caused by lipid peroxidation(Zhang et al., 2013). Yan et al.(2022) found that an 8-week aerobic treadmill training (1 hour/day, 5 days/week) combined with a small amount of medication significantly reduced blood lipids in high-fat diet mice. A study that randomly grouped sedentary, overweight individuals with mild to moderate dyslipidemia into different aerobic exercise intensities found that exercise volume significantly affected lipoproteins and lipoprotein subfractions. In particular, moderate-intensity long-distance jogging significantly reduced small LDL and LDL particle concentrations, increased the average size of LDL particles, and raised the total concentration and large particle concentration of HDL while lowering triglycerides and very-low-density lipoprotein total concentrations(Kraus et al., 2002). Feng Chang et al.(2019) suggested that Tai Chi, square dancing, cycling, playing table tennis, and slow walking could be effective fall-prevention exercises for elderly patients with chronic diseases, with Tai Chi being more effective than slow walking. It is recommended that the elderly actively adopt effective measures to control weight and blood pressure and develop good habits of incorporating physical activity into daily life. Additionally, long-term swimming exercise has been found to improve vascular endothelial function in middle-aged individuals, possibly related to increased shear stress(Qiu et al., 2023). This is a good option for middle-aged men who cannot tolerate high-intensity running to enhance vascular endothelial function. For elderly patients with chronic diseases, exercises such as Tai Chi and square dancing can effectively prevent falls and improve lipid levels. Shaoping Zhao et al. (2022) conducted a systematic review and concluded that moderate-intensity aerobic exercise reduced serum TC, TG, and low-density lipoprotein cholesterol (LDL-C) levels, and increased HDL-C levels. Therefore, moderate-intensity aerobic exercise is recommended as an adjunct treatment for hyperlipidemia patients, provided there are no adverse reactions and the patient's physical condition permits. A regimen of moderate-intensity aerobic exercise 6-7 times per week, 30-90 minutes per session, for 24-48 weeks can serve as an exercise prescription to improve lipid levels. Despite some limitations in this study, further high-quality randomized controlled trials (RCTs) are needed to validate these findings.

In conclusion, aerobic exercise, as an effective health intervention, has significant effects on lowering blood lipids, improving cardiovascular function, and enhancing overall health(Wang et al., 2018; Liu et al., 2018) For hyperlipidemia patients, particularly the elderly and those with chronic diseases, aerobic exercise is not only a feasible adjunct treatment but also an important method for improving quality of life and preventing complications. Although numerous studies support the health benefits of aerobic exercise, more high-quality RCTs are needed to further verify and refine exercise prescriptions, ensuring their scientific validity and applicability.

Effects of Resistance Training on Hyperlipidemia

The impact of resistance training (also known as strength training or weight training) on hyperlipidemia has garnered increasing attention. Resistance training primarily improves body composition and metabolic function by increasing muscle strength and endurance, thereby exerting beneficial effects on lipid levels. Recently, rehabilitation medicine has begun incorporating dynamic aerobic training and circuit resistance training for adjunctive treatment. Aerobic and resistance exercises can reduce blood lipids and aid in lipid control. Multiple clinical trials have demonstrated that resistance training alone can effectively improve lipid metabolism(Bacchi et al., 2012;Kacerovsky et al., 2012). Zhang et al. (2013) conducted a 17-week full-body resistance training program (three times a week, two sets of 8-10 RM per session) on elderly obese women. The results showed increased muscle strength and significantly reduced concentrations of TC and LDL-C, with a significant increase in HDL-C. This suggests that full-body resistance training is an effective non-pharmacological method for reducing lipid and lipoprotein cholesterol concentrations in elderly obese women.

In studies comparing the effects of different intensities on lipid metabolism, moderate-intensity resistance exercise demonstrated greater advantages in reducing TG and LDL-C concentrations and increasing HDL-C concentrations in hyperlipidemic patients after 12 weeks, compared to low-intensity exercise(Zhao et al., 2016). This may be due to the stimulation of the sympathetic nervous system during resistance training, accelerating fat mobilization and subsequently generating free fatty acids that bind to albumin for transport to muscles for energy(Augustine et al., 2014).Compared to aerobic exercise, resistance training more significantly enhances the metabolic capacity of local muscles, leading to an increase in lean body mass and basal metabolic rate, and higher energy expenditure during exercise. This enhanced metabolic capacity helps TG undergo catabolism in peripheral tissues, reducing LDL-C retention in the vascular endothelium(Gavin et al., 2010). Furthermore, resistance exercise can increase muscle metabolic intensity without significantly increasing oxygen consumption. Shaw et al. (2016)reported that eight weeks of resistance training, three times per week, resulted in a 13.05% reduction in fat tissue and a 5.05% increase in muscle tissue, thereby improving body mass index.Therefore, when treating hyperlipidemia patients characterized by high LDL-C and TG levels, it is advisable to appropriately increase the volume of resistance training to enhance lipid metabolism, reduce disease risk, and improve training outcomes. Research also found that planned resistance training for 12 weeks increased muscle strength in the LG and MG muscles, with more significant effects from moderate-intensity resistance training. Muscle strength is primarily influenced by muscle fiber hypertrophy and the synchronous recruitment of neurons. Shortly after the training period, muscle hypertrophy temporarily occurs due to the immediate effects of resistance exercise, but this effect quickly diminishes. Some data indicate that 2-3 weeks of resistance training can significantly increase muscle strength, with noticeable changes in muscle volume appearing after 8 weeks, suggesting that early increases in muscle strength are influenced by neuron recruitment. This indicates that appropriately increasing training intensity in the early stages of training can achieve training effects without significantly increasing body weight.

Currently, aerobic exercise, due to its lower intensity and higher fat oxidation rate, is commonly used in fat reduction studies. Additionally, high-intensity interval training, due to its shorter duration and higher post-exercise energy expenditure, and resistance training, which fully engages muscles throughout the body and increases muscle strength, are also popular

among fitness enthusiasts. However, practice has shown that different exercise modalities, intensities, and durations produce varying effects, thus further research is needed to determine the most suitable exercise regimen for hyperlipidemic individuals.

D. Conclusion

Hyperlipidemia, as a lipid metabolism disorder, causes damage to the cardiovascular and cerebrovascular systems. Epidemiological studies have shown that hyperlipidemia is closely related to cardiovascular and cerebrovascular diseases. Currently, early clinical interventions primarily involve dietary control and lifestyle changes. This paper reviewed the pathogenesis of hyperlipidemia, including primary and secondary factors such as genetic defects and metabolic disorders, and explored the potential mechanisms and actual effects of exercise interventions in regulating blood lipids. The importance of aerobic exercise and resistance training in improving lipid levels, enhancing vascular function, and preventing cardiovascular diseases was particularly emphasized. Aerobic exercise has a significant positive effect on hyperlipidemia by promoting fat oxidation and reducing lipid parameters. Resistance training helps improve lipid metabolism by increasing muscle mass and basal metabolic rate.

Future research should focus more on the impact of different types and intensities of exercise on hyperlipidemia in specific populations to optimize individualized exercise prescriptions. Additionally, research should further explore the synergistic effects of exercise interventions and other lifestyle interventions, such as dietary adjustments. The comprehensive use of multiple intervention methods may provide more holistic treatment plans for patients with hyperlipidemia, thereby more effectively controlling and preventing cardiovascular diseases associated with hyperlipidemia. Moreover, more high-quality randomized controlled trials are needed to verify the long-term effects of exercise interventions and their applicability to different populations.

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