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The impact of aerobic exercise of different intensities on metabolic health and optimization strategies

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ABSTRACT
Aerobic exercise is a key measure to maintain and improve metabolic health, but there are differences in the physiological effects and applicable populations of different intensities of exercise. Sports intervention faces bottlenecks such as insufficient personalization level and lack of supportive environment, and urgently needs innovative strategies from dimensions such as exercise prescription optimization, behavior and environment promotion, and effect evaluation. This article aims to systematically review the impact mechanisms of different intensities of aerobic exercise on metabolic health, focusing on personalized exercise prescriptions, social ecological environment support, big data-driven monitoring and evaluation, and proposing precise intervention strategies to provide reference for innovative exercise intervention models and improving chronic disease management systems, in order to improve the metabolic health level of the population and contribute to the construction of a healthy China.

KEYWORDS
aerobic exercise; Metabolic health; Exercise intensity; influence; optimization measures

With the change of lifestyle and the acceleration of the aging process of the population, chronic metabolic diseases represented by obesity, type 2 diabetes, cardiovascular diseases, etc. are increasingly becoming a major challenge threatening human health. Aerobic exercise, as a safe, economical, and effective non pharmacological intervention, plays an irreplaceable role in the prevention and control of chronic diseases. A large number of epidemiological and experimental studies have shown that regular aerobic exercise can significantly improve insulin sensitivity, reduce blood glucose and lipid levels, reduce weight and visceral fat accumulation, and has unique preventive and therapeutic effects on metabolic syndrome, type 2 diabetes and other diseases.

1 The impact of aerobic exercise of different intensities on metabolic health

1.1 Metabolic health effects of low-intensity aerobic exercise

Low intensity aerobic exercise, such as walking, Tai Chi, etc., has a positive effect on improving the metabolic health of the body. Although this kind of exercise intensity is relatively mild, long-term adherence can significantly improve the insulin sensitivity of the body, which is helpful to prevent and control type 2 diabetes. Meanwhile, low-intensity exercise is beneficial for the breakdown and utilization of body fat, and has a certain effect on weight loss and improving body fat distribution. In addition, low-intensity exercise can improve endothelial function and reduce the risk of cardiovascular disease.

1.2 Metabolic health effects of moderate intensity aerobic exercise

Moderate intensity aerobic exercise, such as brisk walking, jogging, swimming, etc., is considered the "gold standard" for improving metabolic health. This type of exercise intensity is within the range of aerobic metabolism, which can fully mobilize fat mobilization and oxidation, thereby achieving the goal of weight loss and shaping. Meanwhile, moderate intensity exercise has significant effects on improving cardiovascular function and maintaining vascular health. A large number of studies have shown that regular moderate intensity aerobic exercise can prevent chronic diseases such as metabolic syndrome and type 2 diabetes, and improve metabolic disorders such as hypertension and dyslipidemia. It is worth mentioning that moderate intensity exercise is moderately difficult to implement, well tolerated by the general population, and easy to adhere to. It is an ideal way for the public to exercise and plays an important role in the prevention and control of chronic diseases.

1.3 Metabolic health effects of high-intensity intermittent aerobic exercise

High intensity interval aerobic exercise (HIIT) is a popular exercise method in recent years, characterized by repeated

high-intensity exercise and low-intensity recovery interval training in a short period of time. Research has found that HIIT has unique advantages in improving cardiovascular endurance, increasing insulin sensitivity, reducing blood glucose and lipid levels, and other metabolic indicators. The improvement in some indicators is even better than moderate intensity continuous exercise. This may be related to special changes in the body's metabolism and hormone levels during HIIT. In addition, compared to longer duration aerobic exercise, HIIT is popular for its time economy. However, it should be noted that HIIT has high requirements for human cardiovascular and pulmonary function, and the risk of sports injuries is relatively high. In the implementation process, it is necessary to act according to individual circumstances, step by step, and strengthen safety monitoring to achieve the goal of safe and efficient improvement of metabolic health.

2 Exploration of the physiological mechanism of aerobic exercise promoting metabolic health

2.1 The mechanism by which aerobic exercise improves insulin sensitivity

Aerobic exercise can improve insulin sensitivity in the body through various physiological mechanisms. Firstly, skeletal muscle contraction during exercise can stimulate the translocation of glucose transporter GLUT4 from intracellular vesicles to the cell membrane, increasing muscle cell uptake of glucose, and this process is independent of insulin action. Secondly, aerobic exercise can activate AMP activated protein kinase (AMPK), which phosphorylates multiple downstream targets such as AS160 protein, enhancing the translocation and activity of GLUT4 [1]. In addition, exercise induces muscle production of muscle factors such as IL-6, which can improve systemic insulin sensitivity. In the long run, aerobic exercise can also improve the aerobic metabolism capacity of skeletal muscles, increase the number of mitochondria, thereby reducing lipid accumulation and insulin resistance.

2.2 The mechanism of aerobic exercise regulating fat metabolism

Aerobic exercise has a significant regulatory effect on body fat metabolism. During exercise, sympathetic nervous system excitability increases, promoting fat breakdown in subcutaneous and visceral adipose tissue, and releasing free fatty acids into the bloodstream. At the same time, aerobic exercise increases the ratio of AMP/ATP in muscle cells, activates AMPK, further phosphorylates acetyl CoA carboxylase (ACC), relieves its inhibitory effect on fatty acid beta oxidation, and accelerates the utilization of fatty acids in tissues such as muscles and liver. Long term regular aerobic exercise can induce upregulation of genes such as fatty acid transporters and fatty acid oxidases in muscles and liver, improving fat mobilization and utilization ability. In addition, aerobic exercise can improve the secretion disorders of adipokines such as adiponectin and leptin, and regulate the energy balance of the body.

2.3 The mechanism by which aerobic exercise improves chronic inflammation

More and more evidence suggests that aerobic exercise can alleviate chronic low-grade inflammation associated with obesity, metabolic syndrome, and other conditions through a complex immune endocrine regulatory network. Exercise itself is a mild stress stimulus that can upregulate the expression of anti-inflammatory cytokines such as IL-6 and IL-10, while downregulating the levels of pro-inflammatory cytokines such as TNF - α and IL-1 β, helping to maintain the body's inflammation anti-inflammatory balance. The mechanism by which aerobic exercise reduces inflammation of adipose tissue may include: reducing adipocyte hypertrophy and inhibiting the infiltration of pro-inflammatory macrophages; Improve tissue hypoxia status, alleviate oxidative stress and endoplasmic reticulum stress; Regulating the secretion of adipokines such as adiponectin and leptin; Inducing the release of anti-inflammatory muscle factors from muscles. In addition, regular exercise can indirectly alleviate metabolic inflammation by reducing intestinal permeability and optimizing gut microbiota.

3 Optimization strategies for aerobic exercise intervention in metabolic health

3.1 Establish a personalized exercise prescription optimization system

Establishing a personalized exercise prescription optimization system is a key strategy for promoting aerobic exercise intervention in metabolic health. For different populations, such as the elderly, overweight/obese individuals, and high-risk groups for metabolic syndrome, their physiological characteristics, exercise foundation, lifestyle, and other factors should be fully considered to develop personalized and gradient aerobic exercise programs. The optimization of exercise prescription must follow the principles of evidence-based sports medicine, starting from the selection of exercise modes, parameter settings, efficacy evaluation, dynamic adjustment and other aspects, to maximize the benefits of aerobic exercise in improving metabolic health. Personalized prescription is guided by precise administration, achieving a balance

between intervention effectiveness, compliance, and safety by matching the optimal "exercise dose", which is the optimization direction of future exercise therapy.

Specifically, the development of personalized aerobic exercise prescriptions can follow the following process: Firstly, a comprehensive health assessment of the individual is conducted, including body composition analysis, cardiopulmonary function testing, metabolic index testing, etc., to clarify their metabolic health status and exercise contraindications. On this basis, select appropriate aerobic exercise modes such as walking, jogging, cycling, swimming, etc., and set initial exercise parameters. It is generally recommended to adopt the principle of low starting point and gradual increase, starting from low intensity (such as 40% to 50% of maximum oxygen uptake), short time (such as 20-30 minutes/time), gradually transitioning to medium intensity (such as 60% to 70% of maximum oxygen uptake), longer time (such as 60 minutes/time), and forging 3-5 times a week [3]. During the implementation of exercise, objective physiological indicators (such as heart rate, subjective feelings, etc.) and multidimensional indicators such as subjective feeling scores should be used to dynamically evaluate an individual's tolerance and stress response to exercise, and adjust exercise load in a timely manner. In addition, the development of personalized prescriptions should fully respect individuals' exercise preferences and time arrangements, increase interest, and improve exercise compliance. Regularly conduct comprehensive evaluations of metabolic health, dynamically revise prescriptions based on intervention effects, and establish a closed-loop management mechanism.

3.2 Innovative sports behavior promotion and environmental support model

Traditional exercise intervention models tend to focus on individuals and overlook the environmental drivers of behavior change. Numerous studies have shown that environmental factors such as interpersonal interaction, community atmosphere, and venue facilities significantly affect the development and maintenance of individual sports behavior. Therefore, optimizing aerobic exercise to promote metabolic health strategies must start with shaping a "sports friendly" environment. While empowering individuals to change their behavior, attention should be paid to creating a supportive social ecosystem that creates external conditions conducive to sustained exercise in multiple dimensions and all directions. Only then can the benign promotion of exercise behavior and the synergistic effect of environmental support be achieved.

Specifically, the promotion of innovative sports behavior and environmental support models can be approached from the following aspects:

Develop a sports social system that combines online and offline activities. Actively utilizing new media channels such as social networks and mobile applications, developing entertaining and interactive online sports communities, and using gamification methods such as goal setting, point ranking, and virtual rewards to stimulate participants' interest and motivation in sports. Regularly organize various themed sports check-in, challenge competitions and other offline city activities to promote physical interaction and enhance sports stickiness.

Promote the integration of sports and medicine, and optimize the community sports environment. Strengthen the resource sharing and process integration between community health service centers and sports venues, construct fully functional and suitable aerobic sports facilities in the community, and provide personalized exercise prescription guidance services. Utilize the role of family doctors (teams) to incorporate exercise risk assessment and prescription issuance into contracted services, providing residents with nearby and accessible exercise promotion resources.

Improve supportive policies and create a participatory atmosphere for the entire society. Introduce incentive policies that are conducive to the development and persistence of sports behavior, such as providing appropriate subsidies to individuals participating in sports interventions and incorporating sports performance into employee performance evaluations. Actively advocating the health concept that sports are good doctors in the whole society, and improving the public's sports and health literacy through various forms of health education such as publicity, free clinics, and open classes. Encourage employers to create convenient sports conditions for employees and incorporate exercise time into their workday management.

3.3 Develop a new model for evaluating sports performance based on big data

The traditional evaluation of exercise effectiveness often adopts a small sample, short cycle experimental research paradigm, which is difficult to fully reflect the long-term effects of aerobic exercise in the population. The advent of the big data era provides a new opportunity to accurately characterize the dose-response relationship, dynamic characteristics, and influencing factors of aerobic exercise and metabolic health among different populations. Integrating heterogeneous data from multiple sources such as healthcare and exercise monitoring, utilizing new technologies such as machine learning and artificial intelligence, to construct an intelligent exercise health management system with "five in one" functions of perception, analysis, prediction, intervention, and evaluation. This system can achieve a new paradigm of exercise intervention that is personalized, precise, dynamically optimized, and closed-loop. It is the key to promoting

the transformation of exercise prevention and control of chronic diseases from experience driven to data-driven, and from universality to personalization. Specifically, the development of a new model for evaluating sports performance based on big data can follow the following approach:

Establish a multi center exercise queue: Conduct large-scale, long-term prospective queue studies targeting community populations, especially key populations such as middle-aged and elderly people, overweight/obesity, and those at high risk of metabolic syndrome. Collect structured and unstructured data covering demographic characteristics, physical fitness tests, metabolic indicators, exercise behavior, dietary nutrition, environmental exposure, disease endpoints, etc., and build a high-quality sports and health big data platform.

Develop intelligent wearable devices: Develop intelligent wearable devices that integrate exercise monitoring, physiological parameter perception, and health management, to achieve objective, continuous, and dynamic monitoring of an individual's aerobic exercise process (such as steps, intensity, heart rate, etc.) and metabolic health status (such as blood sugar, blood lipids, blood pressure, etc.), break through the limitations of traditional laboratory evaluation models, and comprehensively grasp the laws of individual exercise and health changes in the real world.

Building a Sports Effectiveness Evaluation Model: Taking into account internal factors such as gender, age, genetics, and physical fitness, as well as external factors such as exercise style, intensity, timing, and environment, establish a multi-level and multi-dimensional indicator system. Using information fusion technology to achieve standardized and semantic processing of multi-source data. Develop machine learning algorithms, establish a "dose-response" model for aerobic exercise, quantify the correlation strength, optimal threshold, time window, etc. between exercise parameters and metabolic index improvement, and clarify population heterogeneity.

4 Conclusion

In summary, aerobic exercise of different intensities has a wide and profound impact on the metabolic health of the body. Low, medium, and high-intensity exercise each have their unique physiological effects and target populations, and require targeted selection and prescription optimization based on individual characteristics. Aerobic exercise plays a comprehensive role in promoting metabolic health by improving insulin sensitivity, regulating fat metabolism, alleviating chronic inflammation, and other mechanisms. However, current aerobic exercise interventions still face many bottlenecks. In the future, efforts should be made to establish a personalized exercise prescription system based on precise evaluation and dynamic monitoring, innovate a sports social system that combines online and offline, improve the supportive environment and policy guarantees for multi departmental collaboration, build a new model of integrated medical sports community services, and integrate modern technologies such as artificial intelligence, wearable devices, and cloud computing to establish an intelligent sports big data management platform, achieving precise policy implementation, dynamic optimization, and closed-loop management.

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