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The Effects of High-Intensity Interval Training on Cardiovascular Health

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Abstract: Cardiovascular disease remains the leading global health threat, with its incidence and mortality rates persistently rising, particularly under modern lifestyles characterized by unhealthy habits and sedentary behaviors. Traditional moderate-intensity continuous training (MICT) faces challenges in widespread adherence due to its time-consuming nature, prompting the need to explore more efficient exercise interventions. This study compares the differences between high-intensity interval training (HIIT) and MICT, analyzing their respective impacts on cardiovascular health, underlying mechanisms, and applicability. The findings demonstrate that HIIT, through its alternating pattern of short-duration high-intensity exercise and active recovery, achieves significant improvements in maximal oxygen uptake (VO_2 max), endothelial function, blood pressure, and lipid profiles within a shorter timeframe, with efficacy comparable to or even superior to MICT. However, the long-term benefits of HIIT may be compromised by insufficient maintenance of training intensity, and it poses potential safety risks for individuals with high cardiovascular risk. In contrast, MICT exhibits higher safety and suitability for chronic patients and elderly populations, though its effects require prolonged adherence to manifest. This study highlights HIIT's time-efficiency advantages and limitations, emphasizing the importance of personalized program design to optimize exercise intervention strategies. It also identifies future research priorities, including the standardization of HIIT protocols and investigation of long-term outcomes, to facilitate its evidence-based integration into daily life.

Keywords: HIIT, MICT, Cardiovascular System, Exercise Intervention, Individualized Protocol

1. Introduction

Cardiovascular disease (CVD) remains the leading global health threat, with its incidence and mortality rates showing a persistent upward trend. According to the Global Burden of Disease Study, CVD is responsible for approximately 18.6 million deaths annually, accounting for 32% of total global mortality, with ischemic heart disease and stroke being the primary causes, contributing to 8.9 million and 6.5 million deaths, respectively [1]. The development of CVD is primarily driven by factors, such as poor dietary habits, physical inactivity, and rising obesity rates, which, in combination with health issues like hypertension, insulin resistance, and dyslipidemia, collectively exacerbate the onset of cardiovascular diseases. Although developed countries have achieved a 20% to 40% reduction in age-standardized mortality rates through risk factor control, the burden of CVD continues to worsen in low- and middle-income countries, accounting for over 75% of global

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CVD-related deaths [2]. Despite significant advancements in modern medical treatments for CVD, lifestyle interventions, particularly physical exercise, remain a cornerstone strategy for the prevention and management of cardiovascular diseases. Currently, traditional moderate-intensity continuous training (MICT) has been the primary exercise modality for improving cardiovascular health. However, in the context of modern fast-paced lifestyles characterized by sedentary behavior and time constraints, many individuals find it challenging to adhere to MICT due to its prolonged and uninterrupted nature. This has spurred the exploration of more time-efficient exercise alternatives.

Among emerging exercise modalities, high-intensity interval training (HIIT) has garnered widespread attention for its ability to significantly enhance cardiovascular health within a shorter time frame. HIIT involves alternating periods of short-duration high-intensity exercise with low-intensity recovery phases, combining both anaerobic and aerobic components. This approach requires considerably less time than MICT, making it more accessible for individuals with busy schedules or limited access to fitness facilities. Although evidence supporting the efficacy of HIIT continues to grow, significant knowledge gaps remain regarding its long-term effects, optimal training protocols, and comparative effectiveness against traditional exercise modalities.

Therefore, this paper aims to analyze the differences in effectiveness and applicability between HIIT and traditional MICT, providing insights for future research on HIIT outcomes and program design, while offering recommendations for tailored exercise interventions.

2. Differences Between HIIT and MICT

MICT is an aerobic exercise modality performed at 60%-80% of peak heart rate or 60% of VO_2 max, typically lasting around 45 minutes. It significantly enhances cardiorespiratory endurance and optimizes cardiovascular health through aerobic metabolic stimulation. In contrast, HIIT has gained widespread attention as a promising approach for improving cardiovascular health due to its ability to deliver substantial benefits in a shorter time frame. During the high-intensity phases of HIIT, the target heart rate typically reaches 80%-95% of maximum heart rate and approaches VO_2 max, significantly higher than the 60%-80% peak heart rate and 60% VO_2 max targeted in MICT. A typical HIIT session lasts between 15 and 30 minutes, considerably shorter than the time required for MICT.

2.1. Impact of HIIT and MICT on the Cardiovascular System

From the perspective of their effects on the cardiovascular system, the benefits of MICT primarily manifest through long-term endurance training outcomes. MICT is characterized by low-to-moderate intensity sustained activities such as jogging, swimming, or cycling. Research indicates that the training effects of MICT require long-term adherence to become evident. Prolonged engagement in MICT can improve lipid profiles by reducing low-density lipoprotein levels and increasing high-density lipoprotein (HDL) levels [3], lowering systolic and diastolic blood pressure in hypertensive patients [4], enhancing vascular endothelial function, modulating sympathetic nerve activity, and regulating body fat percentage [5]. Additionally, MICT has been shown to effectively reduce the incidence and mortality of heart disease [6], making it particularly suitable for long-term health maintenance [7].

In contrast, HIIT, due to its short-duration, high-intensity exercise load, can rapidly and significantly enhance the adaptability of the cardiovascular system. Numerous studies have demonstrated that HIIT improves cardiac function, endothelial function, and reduces risk factors for cardiovascular diseases, such as blood pressure and lipid levels [3,4]. Furthermore, research has shown that just six weeks of HIIT can significantly increase participants' maximal oxygen uptake (VO_2 max) and reduce resting heart rate [8], indicating substantial short-term improvements in the cardiovascular system. Compared to MICT, HIIT often achieves similar or even superior

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cardiovascular health benefits in a shorter time frame [9]. Beyond enhancing cardiorespiratory endurance, HIIT also effectively lowers blood pressure, improves lipid profiles, and enhances insulin sensitivity [10]. However, some studies suggest that if training intensity is not maintained, the acute effects of HIIT, such as improved cardiovascular function and reduced risk factors, may diminish over time [11], raising concerns about its ability to provide sustained benefits.

2.2. Exploration of the Mechanisms Underlying HIIT and MICT

From the perspective of their mechanisms of action, HIIT, through its alternating bursts of high-intensity exercise, maintains heart rates above 85% of the maximum, resulting in unique cardiovascular benefits. Recent studies have demonstrated that a HIIT protocol of 20 minutes per session, three times per week, can increase VO_2 max by 9%-13% and improve endothelial function by 28% compared to MICT. Notably, in patients with type 2 diabetes, HIIT has been shown to reduce HbA1c levels by 0.6%, with effects sustained for over six months [12]. Additionally, HIIT exhibits significant synergistic effects when combined with dietary interventions. For example, monounsaturated fatty acids found in olive oil can enhance the HIIT-induced increase in HDL-C levels. While HIIT alone increases HDL-C by 8%, the combined effect can reach 15%. Furthermore, when integrated with cognitive behavioral therapy, patient adherence to exercise improves by 40%, cortisol levels decrease by 22%, and the risk of recurrent cardiovascular events is reduced by 51% [13,14].

2.3. Applicability of HIIT and MICT

From the perspective of target populations, MICT is suitable for beginners, older adults, and individuals with chronic conditions. MICT involves moderate-intensity exercise performed over a prolonged duration, and its lower intensity reduces the risk of injury. As such, it is an ideal choice for individuals with limited physical fitness or health conditions that preclude high-intensity exercise.

In contrast, HIIT is better suited for individuals seeking significant training benefits within a limited time frame. HIIT involves short bursts of high-intensity exercise interspersed with brief recovery periods. While highly efficient, it places greater demands on cardiovascular fitness and is more appropriate for individuals with prior exercise experience. It is not recommended for those with compromised cardiovascular health, severe medical conditions, or no exercise background, as the high intensity may increase the risk of injury or cardiovascular complications in untrained or high-risk populations [15].

Therefore, HIIT is more suitable for healthy individuals, particularly younger and middle-aged adults. For older adults, patients with heart disease, or those with other chronic conditions, HIIT should be performed under medical supervision with controlled intensity. For example, aquatic-based HIIT has shown unique advantages for patients with chronic heart failure, as water-based exercise reduces central venous pressure by 30% and significantly improves 6-minute walking distance when combined with 40%-60% of peak heart rate intensity. For diabetic patients, supplementing with 0.5g/kg of branched-chain amino acids during intervals can effectively prevent hypoglycemia and maintain training intensity [16].

Thus, the development of appropriate training protocols is a critical factor in determining the widespread adoption of HIIT.

3. Gaps and Limitations in Current Research

Current research on HIIT faces two major challenges: the lack of standardized training protocols and insufficient investigation into its long-term effects.

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The variability in HIIT protocols—ranging from intensity, duration, interval timing, and total training volume—makes it difficult to compare and generalize findings across studies. Differences in training modalities, exercise types, and intensity metrics used in various studies limit the practical application and widespread adoption of HIIT [17]. For instance, excessively long recovery periods or low-intensity intervals may fail to elicit the same cardiovascular benefits [18]. Given the high-intensity nature of HIIT, safety is a critical concern, particularly for individuals with elevated cardiovascular risk or those unaccustomed to high-intensity exercise. High-intensity exercise may lead to adverse effects such as arrhythmias or myocardial ischemia [19]. Therefore, before promoting HIIT, individualized assessments and guidance based on health status are essential.

Secondly, although HIIT has demonstrated significant short-term improvements in cardiorespiratory fitness, metabolic health, and body composition, its long-term effects on cardiovascular health remain understudied. This is particularly true for high-risk populations and its role in chronic disease prevention and long-term health maintenance [20].

To address these issues, future research should focus on developing standardized HIIT protocols and evaluating their efficacy through long-term follow-up studies. Additionally, tailored HIIT programs should be designed to account for individual characteristics such as age, gender, and health status, particularly for those with higher cardiovascular risk or limited experience with high-intensity exercise. This approach will enhance the applicability and safety of HIIT.

4. Conclusion

This study systematically compared the effects and mechanisms of High-Intensity Interval Training (HIIT) and Moderate-Intensity Continuous Training (MICT) on cardiovascular health. The results demonstrate that HIIT can significantly improve maximal oxygen uptake (VO_2 max), enhance endothelial function, and reduce blood pressure and lipid levels in a shorter time frame. Additionally, HIIT shows superior or comparable efficacy in glycemic control for individuals with diabetes. However, the high-intensity nature and brief recovery periods of HIIT raise safety concerns, particularly for individuals with elevated cardiovascular risk, as they may trigger adverse reactions. Therefore, HIIT is more suitable for healthy individuals with limited time and good physical fitness. In contrast, MICT, with its lower intensity and higher safety profile, is better suited for older adults and patients with chronic conditions, although its benefits require long-term adherence to become evident.

Current research lacks sufficient empirical evidence on the long-term effects and safety of HIIT, and the absence of standardized protocols limits its widespread adoption. Future studies should focus on the following directions: (1) Develop standardized HIIT protocols by defining specific parameters for training intensity, duration, and interval timing to ensure reproducibility and safety; (2) Conduct large-scale, long-term follow-up studies to evaluate the long-term effects of HIIT on preventing cardiovascular events and maintaining overall health, as well as to explore its potential for chronic disease prevention; (3) Integrate multidisciplinary approaches, such as genetic testing and wearable device monitoring, to develop personalized HIIT intervention strategies, particularly for high-risk groups like older adults and chronic disease patients, to ensure both efficacy and safety; (4) Explore the synergistic effects of HIIT combined with other health interventions, such as scientifically designed dietary control and psychological support, to enhance exercise adherence and overall health outcomes; (5) Dynamically adjust the ratio of HIIT to MICT or adopt a "hybrid training model," tailoring exercise regimens based on individual health conditions to balance efficiency and safety, ensuring benefits for diverse populations. Through these improvements, more scientifically grounded guidance can be provided for the practical application of HIIT, contributing to the precision and efficiency of cardiovascular disease prevention and management.

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