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# Effects of Low-Volume High-Intensity Interval Training on Cardiovascular Disease Risk Factors and Underlying Mechanisms: Evidence and Perspectives

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**Abstract**

Background:Time constraint is one of the most frequently reported barriers to regular physical activity, limiting the real-world scalability of traditional moderate-intensity continuous training (MICT) for cardiovascular disease (CVD) prevention. Low-volume high-intensity interval training (LV-HIIT) has emerged as a time-efficient exercise strategy that preserves high relative intensity while markedly reducing total exercise volume and session duration. Objective:This narrative review aims to synthesize current evidence on the effects of LV-HIIT on major CVD risk factors and to integrate potential physiological mechanisms underlying its multi-system benefits, with particular emphasis on population- and protocol-dependent responses. Methods:Relevant randomized controlled trials, systematic reviews, and meta-analyses investigating LV-HIIT in relation to cardiorespiratory fitness, blood pressure, glucose metabolism, lipid profile, body composition, and vascular function were narratively summarized and critically appraised. Results:Across diverse populations, including sedentary individuals, those with overweight or obesity, metabolic dysfunction, and selected clinical cohorts, LV-HIIT consistently improves cardiorespiratory fitness and often reduces systolic blood pressure, with effects generally comparable to MICT despite substantially lower time commitment. In contrast, outcomes related to glycemic control, lipid profile, and body composition show greater heterogeneity and appear more dependent on baseline metabolic status, intervention duration, and protocol characteristics. Mechanistically, LV-HIIT likely induces coordinated central–peripheral adaptations, including enhanced cardiac output, autonomic regulation, skeletal muscle mitochondrial remodeling, improved substrate utilization, and shear stress–mediated endothelial function. Anti-inflammatory and antioxidative effects may further contribute, particularly in metabolically compromised individuals. Conclusions:LV-HIIT represents a pragmatic and time-efficient exercise strategy capable of delivering robust improvements in key cardiovascular risk factors. While benefits for cardiorespiratory fitness and blood pressure are relatively consistent, metabolic and body composition responses require stratification by population characteristics and training design. Future research should prioritize longer intervention periods, standardized LV-HIIT

definitions, and mechanistic phenotyping to optimize clinical translation and public health implementation.
**Keywords:** Low-Volume High-Intensity Interval Training, Cardiovascular Disease Risk, Cardiorespiratory Fitness, Blood Pressure, Metabolic Health, Physiological Mechanisms

## Introduction

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide and continues to impose a substantial global health burden. The development and progression of CVD are closely linked to multiple modifiable risk factors, including low cardiorespiratory fitness (CRF), elevated blood pressure, impaired glucose and lipid metabolism, obesity, and vascular dysfunction. Exercise-based interventions are widely recognized as a cornerstone non-pharmacological strategy for CVD prevention and management, with moderate-intensity continuous training (MICT) traditionally recommended in clinical and public health guidelines (Piercy et al., 2018; WHO, 2020). However, in real-world settings, "lack of time" is consistently identified as one of the primary barriers to regular exercise participation and long-term adherence, limiting the feasibility and sustainability of conventional endurance-based exercise prescriptions, particularly among inactive and high-risk populations (Kohl et al., 2012; Trost et al., 2002).

In this context, high-intensity interval training (HIIT) has gained increasing attention due to its capacity to induce improvements in CRF and cardiometabolic health within a substantially shorter time commitment than traditional endurance exercise (Gibala et al., 2012; Weston et al., 2014). As research has expanded from athletic cohorts to sedentary individuals and those with metabolic disorders, it has become evident that HIIT does not represent a single, homogeneous training modality. Rather, HIIT protocols vary widely with respect to exercise intensity, interval structure, session duration, and overall training volume (Buchheit & Laursen, 2013). Within this heterogeneous framework, low-volume high-intensity interval training (LV-HIIT), which emphasizes achieving clinically meaningful health benefits with minimal time investment, has emerged as a distinct and increasingly studied paradigm.

The defining feature of LV-HIIT is the maintenance of a high relative exercise intensity while markedly reducing the accumulated duration of high-intensity work and/or total session time (Gibala & Little, 2020; Sabag et al., 2022). Despite growing interest, the conceptual boundaries and operational definitions of LV-HIIT remain inconsistent across the literature. Some studies define "low volume" based on energy expenditure thresholds, such as cumulative metabolic equivalent (MET) minutes (Sultana et al., 2019), whereas others prioritize absolute training time or the minimal effective duration of high-intensity intervals (Taylor et al., 2019). Importantly, evidence from behavioral research suggests that total time commitment is a more salient determinant of exercise uptake and adherence than abstract measures of energy expenditure, particularly among time-constrained individuals (Harris & Kessler, 2019).

Moreover, although accumulating evidence supports the efficacy of LV-HIIT for improving selected CVD risk factors, its effects are not uniform across outcomes or populations. Improvements in CRF and systolic blood pressure appear relatively robust and consistent, whereas changes in glucose metabolism, lipid profiles, and body composition show greater dependence on baseline metabolic status, intervention duration, and training protocol characteristics (Batacan et al., 2017; Milanović et al., 2015; Sultana et al., 2019). In parallel, the physiological mechanisms through which LV-HIIT elicits multisystem adaptations under conditions of markedly reduced training volume—particularly the relative contributions of central cardiovascular versus peripheral skeletal muscle and vascular adaptations—have not yet been fully integrated into a coherent conceptual framework (Joyner & Coyle, 2008; MacInnis & Gibala, 2017).

Despite the rapid growth of research in this area, existing reviews have largely examined HIIT as a broad training category, often without distinguishing LV-HIIT as a discrete and practically relevant paradigm defined by minimal effective exercise dose. As a result, the specific cardiovascular benefits, mechanistic basis, and real-world applicability of LV-HIIT remain insufficiently synthesized. Clarifying these aspects is essential for bridging the gap between laboratory-based exercise science and scalable public health strategies aimed at time-constrained populations.

Accordingly, this narrative review adopts an "evidence and perspectives" approach. First, we summarize the conceptual framework, definitional evolution, and commonly used LV-HIIT protocols. Second, we synthesize current evidence regarding the effects of LV-HIIT on major CVD risk factors, including CRF, blood pressure, glucose metabolism, lipid profiles, and body composition, with particular attention to population-specific responses. Third, we integrate potential physiological mechanisms from the perspectives of central cardiovascular adaptation, peripheral skeletal muscle metabolic remodeling, and vascular endothelial and inflammatory regulation. Finally, we discuss key limitations of the existing literature and outline priorities for future research, with the aim of informing public health strategies and optimizing individualized exercise prescription.

## Conceptual Framework and Characteristics of Low-Volume HIIT

### *Definition and Evolution of Low-Volume High-Intensity Interval Training*

High-intensity interval training (HIIT) is commonly defined as a training modality consisting of repeated bouts of high-intensity exercise interspersed with periods of low-intensity recovery or rest (Billat, 2001; Buchheit & Laursen, 2013). Over the past two decades, a substantial body of evidence has demonstrated that HIIT can elicit marked improvements in cardiorespiratory fitness and cardiometabolic health within relatively short time frames, leading to its widespread attention in exercise science and public health research (Gibala et al., 2012; Weston et al., 2014).

However, as the volume of HIIT-related research has expanded, it has become increasingly clear that HIIT does not represent a single, homogeneous training model. Instead, considerable heterogeneity exists across studies with respect to exercise intensity, interval structure, session duration, and overall training volume (Buchheit & Laursen, 2013; MacInnis & Gibala, 2017).

### *Heterogeneity of Traditional HIIT and Paradigm Refinement*

Early HIIT studies predominantly employed protocols characterized by relatively high training volumes, with prolonged cumulative high-intensity work and total session durations typically ranging from 25 to 40 minutes (Helgerud et al., 2007; Daussin et al., 2008). These protocols have robust evidence supporting their efficacy in improving cardiorespiratory fitness and cardiovascular health. Nevertheless, the substantial time commitment and physiological strain associated with such high-volume HIIT protocols may limit their feasibility and long-term adherence, particularly among sedentary individuals, those with low fitness levels, or people facing significant time constraints (Hardcastle et al., 2014).

As HIIT research progressively shifted from athletic populations toward the general public and clinical cohorts, differences in feasibility, safety, and adherence became increasingly apparent. This transition prompted researchers to further refine and classify HIIT into distinct subtypes based on training volume and intensity characteristics (Buchheit & Laursen, 2013).

Within this refined framework, HIIT is now commonly categorized into high-volume HIIT, sprint interval training (SIT), and low-volume high-intensity interval training (LV-HIIT). Notably, the emergence of LV-HIIT reflects a conceptual shift in HIIT application—from a performance-oriented paradigm toward a public health and exercise prescription–oriented approach (Gibala & Little, 2020).

*Emergence and Core Definitions of LV-HIIT*

Low-volume high-intensity interval training is generally regarded as an important subtype of HIIT, designed to substantially reduce the total volume of high-intensity exercise and overall session duration while maintaining a high relative exercise intensity. Unlike traditional HIIT protocols that emphasize completing a large amount of high-intensity work within a session, LV-HIIT focuses on eliciting clinically meaningful and health-relevant physiological adaptations using the minimal effective training dose (Gibala et al., 2012; MacInnis & Gibala, 2017).

Despite growing interest, there is currently no universally accepted operational definition of LV-HIIT. One major point of debate concerns whether “low volume” should be quantified using energy expenditure (e.g., cumulative metabolic equivalent minutes) or actual exercise time. In a systematic review and meta-analysis, Sultana et al. (2019) defined LV-HIIT as HIIT protocols with a weekly exercise volume not exceeding 500 MET·min, approximately equivalent to the minimum physical activity recommendations for moderate-intensity exercise.

While this energy-based definition provides a standardized metric of training load, it has notable limitations. MET values are not easily interpretable for most individuals and may fail to capture the perceived “time cost” of exercise participation. Behavioral research consistently indicates that lack of time is one of the most frequently cited barriers to initiating and maintaining regular physical activity (Harris & Kessler, 2019).

Consequently, an increasing number of studies have adopted time-based definitions of LV-HIIT, particularly when positioning it as a time-efficient alternative to moderate-intensity continuous training (MICT). Within this framework, Taylor et al. (2019) and Sabag et al. (2022) defined LV-HIIT as interval protocols in which the cumulative duration of high-intensity exercise does not exceed 15 minutes per session, excluding recovery periods. Gibala and Little (2020) further emphasized the concept of a “minimal effective dose,” describing

LV-HIIT as protocols involving approximately 5 minutes of vigorous-intensity exercise per session (e.g., 5 × 1-minute intervals), with total session durations—including warm-up and cool-down—of no more than 15 minutes.

Despite differences in specific thresholds and calculation methods, there is broad consensus that LV-HIIT is characterized by a substantial reduction in training volume and time commitment while preserving high relative exercise intensity, typically corresponding to ~80–100% of maximal heart rate. This intensity appears sufficient to induce robust cardiovascular and metabolic stimuli (Gibala et al., 2012; MacInnis & Gibala, 2017).
From a public health and behavioral perspective, overall exercise duration is more readily perceived and managed than abstract energy expenditure metrics. Therefore, definitions of LV-HIIT that emphasize total session time, time efficiency, and practical feasibility may be particularly conducive to large-scale implementation and align closely with its intended role as a time-efficient alternative to MICT.

*Evolution of Target Populations and Application Contexts*
The development of LV-HIIT reflects not only a reduction in training volume but also a shift in target populations and application contexts. Whereas traditional HIIT protocols were primarily investigated in athletes or regularly trained individuals, LV-HIIT has increasingly been applied to sedentary, physically inactive, or time-constrained populations, including university students, office workers, and individuals at elevated cardiovascular risk (Sultana et al., 2019; Sabag et al., 2022).

This evolution mirrors a broader transition in exercise intervention philosophy—from determining what highly fit individuals can tolerate to identifying strategies that maximize feasibility, adherence, and sustainability in the general population. In this context, LV-HIIT represents a pragmatic compromise between physiological effectiveness and real-world applicability.

In summary, LV-HIIT has emerged as a distinct and increasingly relevant HIIT subtype developed to address barriers related to time constraints and exercise adherence. Characterized by low total volume, short session duration, and high relative intensity, LV-HIIT is conceptually distinct from high-volume HIIT, sprint interval training, and MICT, and provides a theoretical foundation for evaluating its effects on cardiovascular disease risk factors.

As illustrated in **Figure 1**, the conceptual framework of LV-HIIT reflects a progressive evolution from performance-oriented HIIT models toward a pragmatic, time-efficient, and population-based training paradigm with broad applicability in health promotion.

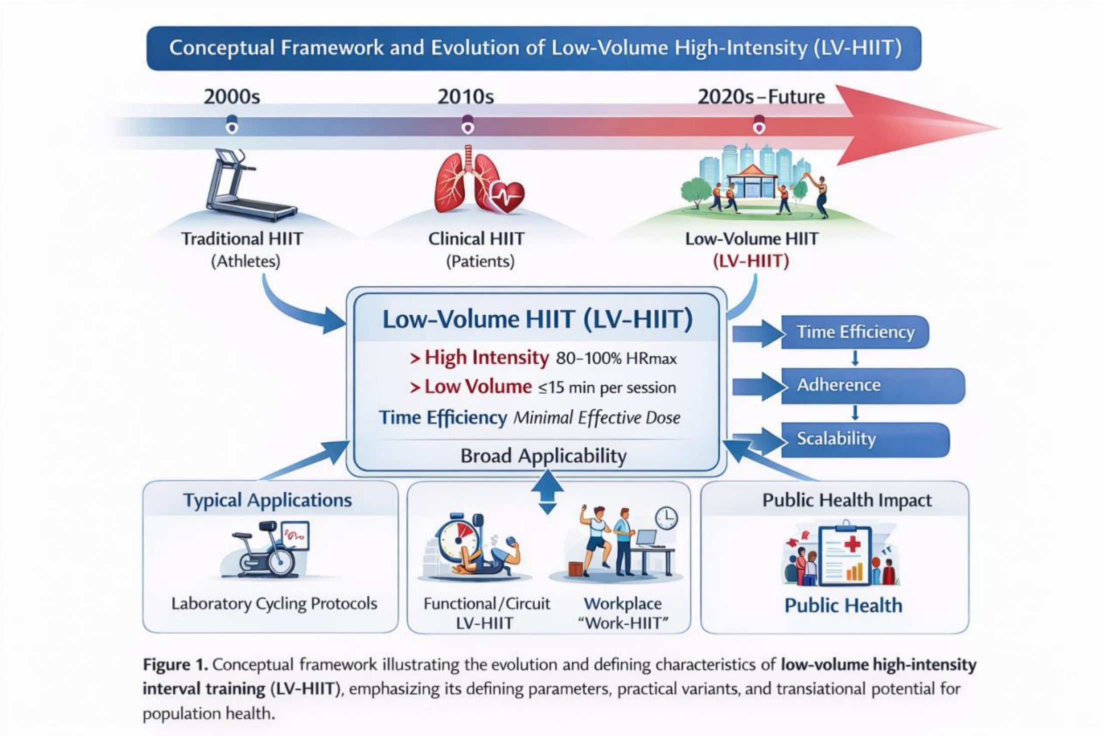


Figure 1. Conceptual framework and evolution of low-volume high-intensity interval training (LV-HIIT)

This schematic illustrates the progressive evolution of high-intensity interval training (HIIT) from traditional athletic models (2000s) to clinical applications (2010s), and finally to low-volume high-intensity interval training (LV-HIIT) as a time-efficient, population-oriented approach for cardiovascular health promotion.LV-HIIT is characterized by high relative intensity (80–100% HRmax) and low total exercise volume (≤15 minutes per session), representing a minimal effective dose capable of eliciting meaningful cardiovascular and metabolic adaptations.The framework emphasizes LV-HIIT's defining features of time efficiency, improved adherence, and broad scalability across settings such as laboratories, fitness environments, workplaces, and public health programs. Collectively, these attributes position LV-HIIT as a practical and evidence-based strategy bridging exercise physiology and population health.

*Common Low-Volume High-Intensity Interval Training Protocols*

Although LV-HIIT shares core defining features, its practical implementation is highly flexible, encompassing a variety of exercise modes and protocol designs. This versatility allows LV-HIIT to be adapted to different environments, equipment availability, and participant characteristics, thereby enhancing its translational potential.

*Wingate-Based Cycling Sprint Protocols*

Wingate-based cycling protocols represent one of the earliest and most extensively studied forms of low-volume interval training. These protocols typically consist of repeated 20–30-second "all-out" cycling sprints against a fixed resistance, interspersed with 2–4 minutes of passive or active recovery. Despite a total high-intensity exercise time of only 2–4 minutes per session, such protocols elicit pronounced cardiovascular and metabolic stress and induce rapid physiological adaptations (Gibala et al., 2006; Burgomaster et al., 2008).

However, due to their extreme intensity and high perceptual demand, these protocols may be less suitable for unsupervised settings or widespread public health implementation, particularly among sedentary or clinical populations (Hardcastle et al., 2014).

*Running-Based or Sprint Interval Protocols*

Running-based LV-HIIT protocols typically involve short bouts of near-maximal or supramaximal running, such as repeated 30–60-second sprints or intervals performed above the speed associated with $VO_2$max. Compared with cycling-based protocols, running-based LV-HIIT generally imposes greater mechanical loading and whole-body oxygen demand, potentially eliciting distinct cardiovascular and neuromuscular adaptations (Billat, 2001; Buchheit & Laursen, 2013).

These protocols often exhibit high ecological validity, particularly in young or physically active populations. However, their higher impact forces and inter-individual variability necessitate careful consideration of injury risk and individual tolerance in practical applications.

*Functional and Circuit-Based LV-HIIT*

Functional or circuit-based LV-HIIT integrates multi-joint, body-weight, or resistance exercises (e.g., squats, burpees, push-ups) performed in short, high-intensity circuits. These protocols typically require minimal equipment and can be easily implemented in community, home, or school settings.

In addition to cardiovascular and metabolic benefits, circuit-based LV-HIIT may enhance neuromuscular fitness, movement control, and muscular strength, thereby broadening its potential health benefits and appeal in public health contexts (Sabag et al., 2022).

*Workplace High-Intensity Interval Training (Work-HIIT)*

Workplace HIIT (Work-HIIT) represents an emerging application of LV-HIIT principles within occupational settings. These interventions are typically designed to fit within brief work breaks, with total session durations ranging from 5 to 10 minutes. Preliminary evidence suggests that Work-HIIT can improve cardiorespiratory fitness and cardiometabolic indicators while directly addressing common barriers such as lack of time and limited access to exercise facilities (Nerhus et al., 2020).

Collectively, the diversity of LV-HIIT protocols underscores the importance of considering intensity prescription, interval structure, and total session duration when interpreting study outcomes. Given this heterogeneity, the following chapter synthesizes evidence on the effects of LV-HIIT on major cardiovascular disease risk factors, with particular emphasis on population-specific responses and protocol characteristics.

**Effects of Low-Volume High-Intensity Interval Training on Cardiovascular Disease Risk Factors**

Cardiovascular disease (CVD) risk factors encompass a broad range of physiological, metabolic, and behavioral determinants, including cardiorespiratory fitness (CRF), blood pressure, lipid profile, glucose metabolism, body composition, vascular function, and systemic inflammation (Yusuf et al., 2004; Lavie et al., 2019). Accumulating evidence suggests that, compared with traditional moderate-intensity continuous training (MICT), low-volume high-intensity interval training (LV-HIIT) can induce clinically meaningful improvements across several key domains despite a substantially reduced time commitment (Gibala et al., 2012; MacInnis & Gibala, 2017). This section synthesizes current evidence regarding the effects of LV-HIIT on major CVD risk factors, with particular emphasis on population-specific responses and outcome-dependent heterogeneity.

*Cardiorespiratory Fitness (CRF)*

Cardiorespiratory fitness, commonly assessed by maximal or peak oxygen uptake ($VO_2max$ or $VO_2peak$), is widely recognized as one of the strongest independent predictors of CVD incidence and all-cause mortality (Blair et al., 1989; Kodama et al., 2009). Large-scale epidemiological studies consistently demonstrate that higher CRF is associated with substantial reductions in cardiovascular and all-cause mortality, even in the absence of significant changes in body weight or body mass index (BMI), highlighting CRF as a critical and independent health outcome (Lee et al., 2011; Ross et al., 2016).

Randomized controlled trials consistently report that LV-HIIT elicits significant improvements in CRF across diverse populations, including sedentary young adults, individuals with overweight or obesity, patients with metabolic syndrome, and those with established CVD (Helgerud et al., 2007; Little et al., 2011; Rognmo et al., 2012). In most studies, the magnitude of $VO_2max$ improvement achieved with LV-HIIT ranges from moderate to large and is comparable to, or occasionally greater than, that observed following MICT, despite a 40–70% reduction in total exercise volume (Gibala et al., 2012; Weston et al., 2014).

Evidence from meta-analyses further supports these findings. Su et al. (2019) reported no significant difference between HIIT and MICT in CRF improvements among adults with overweight or obesity, while the average session duration was approximately 9.7 minutes shorter in the HIIT condition. Similarly, meta-analyses by Milanović et al. (2015) and Sultana et al. (2019) indicate that HIIT is at least as effective as MICT for improving CRF and may confer a slight advantage under certain conditions.

From a mechanistic perspective, CRF improvements following LV-HIIT are thought to arise from rapid central and peripheral adaptations, including increases in stroke volume, enhanced myocardial contractility, improved skeletal muscle oxidative capacity, and upregulation of mitochondrial biogenesis (Helgerud et al., 2007; Daussin et al., 2008; MacInnis & Gibala, 2017). Although total training time is limited, the intermittent exposure to near-maximal cardiovascular stress appears sufficient to trigger key physiological adaptations comparable to those induced by traditional endurance training.

**Blood Pressure Regulation**

Hypertension and impaired vascular function represent among the most important modifiable risk factors for CVD development and progression (Whelton et al., 2018). Overall, available evidence suggests that LV-HIIT exerts favorable effects on blood pressure, particularly in individuals with elevated baseline blood pressure or concomitant cardiometabolic risk factors such as overweight and obesity (Cornelissen & Smart, 2013; Batacan et al., 2017).

Several intervention studies report reductions in systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) following LV-HIIT compared with non-exercise controls (Tjønna et al., 2008; Molmen-Hansen et al., 2012). These findings are supported by broader HIIT literature, which provides important context for interpreting LV-HIIT-specific effects.

A systematic review by Batacan et al. (2017) demonstrated that short-term HIIT interventions exert minimal effects on blood pressure in normal-weight individuals, whereas consistent and clinically relevant reductions in SBP and DBP are observed among individuals with overweight or obesity, irrespective of intervention duration. This pattern suggests that baseline adiposity and metabolic status may modulate blood pressure responses to high-intensity exercise.

Further evidence indicates that the antihypertensive effects of LV-HIIT may be particularly pronounced in individuals with diagnosed hypertension. For example, Molmen-Hansen et al. (2012) reported greater SBP reductions in hypertensive compared with prehypertensive individuals following HIIT. Given epidemiological data indicating that each 4-mmHg reduction in SBP is associated with a substantial decrease in cardiovascular mortality (Lewington et al., 2002), SBP reductions approaching 10 mmHg observed in some LV-HIIT studies are of clear clinical relevance.

Comparative studies generally suggest that LV-HIIT and MICT yield similar blood pressure reductions, although LV-HIIT achieves these benefits with a markedly lower time commitment (Cornelissen & Smart, 2013; Batacan et al., 2017). Nonetheless, heterogeneity remains across studies, particularly in adolescent populations and among individuals with well-controlled hypertension, underscoring the need for cautious interpretation.

*Glucose Metabolism and Insulin Resistance*

Disturbances in glucose metabolism and insulin resistance constitute key pathophysiological mechanisms underlying type 2 diabetes and CVD (DeFronzo & Ferrannini, 1991). A growing body of evidence suggests that LV-HIIT favorably influences glycemic control, with more consistent benefits observed in adults with overweight, obesity, or type 2 diabetes (Little et al., 2011; Jelleyman et al., 2015).

Overall, LV-HIIT protocols characterized by sustainable intensity, adequate recovery intervals, and controlled session duration are more likely to elicit reductions in fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c), with improvements comparable to those achieved with MICT despite substantially reduced exercise time (Little et al., 2011; Karstoft et al., 2013). In contrast, extremely low-volume sprint-based protocols with very short supramaximal efforts have shown inconsistent effects on glycemic outcomes, suggesting that "low volume" does not necessarily equate to "lower is better" and that training structure plays a critical role in metabolic adaptations (Jelleyman et al., 2015).

Findings regarding insulin resistance are more heterogeneous. Several studies report limited changes in fasting insulin or HOMA-IR, which may reflect the hepatic emphasis of these indices, whereas LV-HIIT may preferentially improve peripheral insulin sensitivity via skeletal muscle adaptations (Richter & Hargreaves, 2013). Consequently, dynamic assessments such as oral glucose tolerance test-derived indices may be more appropriate for capturing LV-HIIT-induced changes in insulin action.

Mechanistically, LV-HIIT may enhance glucose utilization through increased skeletal muscle oxidative capacity, augmented GLUT4 translocation, and elevated fat oxidation, while neuroendocrine responses elicited during high-intensity bouts and recovery phases may further contribute to metabolic regulation (Hawley & Lessard, 2008). Collectively, these adaptations support the use of LV-HIIT as a time-efficient strategy for glycemic control in metabolically compromised populations, although potential impacts on long-term adherence warrant careful consideration.

*Lipid Regulation*

Dyslipidemia, characterized by elevated triglycerides (TG), reduced high-density lipoprotein cholesterol (HDL-C), and increased low-density lipoprotein cholesterol (LDL-C), is a major contributor to atherosclerotic CVD (Ference et al., 2017). Increasing attention has been directed toward LV-HIIT as a time-efficient approach for lipid modulation.

Evidence from systematic reviews and randomized trials suggests that LV-HIIT can induce favorable changes in lipid profiles, particularly among individuals with obesity, type 2 diabetes, or metabolic syndrome, commonly manifesting as reductions in TG and increases in HDL-C (Weston et al., 2014; Sultana et al., 2019). The magnitude of these changes is generally comparable to that observed following MICT, with occasional reports of superior effects.

In contrast, lipid responses in individuals with normal baseline lipid levels are often minimal, underscoring the population-dependent nature of LV-HIIT-induced lipid adaptations (Batacan et al., 2017). Potential mechanisms include enhanced lipoprotein lipase activity, increased fatty acid oxidation, and improved skeletal muscle lipid handling (Shepherd et al., 2015). Notably, combining LV-HIIT with dietary interventions or extending intervention duration appears to potentiate lipid-related benefits.

*Body Composition and Obesity*

Abnormal body composition, particularly excess adiposity and central obesity, is a key determinant of cardiometabolic risk (Després, 2012). Current evidence indicates that LV-HIIT exerts modest but consistent effects on selected body composition indices, with pronounced heterogeneity across outcomes and populations.

Most studies report small but significant reductions in fat mass, body fat percentage, and waist circumference following LV-HIIT, whereas changes in fat-free mass are generally negligible (Keating et al., 2017; Sultana et al., 2019). These findings suggest that, under conditions of limited total energy expenditure, LV-HIIT may preferentially influence fat distribution rather than induce substantial changes in lean tissue.

Inter-study variability in adiposity outcomes may be partly attributable to intervention duration and exercise modality. Evidence suggests that running-based HIIT may be more effective for fat reduction than cycling-based protocols, potentially due to greater muscle mass involvement and higher energy expenditure (Keating et al., 2017). Despite modest effects on total fat mass, reductions in waist circumference are clinically relevant, as this measure reflects visceral adiposity and is strongly associated with cardiovascular risk (Ross et al., 2020).

Comparisons with MICT indicate broadly similar effects on body composition, achieved with considerably less time commitment in LV-HIIT. Accordingly, LV-HIIT may be best positioned as a component of comprehensive lifestyle interventions or in combination with resistance training, rather than as a standalone strategy for substantial body composition change.

**Summary**

In summary, accumulated evidence indicates that LV-HIIT can elicit meaningful improvements in multiple cardiovascular disease (CVD) risk factors despite a markedly reduced time commitment. The most consistent benefits are observed in cardiorespiratory fitness (CRF) and systolic blood pressure, while improvements in glucose regulation are more pronounced among individuals with metabolic dysfunction. In contrast, lipid profile and body composition outcomes exhibit greater variability, reflecting population- and protocol-specific influences, with more consistent benefits observed in individuals at elevated cardiometabolic risk.

Overall, the effects of LV-HIIT can be characterized by robust improvements in cardiorespiratory and hemodynamic outcomes, accompanied by more heterogeneous metabolic and compositional responses. These outcomes are broadly comparable to those achieved through moderate-intensity continuous training (MICT), yet attained with substantially reduced total training time.

The integrated effects of LV-HIIT across major cardiovascular risk factors are illustrated in **Figure 2**, which summarizes consistent improvements in CRF and blood pressure, alongside variable but beneficial adaptations in glucose metabolism, lipid regulation, and body composition. Collectively, these findings provide a physiological foundation for the mechanistic framework explored in the following section, linking central and peripheral adaptations to the observed cardiometabolic benefits of LV-HIIT.

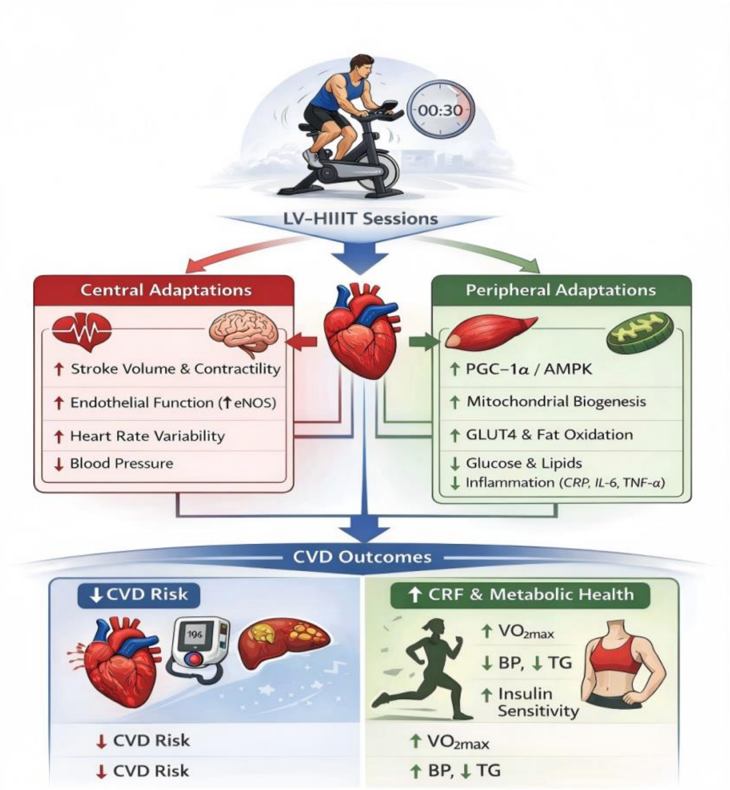


**Figure 2.** Integrated Mechanistic and Functional Effects of Low-Volume High-Intensity Interval Training (LV-HIIT) on Cardiovascular Health

Figure 2. Integrated Mechanistic and Functional Effects of Low-Volume High-Intensity Interval Training (LV-HIIT) on Cardiovascular Health

This schematic illustrates the integrated central and peripheral mechanisms through which low-volume high-intensity interval training (LV-HIIT) improves cardiovascular and metabolic health. Central adaptations include enhanced stroke volume, myocardial contractility, autonomic balance, and endothelial nitric oxide synthase (eNOS) activation, leading to improved vascular compliance and reduced blood pressure. Peripheral adaptations involve activation of the AMPK–PGC-1α signaling pathway, mitochondrial biogenesis, increased glucose transporter-4 (GLUT4) translocation, and enhanced lipid oxidation. These changes collectively improve cardiorespiratory fitness (CRF), glucose and lipid metabolism, and body composition, thereby reducing major cardiovascular disease (CVD) risk factors and systemic inflammation.

*Potential Mechanisms: Central and Peripheral Adaptations Underlying the Effects of LV-HIIT on Cardiovascular Disease Risk Factors*

As summarized in **Figure 2**, low-volume high-intensity interval training (LV-HIIT) elicits consistent improvements in cardiorespiratory fitness and blood pressure, along with favorable—though more variable—changes in metabolic and body composition parameters. These integrated outcomes suggest that the health benefits of LV-HIIT arise from a constellation of multilevel physiological adaptations rather than a single pathway.

Current evidence indicates that these adaptations reflect a coordinated interaction between central cardiovascular regulation and peripheral tissue remodeling, encompassing cardiac, autonomic, muscular, and vascular–endothelial domains (MacInnis & Gibala, 2017;

Joyner & Coyle, 2008). Together, these synergistic processes provide a mechanistic basis for the time-efficient yet comprehensive improvements observed with LV-HIIT in cardiovascular disease (CVD) risk reduction.

*Central Mechanisms: Adaptations in Cardiovascular Function and Autonomic Regulation*

The consistent improvements in cardiorespiratory fitness (CRF) and blood pressure observed following LV-HIIT are likely attributable, at least in part, to structural and functional adaptations of the central cardiovascular system. During high-intensity intervals, the heart is repeatedly exposed to near-maximal hemodynamic stress. Even with a short total training duration, such stimuli appear sufficient to induce increases in stroke volume and myocardial contractile function, thereby augmenting maximal cardiac output (Helgerud et al., 2007; Daussin et al., 2008). These central adaptations are considered a primary physiological determinant of improvements in maximal oxygen uptake ($VO_2max$), which is itself a strong predictor of cardiovascular prognosis (MacInnis & Gibala, 2017).

In terms of blood pressure regulation, LV-HIIT may exert favorable effects through modulation of autonomic nervous system balance. Previous studies have shown that high-intensity exercise can enhance parasympathetic (vagal) tone while attenuating sympathetic activity, leading to improvements in resting heart rate and vascular tone regulation (Cornelissen & Smart, 2013). In addition, the repeated exposure to elevated shear stress during interval exercise may improve large-artery compliance and reduce peripheral vascular resistance—effects that appear particularly relevant in individuals with hypertension or elevated baseline blood pressure (Green et al., 2017). Although direct evidence specifically linking LV-HIIT to changes in autonomic function and arterial stiffness remains limited, the relatively consistent benefits observed for CRF and systolic blood pressure suggest that central hemodynamic adaptations play a substantial role (Buchheit & Laursen, 2013).

*Peripheral Mechanisms: Skeletal Muscle Metabolism and Vascular Remodeling*

In parallel with central adaptations, peripheral metabolic and functional remodeling of skeletal muscle is thought to underpin the effects of LV-HIIT on glucose and lipid metabolism, as well as aspects of body composition. High-intensity exercise markedly increases the demand for adenosine triphosphate (ATP) in working muscles, thereby accelerating glucose and fatty acid uptake and oxidation. Despite the brief duration of LV-HIIT sessions, the repeated metabolic stress imposed by intense intervals can robustly activate mitochondrial biogenesis signaling pathways and enhance oxidative enzyme activity, leading to improvements in overall oxidative capacity (Gibala et al., 2006; Burgomaster et al., 2008).

With respect to glucose metabolism, LV-HIIT may improve glycemic control by increasing the expression and translocation of skeletal muscle glucose transporters, such as GLUT4, thereby enhancing insulin-independent glucose uptake (Richter & Hargreaves, 2013). Moreover, the transient increase in insulin sensitivity during the post-exercise recovery period may further contribute to improved whole-body glucose regulation (Hawley & Lessard, 2008). These peripheral adaptations provide a plausible explanation for the relatively consistent reductions in fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c) observed following LV-HIIT in individuals with metabolic disorders (Little et al., 2011; Shepherd et al., 2015).

Regarding lipid metabolism, LV-HIIT may enhance triglyceride clearance and increase high-density lipoprotein cholesterol (HDL-C) through upregulation of lipoprotein lipase activity, improved fatty acid oxidation, and greater efficiency of skeletal muscle lipid handling (Shepherd et al., 2015). Improvements in metabolic flexibility may also indirectly reduce visceral fat accumulation, thereby contributing to favorable changes in waist circumference and other indicators of fat distribution.

*Endothelial Function and Inflammation-Related Mechanisms*

Improvements in vascular endothelial function represent another important mechanistic pathway through which LV-HIIT may reduce CVD risk. The oscillatory increases in blood flow and shear stress generated during high-intensity interval exercise stimulate endothelial nitric oxide synthase activation and increase nitric oxide bioavailability, resulting in enhanced endothelium-dependent vasodilation and arterial compliance (Tjønna et al., 2008; Green et al., 2017). These vascular adaptations may partly explain the reductions in blood pressure observed following LV-HIIT interventions.

In addition, although LV-HIIT protocols are typically brief, emerging evidence suggests that high-intensity interval exercise can favorably modulate low-grade chronic inflammation and oxidative stress, particularly in populations with metabolic dysfunction. Previous studies have reported reductions in circulating inflammatory markers following HIIT, potentially mediated by decreases in visceral adiposity, improvements in adipose tissue function, and regulation of inflammation-related signaling pathways . Such anti-inflammatory effects may indirectly contribute to reductions in overall CVD risk.

*An Integrative Perspective: Central–Peripheral Interaction*

Taken together, the health benefits of LV-HIIT are unlikely to be driven by a single physiological mechanism, but rather by the synergistic interaction between central cardiovascular adaptations and peripheral metabolic remodeling. Central improvements in cardiac function and hemodynamics enhance oxygen and substrate delivery to peripheral tissues, while enhanced skeletal muscle metabolic capacity reduces circulatory metabolic burden and vascular stress. This bidirectional interaction may explain how LV-HIIT, despite a markedly reduced training volume, can simultaneously improve CRF, blood pressure, and selected metabolic and body composition outcomes (Joyner & Coyle, 2008; MacInnis & Gibala, 2017).

**Integrated Discussion and Future Perspectives**

*Overall Interpretation of the Current Evidence*

This narrative review synthesizes the available evidence on the effects of low-volume high-intensity interval training (LV-HIIT) on major cardiovascular disease (CVD) risk factors. Overall, the benefits of LV-HIIT appear most consistent for cardiorespiratory fitness and systolic blood pressure, whereas outcomes related to glucose metabolism, lipid profiles, and body composition show greater dependence on population characteristics and training protocols. Improvements in these latter domains are more frequently observed in individuals who are overweight, obese, or metabolically compromised. Collectively, the evidence suggests that the primary value of LV-HIIT does not lie in its universal superiority over moderate-intensity continuous training (MICT), but rather in its ability to achieve comparable overall cardiovascular health benefits with greater feasibility and time efficiency.

*Practical Applications and Clinical Relevance*

From a public health and clinical exercise prescription perspective, lack of time remains one of the most commonly reported barriers to regular physical activity participation. By substantially reducing the duration of individual training sessions while preserving key cardiovascular benefits, LV-HIIT offers a potentially more feasible and scalable exercise strategy. Nevertheless, LV-HIIT should not be viewed as universally applicable. Its relatively high exercise intensity may pose challenges for individuals with low fitness levels or limited prior exercise experience. Accordingly, LV-HIIT may be best positioned as one component within a graded and individualized exercise prescription framework, complementing MICT, resistance training, and broader lifestyle interventions, rather than serving as a direct replacement for traditional endurance-based exercise.

**Limitations of the Current Evidence Base**

Several limitations in the existing literature warrant consideration. First, most intervention studies are of relatively short duration, typically ranging from 4 to 12 weeks, which constrains the ability to draw conclusions regarding long-term cardiovascular outcomes and the sustainability of observed benefits. Second, considerable heterogeneity exists in the operational definitions and protocol designs of LV-HIIT, complicating cross-study comparisons and interpretation. In addition, many studies are limited by small sample sizes and focus predominantly on overweight, obese, or metabolically impaired populations, while high-quality evidence in healthy young adults, older individuals, and patients with established CVD remains scarce. Variability in outcome measurement methods further limits comparability across studies.

**Directions for Future Research**

Future research should prioritize longer-duration, methodologically robust randomized controlled trials to clarify the long-term effects of LV-HIIT on clinically relevant cardiovascular outcomes. Greater standardization of LV-HIIT definitions and training parameters is also needed to identify the minimal effective dose across different combinations of intensity, interval duration, and training frequency. Moreover, greater attention should be given to individual-level modifiers, including age, sex, baseline fitness, metabolic status, and subjective exercise experience, to enhance population-specific applicability and long-term adherence. From a mechanistic standpoint, integrating central and peripheral physiological assessments will be essential to delineate the relative contributions of different adaptive pathways to improvements in specific CVD risk factors.

**Concluding Perspective**

In summary, LV-HIIT represents a time-efficient exercise intervention with clear potential to improve multiple CVD risk factors. Its primary advantage does not lie in outperforming traditional endurance training across all outcomes, but in maintaining key cardiovascular and metabolic benefits while substantially reducing time demands. As higher-quality evidence continues to accumulate and training protocols are further refined, LV-HIIT is likely to assume a more clearly defined and pragmatic role in both public health promotion and individualized exercise prescription.

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