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Cardiovascular responses to high-intensity exercise: A systematic literature review comparing trained and untrained individuals

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ABSTRACT

Background: High-intensity exercise induces distinct cardiovascular responses, but systematic comparisons between trained and untrained individuals remain limited. **Objective**: The primary objective of this study was to compare cardiovascular responses to HIIT specifically heart rate, blood pressure, and blood lactate levels and to identify factors influencing these differences. **Methods**: A systematic literature review following the PRISMA framework was conducted for this study. The initial search on the Scopus database using keywords such as "High-Intensity Exercise," "Cardiac Output," "Trained," and "Untrained" yielded 380 articles. After a rigorous screening process, which applied strict inclusion and exclusion criteria including the requirement that articles be published in Q1-Q4 ranked journals between 2014 and 2024 a final set of 10 primary articles was selected for in-depth analysis. **Findings/Results**: High Intensity Interval Training effectively improves cardiovascular function in both trained and untrained individuals. Significant increases in cardiac output and VO_2 max are observed, particularly in trained cyclists. While untrained individuals also benefit, superior cardiovascular adaptations are seen in those who are trained. Furthermore, HIIT is proven to be safe; it does not increase the risk of cardiovascular dysfunction and even has a cardioprotective effect, demonstrated by an increase in cardiac ejection fraction. **Conclusion**: This review provides the first systematic synthesis comparing cardiovascular responses to high-intensity exercise between trained and untrained individuals. The findings highlight the importance of training status in exercise prescription and offer practical insights for coaches and health practitioners in optimizing high-intensity training programs.

Keywords: High-intensity interval training; cardiac output; trained individuals; untrained individuals

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INTRODUCTION

The cardiovascular system plays a crucial role in delivering oxygen and essential nutrients to bodily tissues. Engaging in physical activity, particularly high-intensity interval training (HIIT), significantly increases cardiovascular demands to accommodate heightened metabolic requirements. HIIT, which efficiency and effectiveness in enhancing cardiovascular fitness. However, individual cardiovascular responses to HIIT can vary considerably due to factors such as baseline fitness levels, physiological adaptations, and pre-existing health conditions (Wahl et al., 2022). Consequently, this study aims to evaluate and compare cardiovascular responses to a standardized HIIT protocol in both trained and untrained individuals (Saugel et al., 2021).

Variations in cardiovascular responses between trained and untrained individuals are largely attributed to distinct physiological adaptations within the cardiovascular system. Those with training experience typically demonstrate superior cardiac and pulmonary capacity, greater stroke volume, and enhanced metabolic efficiency (Astorino et al., 2016). These adaptations allow them to sustain higher workloads with a comparatively lower rise in heart rate and blood pressure than their untrained counterparts. A thorough understanding of these physiological differences is essential for designing safe and effective HIIT programs tailored to individual fitness levels (Alekya et al., 2023).

Understanding the effects of high-intensity exercise on cardiovascular health is particularly important for athletes, fitness enthusiasts, and individuals striving to improve overall well-being. While extensive research has shown that high-intensity exercise enhances cardiac function, the precise physiological mechanisms underlying these benefits remain partially unclear (Bostad et al., 2021).

Previous studies indicate that HIIT can lead to significant increases in cardiac output among trained individuals, whereas untrained individuals often exhibit minimal or no significant changes (Strasser & Burtscher, 2018). Trained individuals demonstrate a greater capacity to increase stroke volume during high-intensity exercise, resulting in a more pronounced rise in cardiac output compared to their untrained counterparts (Yulianto et al., 2024). These findings suggest that HIIT promotes beneficial cardiovascular adaptations in both trained and untrained individuals, albeit to varying degrees (Haris et al., 2024).

Despite its well-documented health benefits, HIIT also presents potential risks, particularly for untrained individuals or those with pre-existing cardiovascular conditions. The rapid increase in cardiac workload may elevate the risk of cardiovascular events such as arrhythmia, hypertension, or myocardial infarction (Atakan et al., 2021). Consequently, thorough pre-exercise risk assessments and continuous monitoring during HIIT sessions are crucial to ensuring participant safety. HIIT has been widely recognized for its effectiveness in improving aerobic capacity, enhancing insulin sensitivity, and supporting weight management (Holloway et al., 2018). However, its safety and efficacy largely depend on well-structured training programs, appropriate intensity regulation, and professional supervision. This study aims to provide deeper insights into optimizing HIIT to maximize its benefits while mitigating potential risks (Plizga et al., 2024).

A major challenge in HIIT research lies in the rigorous control of variables that influence cardiovascular responses. Factors such as baseline fitness levels, specific HIIT protocols, work-to-recovery ratios, and environmental conditions must be meticulously managed to ensure the validity and reliability of findings (Wiewelhove et al., 2015). Standardized HIIT protocols are essential for enabling accurate comparisons across different studies (Artiluhung et al., 2024).

Additionally, this study will address ethical and legal considerations in HIIT research, ensuring strict adherence to guidelines and regulations that safeguard participant safety and well-being. Informed consent will be obtained from all participants, and the study protocol will undergo review and approval by the appropriate ethics committee before implementation (Permana et al., 2024).

The primary goal of this study is to conduct both quantitative and qualitative analyses of cardiovascular responses—specifically heart rate, systolic and diastolic blood pressure, and blood lactate levels—following a standardized HIIT protocol in trained and untrained individuals. Additionally, this research aims to identify physiological and genetic factors that contribute to variations in these responses. The findings are expected to significantly enhance the understanding of cardiovascular adaptations to HIIT and their broader implications for health and fitness. These insights will support the development of safer and more effective training guidelines, tailored to diverse populations based on individual fitness levels and health conditions. By examining the distinctions in cardiovascular responses between trained and untrained individuals, this study offers a foundation for optimizing HIIT programs to maximize benefits while minimizing potential risks.

In summary, this research aspires to make a meaningful contribution to the fields of sports science and cardiovascular health. By comparing cardiovascular responses to HIIT across different fitness levels, it will provide essential knowledge for designing more effective and safer training approaches aimed at improving cardiovascular function. The outcomes will be valuable for healthcare professionals, fitness trainers, and individuals seeking to enhance the benefits of HIIT. Furthermore, this study will serve as a foundation for future research on optimizing HIIT protocols for a wide range of populations and health conditions (Karlsen et al., 2017). Many previous studies have only examined trained or untrained populations separately, No SLR has specifically compared the two systematically. Therefore, this review aims to systematically synthesize evidence on cardiovascular responses to high-intensity exercise by directly comparing trained and untrained individuals, addressing a gap that has not been clearly explored in previous reviews.

METHOD

A systematic literature review (SLR) is a structured methodological approach aimed at providing an objective synthesis of existing research on a specific hydrological topic (De León Pérez et al., 2024). This process follows a transparent and rigorous framework to evaluate the quality and relevance of selected studies, thereby enhancing the reliability of references and ensuring the reproducibility of the research (De León Pérez et al., 2024). In this review, the effects of high-intensity interval training (HIIT) on cardiac output and cardiovascular function were systematically examined, following the guidelines established by (Kitchenham et al., 2010). The study employs the Scopus indexing system, utilizing a predefined search string strategy to systematically identify relevant literature. Scopus was chosen for its comprehensive coverage of journals and conferences, particularly in the domains of Software Engineering and Computer Science. Previous research has demonstrated the effectiveness of this search strategy in retrieving high-quality papers (McCafferty & Mercado Garcia, 2024). A summary of the research methodology, including the number of studies retained at each stage, is presented in Figure 1.

Search Strategy

The literature review was carried out by searching multiple academic databases, with a primary focus on Scopus, a leading platform curated by Elsevier that provides comprehensive abstracts and citation data. Scopus was selected due to its broad coverage of scientific articles, conference proceedings, and other relevant publications, ensuring access to up-to-date and credible information to support this research. For further details, refer to Elsevier Scopus.

Research Question Using the PICO Framework

P = Population/patient/problem.
I/E = Intervention/exposure/treatment/process/management strategy/test.
C = Comparison/control, comparator/alternative.
O = Outcome/health risk/adverse events consequence.

Table 1. Research Question

Research Question	PICO
RQ1: How does high-intensity training affect cardiac output compared to no training or moderate-intensity training in trained and untrained individuals?	• **P (Population):** Trained and untrained individuals. • **I (Intervention):** High-intensity training. • **C (Comparison):** No training or moderate-intensity training. • **O (Outcome):** Changes in cardiac output (stroke volume, heart rate).
RQ2: What are the differences in cardiac function adaptations following high-intensity training between trained and untrained individuals?	• **P (Population):** Individuals with different fitness levels (trained vs. untrained). • **I (Intervention):** High-intensity interval training (HIIT). • **C (Comparison):** Baseline measurements before training.

Research Question	PICO
RQ3: Does high-intensity training increase the risk of cardiovascular dysfunction in trained individuals compared to untrained individuals?	• **O (Outcome):** Adaptations in cardiac function (increase in stroke volume, left ventricular capacity). • **P (Population):** Trained and untrained individuals. • **I (Intervention):** High-intensity interval training (HIIT). • **C (Comparison):** Resting condition or low-intensity training. • **O (Outcome):** Risk of cardiovascular dysfunction (biventricular dysfunction or reduced ejection fraction).

The next step in this Systematic Literature Review (SLR) is to design an appropriate search strategy to identify relevant studies. Our search string consists:

Inclusion Criteria:
(i) Articles published in indexed international journals.
(ii) Research relevant to the relationship between High-Intensity Exercise and Trained and Untrained Cardiac Output.
(iii) Publications within the last 10 years (2014-2024).
(iv) Articles written in English.

Exclusion Criteria:
(i) Articles that do not focus on High-Intensity Exercise and Trained and Untrained Cardiac Output.
(ii) Gray literature, such as reports that have not undergone peer review.
(iii) Articles with restricted access that are not fully accessible.

To ensure a high-quality selection of studies, researchers established a set of inclusion and exclusion criteria. The selection process, along with the specific criteria, is depicted in Figure 1. These criteria were systematically applied to all 380 studies retrieved from the database through a multi-stage screening process. In the initial phase, non-English publications were excluded. Additionally, non-research documents, such as reports and notes, were omitted from consideration. Additionally, studies that were not indexed in quartile rankings (Q1-Q4) were excluded to ensure comprehensiveness and quality. To avoid redundancy, duplicate papers across databases were removed before content review.

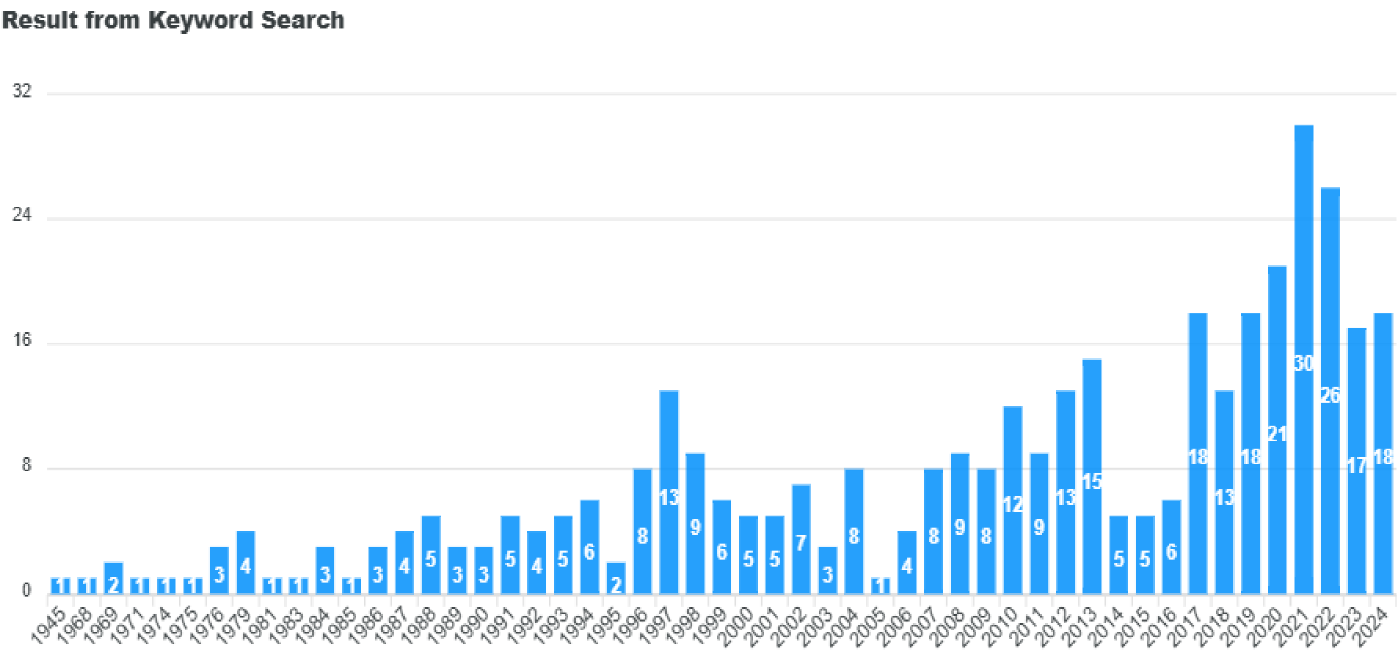

Figure 1. Analysis of Sources

In the next stage, the researchers screened the titles and abstracts to categorize the papers into two lists and to identify potentially relevant research articles. Subsequently, a comprehensive full-text review was conducted to verify the relevance and quality of the article content. During this screening process, a total of 101 papers were reviewed, while several records were excluded for specific reasons 272 papers were deemed ineligible by an automation tool due to being published between 2014 and 2024, 6 papers were eliminated based on their classification within journal tiers Q1 to Q4, and 1 paper was excluded due to the absence of an abstract, rendering it unsuitable for screening.

Following the review of these 101 potential papers, a further selection process was conducted based on the established inclusion and exclusion criteria, resulting in the refinement of 29 studies. Ultimately, 10 articles specifically examining the impact of high-intensity exercise on cardiac output in trained and untrained individuals were chosen for the final analysis.

Data Extraction

Following the guidelines proposed by Kitchenham et al. (2010), this study employs a structured form to systematically collect information, including demographic data from the selected studies. The first author is responsible for organizing the extracted data into a Microsoft Excel spreadsheet, To ensure data accuracy, random checks are conducted by other authors as a validation measure.

Data Synthesis

This study aims to analyze, categorize, and systematically present both qualitative and quantitative data. Thematic analysis serves as the primary method for synthesizing qualitative data, a widely recognized approach in software engineering research. In contrast, quantitative data are presented either in their raw form, including demographic information, or derived through the synthesis of qualitative findings.

The qualitative thematic analysis process follows six key stages as initially designed. The first author conducts the initial implementation of these stages, followed by an in-depth discussion with the second author to evaluate and refine the analysis as needed. Subsequently, the third and fourth authors oversee the process, providing critical feedback to ensure accuracy and alignment with the study's research objectives.

Identification and Screening of Articles

This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, employing the Watase UAKE website as a reference throughout the research process. This platform plays a crucial role in the screening phase, facilitating the systematic application of inclusion and exclusion criteria to ensure a rigorous selection process.

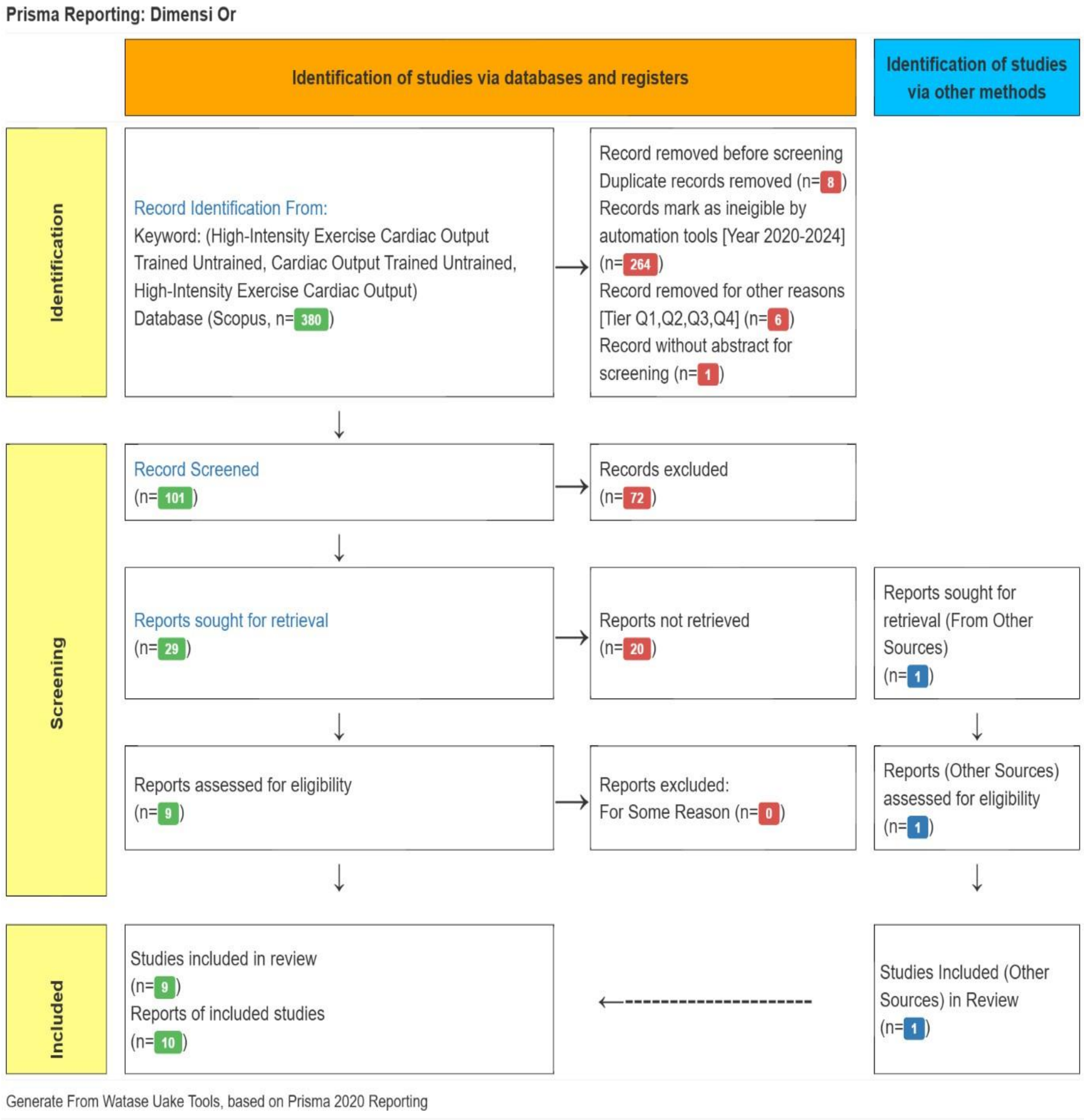

Figure 2. PRISMA Flow Chart

Quality Assessment/Eligibility of Literature

The quality of the studies included in this review was assessed based on criteria adapted from the Consolidated Standards of Reporting Trials (CONSORT) guidelines Moher et al. (2010) as applied in the study by Pozo et al. (2018). The evaluation process was conducted based on six key aspects that reflect the quality and relevance of each study. The first aspect is research relevance, which assesses the extent to which the study aligns with the objectives of this review. Second, methodological quality is examined through an assessment of the research design, procedures, and the accuracy of implementation. Third, journal indexation is considered to determine whether the article was published in a reputable, officially indexed journal. Fourth, sample size is evaluated to ensure that the number of participants is sufficient to support the validity of the findings. Fifth, the statistical methods and data analysis techniques employed are reviewed to assess their appropriateness. Lastly, findings and interpretation are evaluated in terms of the clarity and accuracy of the conclusions drawn from the analyzed data. Each aspect is rated on a scale from 0 to 2 based on predefined criteria. The total score for each study is calculated by summing the positive attributes identified, allowing for a systematic categorization into three quality levels: High Quality (HQ) with a total score of 5-6, Average Quality (AQ) with a score of 3-4, and Low Quality (LQ) with a score below 3. This classification ensures that only studies with adequate credibility are included in the subsequent analysis.

Table 2. Overview of Included Articles

No	Author (Year)	Indeks	Subject Population	Duration HIIT	Primary Parameters Measured	Finding	More Responsive Group
1	Carrick-Ranson et al., 2020.	Q1	Elderly women, trained.	≥ 25 years.	VO_2 max, SV, CO, EF.	Significant increase in VO_2 max & SV in the trained group.	Trained.
2	Jeremic et al., 2020.	Q1	• Kontrol (sedentary). • ET (endurance training). • HIIT (high-intensity interval training).	Duration is not specifically mentioned; focus is on comparing the effects of HIIT vs ET.	• Ejection fraction. • Fractional shortening. • Abdominal aortic blood flow. • Cardiac cross-sectional area. • Mitochondrial and antioxidant markers. • MicroRNA expression.	• HIIT increased ejection fraction and fractional shortening higher than ET and control. • Both types of exercise increased aortic blood flow compared to control. • HIIT increased cardiac cross-sectional area, mitochondrial markers, and antioxidants. • Significant changes were also found in microRNA expression.	HIIT group.
3	Xin et al., 2024.	Q1	Aquatic Group (n = 15), Land Group (n = 15).	8 weeks, 3 times per week, carried out in water and land media.	• Body composition (weight, BMI, body fat). • Cardiac function (SV, EDV, CO, FS, HR, ESV). • Hemodynamics (SBP, DBP, WSS, PSV). • Vascular function (basal diameter, FMD, PWV).	Both groups experienced significant improvements in all parameters after 8 weeks. The aquatic group showed greater improvements.	Aquatic Group.
4	Heber et al., 2023.	Q1	82 men in outpatient cardiac rehabilitation after acute coronary syndrome, mean age: • CET group: 61.7 ± 9.8 years. • HIIT+CET group: 60.0 ± 9.4 years.	12 weeks, 4 sessions/week: • HIIT+CET: 2 HIIT sessions + 2 CET sessions per week. • CET: 4 CET sessions per week. Duration and energy expenditure were equalized between groups.	• Ventilatory equivalents: EqO_2, $EqCO_2$. • Blood lactate (BLa). • Maximal power output (P max) from CPET.	P max increased in both groups, but was greater in HIIT + CET (up to 124.7% of baseline) HIIT + CET resulted in more significant decreases in EqO_2 and $EqCO_2$ as it approached or exceeded 100% of Pmax ($p < 0.0001$).	HIIT+CET group.
5	Tangchaisuriya, et al., 2021.	Q1	50 male master road cyclists, aged 35-49 years, were divided into three groups: • Continuous training (n = 16).	12 weeks, 2 sessions of HIIT/BFRIT per week (on top of regular continuous training) using a	• $\dot{V}O_2$ max, cardiac output, stroke volume. • 40-km time trial performance.	• $\dot{V}O_2$ max, cardiac output, and stroke volume increased in both HIIT and BFRIT groups ($p < 0.05$). • 40-km time trial performance increased	BFRIT group.

No	Author (Year)	Indeks	Subject Population	Duration HIIT	Primary Parameters Measured	Finding	More Responsive Group
			• Continuous + HIIT (n = 17). • Continuous + HIIT with Blood Flow Restriction (BFRIT; n = 17).	bicycle ergometer.	• Peak power output, isokinetic knee extensor torque. • Vascular function: flow-mediated dilation (FMD), carotid intima-media thickness, arterial stiffness. • Muscle mass and structure: total lean mass, rectus femoris & vastus lateralis size. • Tissue saturation index.	in all groups ($p < 0.05$). • Peak power output increased in both HIIT and BFRIT groups. • FMD increased in all groups. • Lean mass, muscle size, and peak torque increased only in BFRIT. • Tissue saturation index decreased only in BFRIT. • Improvement in 40-km performance correlated with changes in $\dot{V}O_2$ max ($r = -0.312$, $p = 0.029$) and peak torque ($r = -0.432$, $p = 0.002$).	
6	Langeard et al., 2021.	Q1	Prehypertension in adults aged ≥ 60 years (n = 60), divided into two groups: HIIT (n = 30) Hydrochlorothiazide (HCTZ) 12.5 mg/day (n = 30).	12 weeks, performed 3 times per week.	• Primary outcome: 24-hour ambulatory blood pressure. • Secondary outcomes: Cognitive function, Balance and gait performance, $\dot{V}O_2$ max, Peripheral endothelial function, Arterial stiffness.	The goal is to compare the efficacy of HIIT versus HCTZ in lowering blood pressure and see the potential additional benefits of HIIT on cognitive and cardiovascular function.	HIIT
7	Ksoll et al., 2021.	Q1	24 healthy adult participants, randomly assigned to two HIIT protocols.	Two interval training protocols with the same total duration and work intensity: • HIIT3m: 3 min work / 3 min active rest • HIIT30s: 30 s work /30 s active rest.	• VO_2 (oxygen consumption). • Cardiac output. • Local muscle oxygenation (NIRS). • Duration above gas exchange threshold (GET). • Fractional VO_2 peak utilization.	HIIT30s resulted in longer duration above gas exchange threshold ($p = 0.034$) Mean VO_2 peak utilization was similar between protocols (not significant). HIIT3m produced higher cardiovascular responses during the work phase (VO_2 & CO, $p < 0.001$) Local hemodynamics were not significantly different Mean physiological adaptations were similar, as HIIT30s Rest was insufficient for full recovery Large response amplitudes in HIIT3m.	• HIIT3m is more acutely burdensome for the cardiovascular system, suitable for the purpose of increasing cardiorespiratory capacity. • HIIT30s can induce microvascular & metabolic adaptations with a lighter acute load, suitable for sensitive populations.
8	Spee et al., 2020	Q1	24 patients with chronic heart failure (CHF), NYHA class II/III, underwent Cardiac Resynchronization Therapy (CRT).	36 sessions of HIIT after 3 months of CRT, intensity 85-95% VO_2peak.	• VO_2 peak • Peak workload. • Cardiac output. • VO_2 recovery kinetics. • Left ventricular ejection fraction (LVEF).	• VO_2 peak increased significantly after CRT, not significantly after added HIIT. • Peak workload increased significantly after CRT, and increased further after HIIT ($p = 0.03$).	Patients undergoing CRT + HIIT showed greater increases in workload than those receiving usual care (UC), although VO_2 peak did not increase further.

No	Author (Year)	Indeks	Subject Population	Duration HIIT	Primary Parameters Measured	Finding	More Responsive Group
					• Quality of life (QoL).	• Cardiac output did not change significantly after either CRT or HIIT. • VO_2 recovery kinetics improved after CRT, not improved after HIIT. • LVEF increased by 25% after CRT, not improved after HIIT. • Exercise capacity improvements from HIIT were due to improvements in anaerobic, not aerobic, performance.	
9	Nyberg et al., 2017.	Q1	• 20 premenopausal women (age ± 50 years). • 16 early postmenopausal women (mean 3.1 ± 0.5 years after menopause, age ± 54 years). • Both groups were well balanced in age and similar baseline fitness.	12 weeks of aerobic high-intensity exercise training.	• Leg blood flow. • O_2 delivery and uptake. • Lactate release. • Blood pressure and heart rate. • Quadriceps muscle protein content: Mitochondrial complex II-V, eNOS, COX-1 and COX-2, ERRα.	• Pre-exercise, hemodynamic responses to exercise were similar between groups. • Post-exercise, postmenopausal women showed significant decreases in: • Leg blood flow, O_2 delivery, O_2 utilization, lactate release. • Blood pressure and heart rate during exercise were similar. • Increases in mitochondrial and vascular protein content were more extensive in women postmenopausal versus premenopausal. • Acute vascular responses to exercise persist in early menopause.	Early postmenopausal women demonstrate stronger mitochondrial and vascular adaptations to high-intensity exercise than premenopausal women.
10	Luo et al., 2024.	Q1	24 trained rowers.	6 HIIT sessions (1 session per week).	VO_2 max, Lactate threshold, Cardiac hemodynamics, Locomotor ability, 2000 m time-trial performance.	Both protocols (HIIT APR and HIIT WVO_2 max) improved: VO_2 max, Lactate threshold, Cardiac hemodynamics, 2000 m performance. There were no significant differences between groups in mean changes in performance or physiology. HIIT APR produced more homogeneous physiological adaptations (lower interindividual variability) However, variability in athletic performance remained high in both groups (due to multifactorial factors).	HIIT APR was superior in producing uniform physiological adaptations, especially in maximal variables such as VO_2 max.

Table 3. Quality Assesment

No	Authors	Relevance	Quality Methodology	Index	Sample Size	Data Analysis	Findings and Interpretations	Total Score (0-6)	Quality Assesment
1	Carrick-Ranson et al., 2020.	YES	YES	YES	YES	YES	YES	6	HQ
2	Jeremic et al., 2020.	YES	YES	YES	YES	YES	YES	6	HQ
3	Xin et al., 2024.	YES	YES	YES	YES	YES	YES	6	HQ
4	Heber et al., 2023.	YES	YES	YES	YES	YES	YES	6	HQ
5	Tangchaisuriya, et al., 2021.	YES	YES	YES	YES	YES	YES	6	HQ
6	Langeard et al., 2021.	YES	YES	YES	YES	YES	YES	6	HQ
7	Ksoll et al., 2021.	YES	YES	YES	YES	YES	YES	6	HQ
8	Spee et al., 2020.	YES	YES	YES	YES	YES	YES	6	HQ
9	Nyberg et al., 2017	YES	YES	YES	YES	YES	YES	6	HQ
10	Luo et al., 2024.	YES	YES	YES	YES	YES	YES	6	HQ

Parameters

(i) Is this article relevant to the research topic?
(ii) Are the research methods used valid and reliable (research design, data collection, data analysis)?
(iii) Is the publishing journal indexed in an international journal database?
(iv) Is the sample size large enough to provide significant results?
(v) Are the analysis results presented clearly and transparently?
(vi) Are the interpretations of findings supported by sufficient data?

Rating Scale

(i) NO, incomplete or inaccurate.
(ii) YES, with detailed definition.

Synthesis and Qualitative Analysis

Descriptive analysis is conducted qualitatively to provide an overview of dominant topics related to the research . This approach focuses on interpreting the collected data, using thematic analysis methods to identify key patterns, themes, and relationships relevant to the study by (Kim et al., 2017).

RESULTS AND DISCUSSION

Results

This study adopts a Systematic Literature Review (SLR) methodology to assess scientific research on the effects of High-Intensity Interval Training (HIIT) on cardiac output and cardiovascular function. The literature search strategy was designed in accordance with the guidelines proposed by (Kitchenham et al., 2010). The identification process utilized the Scopus database, employing a search string that included keywords such as High-Intensity Exercise, Cardiac Output, Trained, Untrained, and other relevant terms. The initial search retrieved 380 articles, which were subsequently screened using the PRISMA framework.

The selection process was guided by predefined inclusion and exclusion criteria, considering only peer-reviewed articles published in Q1-Q3 indexed journals between 2014 and 2024. Following a rigorous screening of 101 eligible articles, 10 primary studies were selected for in-depth analysis. Data extraction was performed using a standardized form covering key aspects such as research objectives, methodologies, findings, and participant characteristics.

The selected studies originate from various countries, including Austria, Germany, China, the Netherlands, and the United States, and encompass research on both trained and untrained individuals. This study aims to evaluate the effects of HIIT on cardiac parameters such as stroke volume (SV), cardiac output (CO), and cardiovascular function adaptations. Furthermore, it investigates the potential cardiovascular risks associated with HIIT compared to rest conditions or low-intensity training.

Population

The population analyzed in this study is highly diverse. The trained group consists of athletes, road cyclists, and rowers. Meanwhile, the untrained group includes cardiac rehabilitation patients, middle-aged men, and heart failure patients. The sample sizes in the reviewed studies range from 15 to 82 participants, with an age range of 35 to 69 years.

Citation Count and Study Quality

The analyzed studies demonstrate high quality, as evidenced by their indexing in Q1-Q2 journals. This quality is further reflected in the citation count, which ranges from 0 to 12, indicating significant relevance in recent scientific research.

In general, HIIT has been proven effective in increasing cardiac output (CO) in both trained and untrained individuals, although a more significant improvement was observed in the trained group. A study by Heber et al., (2023) reported that HIIT could enhance Pmax by up to 124.7%, surpassing the improvement achieved through moderate-intensity continuous training (CET), which only reached 117.5%. Another study by Tangchaisuriya et al., (2021) found that HIIT contributes to an increase in maximal cardiac output and VO_2 max in cycling athletes.

More substantial cardiovascular adaptations were observed in trained individuals, including increased stroke volume, cardiac output, and efficiency in gas exchange. Meanwhile, although untrained individuals exhibited a lower level of adaptation compared to trained individuals, HIIT remained effective in improving cardiovascular function.

Furthermore, the findings indicate that HIIT does not increase the risk of cardiovascular dysfunction in either healthy individuals or patients with specific conditions such as chronic heart failure or hypertrophic cardiomyopathy (HCM). Some studies even suggest a protective effect of HIIT, demonstrated by an increase in the heart's ejection fraction.

Summary of Findings Based on Research Questions

Table 4. Findings Based on Research Question

Research Question	Summary of Findings
RQ1: How does high-intensity training affect cardiac output compared to no training or moderate-intensity training in trained and untrained individuals?	HIIT significantly improves cardiac output (CO) in both groups. Trained individuals show greater increases compared to untrained ones. In some studies (e.g., Heber et al., 2023), HIIT outperformed CET, with a Pmax increase of 124.7% (vs. 117.5% for CET).
RQ2: What are the differences in cardiac function adaptations following high-intensity training between trained and untrained individuals?	Trained individuals exhibited more substantial improvements in stroke volume (SV), CO, and gas exchange efficiency. However, untrained individuals still demonstrated positive cardiovascular adaptation, especially in patients with heart failure and older adults.
RQ3: Does high-intensity training increase the risk of cardiovascular dysfunction in trained individuals compared to untrained individuals?	No study reported increased cardiovascular risk in either group. HIIT was safe across all populations, including those with chronic heart failure and hypertrophic cardiomyopathy. In some cases, HIIT even had protective effects (e.g., ↑ ejection fraction).

Conclusions from the SLR, HIIT is effective in enhancing cardiac output and cardiovascular adaptations across both trained and untrained populations. The magnitude of benefits is greater in trained individuals, likely due to pre-existing conditioning and adaptive capacity. Importantly, HIIT is safe even for clinical populations when applied appropriately, with no evidence of increased cardiovascular risk.

Comparison Between Trained and Untrained Individuals

Table 5. Trained vs. Untrained Individuals in HIIT Studies

Parameter	Trained Individuals	Untrained Individuals
Typical Populations.	Athletes, rowers, cyclists.	CHF patients, middle-aged men, cardiac rehab.
Age Range.	20-45 years.	35-69 years.
Sample Size Range.	15-82	15-82
Cardiac Output (CO).	Significant increase (especially during exercise).	Moderate increase.
Stroke Volume (SV).	Marked improvement.	Mild to moderate improvement.
VO_2 max.	Substantial increase.	Moderate increase.
Pmax (Heber et al., 2023).	124.7% (HIIT) vs. 117.5% (CET)	Not reported.
Gas Exchange Efficiency.	Improved.	Slight improvement.
Risk of Dysfunction.	No increase; some studies show protective effect.	No increase; HIIT shown to be safe.

The results of this study reveal that trained individuals exhibit greater cardiovascular adaptations compared to untrained individuals. This is reflected in the more significant increases in stroke volume and cardiac output during HIIT sessions. Nevertheless, untrained individuals still benefit from HIIT, although the level of adaptation achieved is relatively lower than that of trained individuals.

Overall, this study confirms that HIIT has a significant positive impact on cardiac output and cardiovascular adaptation. This effect is more pronounced in trained individuals; however, untrained individuals also gain substantial benefits from this training program. Moreover, HIIT has been proven to be safely applicable across various populations, including individuals with specific cardiovascular conditions, without increasing the risk of cardiac dysfunction.

Discussion

RQ1: How does high-intensity training affect cardiac output compared to no training or moderate-intensity training in trained and untrained individuals?

The impact of high-intensity exercise on cardiac output compared to the absence of exercise or moderate-intensity training has been the primary focus of several studies reviewed in this research. Overall, high-intensity exercise has a significant effect on increasing cardiac output through various physiological adaptations, such as enhanced stroke volume and improved cardiac efficiency, in both trained and untrained individuals.

In untrained individuals, high-intensity exercise has been shown to be more effective in stimulating cardiovascular adaptation compared to moderate-intensity training or no exercise at all. A study conducted by Heber et al. (2023) reported that after undergoing a 12-week HIIT program, participants exhibited a significant improvement in gas exchange efficiency during exercise. This was reflected in the reduction of ventilatory equivalents for oxygen (eQO_2) and carbon dioxide ($eQCO_2$), which directly contributed to an increase in cardiac output. Furthermore, research by Xin et al. (2024) found that untrained individuals who participated in an eight-week HIIT program experienced increases in stroke volume and cardiac output. This improvement occurred as a result of enhanced cardiac efficiency in pumping blood, driven by physiological adaptations to the demands of high-intensity exercise.

Meanwhile, in trained individuals, high-intensity exercise also provides substantial benefits in enhancing cardiac output. A study by Tangchaisuriya et al. (2021) demonstrated that HIIT significantly increased cardiac output and VO_2 max in trained cyclists. This adaptation occurred in response to the heightened oxygen and energy demands during high-intensity training, ultimately prompting the left ventricle to function more efficiently in pumping blood throughout the body. Another study by Ksoll et al. (2021) found that the duration of training intervals influenced cardiac output responses. Longer intervals in HIIT tended to yield greater increases in cardiac output compared to shorter intervals due to the higher physiological demands placed on the heart over extended exercise periods.

When compared to individuals who do not engage in exercise, those who follow a HIIT program exhibit significantly greater increases in cardiac output. This is attributed to better cardiac adaptation capacity, including an increased volume of blood pumped per heartbeat (stroke volume) and improved left ventricular efficiency. Conversely, in individuals who do not exercise, cardiac output tends to remain stagnant or decline due to a lack of stimuli for cardiovascular capacity enhancement.

Moreover, when compared to moderate-intensity training, high-intensity exercise has been proven to be more effective in increasing cardiac output. A study conducted by Luo et al. (2024) indicated that HIIT resulted in more significant improvements than moderate-intensity training. However, in certain conditions, such as hypertrophic cardiomyopathy, the adaptive response may be limited. These findings suggest that high-intensity exercise provides a greater physiological stimulus for cardiac adaptation, although the extent of the response remains dependent on baseline fitness levels and individual health conditions.

In conclusion, high-intensity exercise has a significant impact on increasing cardiac output in both trained and untrained individuals. This adaptation is primarily driven by improvements in stroke volume, left ventricular efficiency, and VO_2 max. Compared to moderate-intensity training or a lack of exercise, high-intensity training provides a stronger stimulus for cardiac adaptation, leading to more optimal cardiovascular function improvements. However, it is essential to consider an individual's initial health condition to ensure that high-intensity exercise can be implemented safely and effectively.

RQ2: What are the differences in cardiac function adaptations following high-intensity training between trained and untrained individuals?

The difference in cardiac function adaptation following high-intensity training between trained and untrained individuals reflects variations in physiological responses arising from differences in baseline fitness levels and the heart's adaptive capacity.

For individuals without a history of training, high-intensity exercise induces more significant adaptations, as their hearts are not accustomed to handling high workloads. A study conducted by Heber et al. (2023) revealed that untrained individuals who participated in a 12-week HIIT program experienced an improvement in gas exchange efficiency, as indicated by a reduction in the ventilatory equivalent for oxygen (eQO_2) and carbon dioxide ($eQCO_2$). This adaptation occurs due to the increased workload on the heart during high-intensity training, which drives an increase in stroke volume and overall cardiovascular efficiency. During the initial phase of a training program, untrained individuals typically exhibit a more rapid increase in stroke volume and cardiac output, as fundamental adaptations are required to meet the physiological demands of physical activity.

Another study by Xin et al. (2024) supports these findings, demonstrating that previously untrained middle-aged men experienced significant increases in cardiac output, left ventricular end-diastolic volume (EDV), and hemodynamic function after undergoing an eight-week HIIT regimen. These increases serve as compensatory mechanisms that enable the heart to meet oxygen demands during exercise, ultimately enhancing its pumping efficiency.

Conversely, in individuals with a higher level of fitness, cardiac function adaptations following high-intensity training tend to be more specific and occur at a more advanced level. A study by Tangchaisuriya et al. (2021) indicated that trained individuals, such as cyclists undergoing HIIT, exhibited greater improvements in cardiac output and maximal oxygen uptake (VO_2 max) compared to untrained individuals. These enhancements are not only due to increased stroke volume but also result from optimized left ventricular efficiency. Because trained individuals' hearts have already adapted to high workloads, their adaptive responses tend to be more gradual and focused on improving cardiac efficiency during exercise.

Additionally, a study by Ksoll et al., (2021) demonstrated that in trained individuals, long-interval training (with three-minute durations) in HIIT programs elicited a higher cardiac output response compared to short-interval training (30 seconds). This finding suggests that trained individuals have a greater capacity to sustain prolonged high-intensity exercise. Such differences indicate that cardiac function adaptations in trained individuals tend to be more stable, allowing them to maintain stroke volume and cardiac output for extended periods during high-intensity exercise.

Overall, the differences in cardiac function adaptation between trained and untrained individuals lie in the magnitude of response and the adaptation mechanisms involved. In untrained individuals, adaptations tend to occur more rapidly and fundamentally, such as increases in stroke volume and cardiac output, as their hearts are not yet accustomed to high workloads. In contrast, trained individuals experience more specific and efficient adaptations, with improvements focusing on optimizing cardiac function, increasing VO_2 max, and sustaining cardiac efficiency during high-intensity training. This suggests that while high-intensity training benefits both groups, trained individuals tend to experience more measured improvements and more stable adaptations compared to untrained individuals.

RQ3: Does high-intensity training increase the risk of cardiovascular dysfunction in trained individuals compared to untrained individuals?

A review of the articles in this study found no conclusive evidence that high-intensity training directly increases the risk of cardiovascular dysfunction in either trained or untrained individuals, provided that the exercise is carefully monitored and takes into account each individual's physical condition. However, physiological responses to high-intensity training differ significantly between these two groups.

In trained individuals, the cardiovascular system has undergone more optimal adaptations as a result of long-term routine training. A study by Carrick-Ranson et al. (2020) demonstrated that individuals who had engaged in training for several years experienced significant increases in cardiac output, stroke volume, and maximal oxygen uptake (VO_2 max). These findings suggest that the hearts of trained individuals function more efficiently, both at rest and during intense physical activity. This stability in physiological responses helps reduce the risk of cardiovascular dysfunction, although high-intensity training still increases cardiac workload.

Another study by Ksoll et al. (2021) compared the effects of interval duration in high-intensity training among trained individuals. The results indicated that this group had a greater capacity to tolerate increased physiological demands during exercise, such as elevated cardiac output and stroke volume. These adaptations occur due to structural and functional changes in the heart, including increased left ventricular mass and myocardial elasticity. Consequently, the risk of cardiac dysfunction due to high-intensity training is relatively lower in trained individuals.

Conversely, for individuals unaccustomed to high-intensity physical activity, such training may place greater strain on the cardiovascular system. A study by Heber et al. (2023) reported that untrained individuals exhibited significant increases in cardiac output and gas exchange efficiency after participating in a HIIT program. However, this adaptation process requires time, and untrained individuals are more susceptible to acute blood pressure spikes or cardiovascular fatigue if training is not introduced progressively. In this regard, Langeard et al. (2021) emphasized that individuals with a history of hypertension or mild cardiac dysfunction should undergo high-intensity training under strict supervision to minimize potential risks.

Nevertheless, research by Jeremic et al. (2020) provides an interesting perspective on the cardioprotective effects of high-intensity training. This study revealed that HIIT plays a role in regulating the expression of specific microRNAs that enhance mitochondrial function and reduce oxidative stress in cardiac tissue. These effects were observed in both trained and untrained individuals, indicating that high-intensity training may contribute to protection against cardiovascular dysfunction when performed using appropriate methods.

However, despite the numerous benefits of high-intensity training, potential risks still exist, particularly for individuals with undiagnosed health conditions such as coronary artery disease or cardiac hypertrophy. Spee et al. (2020) stated that patients with chronic heart failure undergoing cardiac resynchronization therapy (CRT) could safely participate in high-intensity training. However, initial evaluation and close monitoring during exercise are critical factors in preventing the risk of cardiovascular dysfunction.

Thus, it can be concluded that high-intensity training does not directly increase the risk of cardiovascular dysfunction in either trained or untrained individuals, provided that training is conducted with the appropriate approach. Trained individuals possess a greater adaptive capacity, thereby reducing their risk of cardiovascular complications. Meanwhile, untrained individuals can still benefit from such training but should adopt a gradual approach and receive adequate supervision to ensure the heart can adapt to increased workload demands.

Furthermore, the cardioprotective mechanisms through microRNA regulation and oxidative stress reduction further support the finding that high-intensity training can offer protective benefits for cardiac function when implemented following proper procedures.

The difference between trained and untrained individuals in cardiovascular responses to high-intensity exercise occurs because of physiological adaptations that develop with regular training. Based on your document, here are the main reasons:

1. Stroke Volume and Cardiac Output.
   Trained individuals have larger and stronger hearts, especially the left ventricle. This allows them to pump more blood per beat (higher stroke volume), so their cardiac output rises more efficiently during exercise. Untrained individuals rely more on increasing heart rate to meet oxygen demands, leading to quicker fatigue and less efficient blood circulation.
2. VO_2 max and Oxygen Utilization.
   Trained individuals have higher VO_2 max, meaning they can take in, transport, and use oxygen more effectively. Their muscles have more mitochondria and capillaries, enhancing endurance. Untrained individuals show improvements with training, but their VO_2 max is generally lower, limiting their exercise capacity.
3. Gas Exchange Efficiency.
   Trained individuals exhibit better ventilatory efficiency (lower eQO_2 and $eQCO_2$), meaning their lungs and cardiovascular system exchange gases more effectively. Untrained individuals improve after HIIT, but the changes are smaller.
4. Adaptation Speed vs. Stability.
   Untrained individuals often show rapid early improvements (e.g., stroke volume, gas exchange) because their cardiovascular system is adapting from a low baseline. Trained individuals adapt more slowly but achieve more stable and specific changes, such as sustained cardiac output and optimized left ventricular function.
5. Risk and Safety.
   In trained individuals, the cardiovascular system is already adapted, so HIIT rarely increases health risks. In untrained individuals, HIIT must be introduced progressively, since sudden high loads can cause acute stress (e.g., blood pressure spikes) before adaptation occurs.

The differences occur because trained individuals have long-term structural and functional cardiovascular adaptations (larger stroke volume, stronger cardiac muscle, higher VO_2 max, better oxygen utilization), while untrained individuals start from a lower baseline, showing faster but less stable improvements. Both groups benefit from HIIT, but the magnitude and efficiency of adaptations are greater in trained individuals.

CONCLUSION

High-Intensity Interval Training (HIIT) significantly enhances cardiac output through various physiological adaptation mechanisms, including increased stroke volume, improved cardiac efficiency, and enhanced maximal oxygen uptake (VO_2 max) in both trained and untrained individuals. In untrained individuals, cardiovascular adaptation tends to occur more rapidly, whereas in trained individuals, improvements are more specific and stable. HIIT has been proven to be more effective than moderate-intensity exercise or physical inactivity in enhancing cardiovascular function. The risk of cardiovascular dysfunction remains low as long as the training is conducted progressively and under adequate supervision. Furthermore, HIIT provides protective benefits for heart health through the regulation of microRNA expression and the reduction of oxidative stress. Future research is recommended to explore additional factors such as age, sex, health status, and genetic predisposition that may influence individual responses to HIIT. Finally, the researchers stated that the findings should be interpreted with caution due to methodological limitations.

For practice, trainers and health professionals should apply HIIT gradually, tailoring intensity to fitness, age, and health status. Safety requires screening, warm-up, and cool-down, while special populations may benefit from lower-impact options with longer recovery. Educating clients on HIIT's heart health benefits can improve adherence, and practitioners should adapt methods as new evidence emerges.

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