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Review Article

Effectiveness of Interval Training in Increasing Cardiorespiratory Endurance: A Systematic Review

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Abstract

Background. The rise in cardiovascular diseases has necessitated implementing effective interventions to improve cardiorespiratory endurance.

Objectives. This systematic review aimed to evaluate the effectiveness of interval training (IT), particulary high-intensity interval training (HIIT), in enhancing cardiorespiratory endurance across various demographics. IT, characterized by high-intensity exercise followed by recovery periods, has gained attention for its potential to improve key cardiovascular markers such as VO_2max and cardiovascular efficiency.

Materials and methods. A comprehensive literature search was conducted using multiple databases, adhering to the PRISMA guidelines. From 893 initially screened articles, eight studies met the inclusion criteria. These studies examined the effects of IT, especially HIIT, on cardiorespiratory endurance across various population groups, including sedentary individuals, athletes, and older adults. Metrics such as VO_2max and cardiovascular efficiency were the primary outcomes measured.

Results. The findings indicate that IT, especially HIIT, consistently improves VO_2max and overall cardiovascular fitness in diverse populations. HIIT has been observed to outperform moderate-intensity continuous training (MICT) in generating faster cardiovascular adaptations. Despite its benefits, the high intensity of IT requires careful individualization to mitigate the risk of injury, particularly in populations with lower baseline fitness levels.

Conclusions. This review concludes that IT is an effective and time-efficient method for improving cardiorespiratory endurance. It should be considered a viable option in both clinical and athletic populations. However, further research is recommended to investigate the long-term safety of HIIT in high-risk populations and to enhance adherence to these exercise protocols.

Keywords: interval training, cardiorespiratory endurance, high-intensity interval training, systematic review, VO_2max, cardiovascular health.

Introduction

The rise in the prevalence of cardiovascular disease has become a significant global concern in the modern era, affecting millions of individuals and placing a considerable burden on health systems (Manne-Goehler et al., 2022; Sun et al., 2023; Zhang et al., 2023). Cardiorespiratory health has become a significant focus on preventing and managing chronic diseases (Temporelli, 2018). One effective way to overcome this problem is by increasing cardiorespiratory endurance, a key indicator of heart and lung health (Benck et al., 2017; Tesema et al., 2019).

Interval training, an exercise where high-intensity intervals are interspersed with recuperation times, has emerged as an effective and efficient method for increasing cardiorespiratory capacity (Heber et al., 2023; Ma et al., 2023; Wang & Zhao, 2023). Although various studies have explored the benefits of interval training, the results often need to be more consistent (Marillier et al., 2022; Tamayo Acosta et al.,

2022). As a result, a systematic review is required to compile the available data and present a thorough picture of how well interval training works to increase cardiorespiratory endurance (Men et al., 2023; Yue et al., 2022). This research is crucial because, despite the abundance of empirical evidence demonstrating the advantages of interval training in enhancing physical fitness, there is still a requirement for a more profound comprehension of the biological mechanisms that underlie this procedure and how it can be customized to suit various professional athlete populations. The objective is to evaluate and synthesize the findings from existing studies and identify the practical implications and potential benefits of interval training in the context of cardiorespiratory health (Wang & Zhao, 2023). Using a rigorous systematic review methodology, we hope to significantly contribute to the existing literature and assist healthcare practitioners in designing exercise programs and offering more effective prevention strategies against cardiovascular disease (da Silva et al., 2022; Khalafi et al., 2023; Palozzi & Antonucci, 2022).

The state of the art in this research shows that most previous research has focused on the general effects of interval training on VO_2max and physical performance. However, this study offers a more holistic approach by comprehensively exploring cardiovascular adaptations, energy metabolism, and muscle recovery responses (Sánchez-Otero et al., 2022). In addition, this study's novelty lies in using the latest monitoring technologies, such as real-time respiratory gas analysis and high-variability heart rate monitoring, to obtain more accurate and in-depth data. This study differs from others in that it focuses on particular adaptations in various demographic groupings. This study looked at the general effects of interval training and how the body's response differs between healthy individuals, patients with certain health conditions, and professional athletes. Thus, this research provides more prosperous and practical insight into how interval training can be optimized according to individual needs (Metcalfe et al., 2020). This study's findings are intended to significantly advance fitness science and practice and offer effective prevention strategies against cardiovascular disease. The urgency of this problem cannot be ignored, considering the high mortality and morbidity rates caused by cardiovascular disease (Amini et al., 2021; Temporelli, 2018). Increasing cardiorespiratory endurance through efficient and measurable training methods such as interval learning can be a much-needed solution to reduce the burden of this disease in society (Blackwell et al., 2018; Reuter et al., 2023).

This study was designed to comprehensively evaluate the biological mechanisms that underlie the adaptation of the cardiorespiratory system's endurance in various demographics through interval learning. If the anticipated results are realized, this research may provide more effective and safe guidance in designing exercise programs.

Materials and Methods

Study Design

This study conducted a thorough analysis using article databases like Science Direct and PubMed.

Eligibility criteria. Articles describing interval learning and cardiorespiratory conditions published during the last five years met the inclusion criteria for this study. Articles published in shady journals were excluded from our analysis.

Procedure. Article titles, abstracts, and complete texts were vetted, validated, and entered into Mendeley software. Eight hundred ninety-three publications from the Science Direct and Pubmed databases were found in the first phase. The suitability of the title and abstract was the basis for screening 98 articles in the second round. Thirty-four products were ordered for additional processing in the third stage. At this point, we screen articles based on their general suitability. Eight publications that satisfied the inclusion criteria were then chosen for analysis in the final step to support this systematic observation. Implementing the Prefered Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, this study assesses traditional methods.

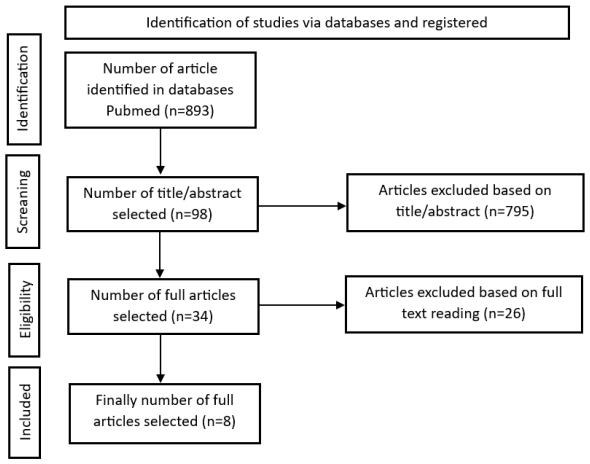

Fig. 1. PRISMA flowchart of the article selection process

Results

Based on the data from the eight tables above, each has similarities and differences. The similarities lie in the research design, where all studies presented used experimental designs. This indicates that the study aimed to determine how different interventions would affect the intended results, cardiorespiratory fitness, or CRF. The eight tables likewise center on interval training (HIT, HIIT, and REHIT). All of the research investigates how various interval training modalities, such as High-Intensity Interval Training (HIT), Reduced-Exertion High-Intensity Interval Training (REHIT), or other variations, affect the development of cardiorespiratory fitness. All studies measured outcomes in the form of improvements in cardiorespiratory fitness; each study had a different duration of intervention, but all applied interval training in several sessions or weeks to measure the effects on cardiorespiratory fitness.

The differences lie in sample characteristics, interventions, outcomes, and study populations. Some studies involved physically inactive participants, while others involved more active participants. Although all used a form of interval training, there was variation in its implementation, such as intensity, session duration, number of sessions, and supervision of the exercise. There were also differences in

Table 1. Result of a review of the effects of interval learning in increasing cardiorespiratory endurance

Author	Sample Characteristics	Study Design	Intervention	Result
Jung et al., 2020	Eligible participants were between the ages of 30 and 65, were low-active (i.e., engaged in 2 or fewer bouts of moderate and/or vigorous aerobic exercise per week in the previous six months), had a body mass index (B.M.I.) be-tween 25 and 40 kg/m2, and were cleared to engage in vigorous exercise using the Physical Activity Readiness Questionnaire-Plus (PAR-Q+).	Experimental	Participants in both conditions completed 10 exercise sessions over a two week period, seven of which were one on one supervised sessions conducted in the laboratory (exercise training plus counselling), while three were conducted at home to foster independence.	The results of this research show that these findings suggest a brief behavior change counseling intervention, coupled with either HIIT or MICT, promotes improvements in CRF, exercise, and body composition over 12 months in free-living conditions.
Scoubeau et al., 2023	To be included, subjects had to be aged between 18 and 50 years, and to be below the World Health Organization's recommendations regarding physical activity participation.	Experimental	During the first session, participants under-went body composition assessment and a maximal cardiopulmo nary exercise test to assess cardiorespiratory fitness. Neuromuscular assessment was performed during two separate sessions to avoid fatigue accumulation. Firstly, knee extensors' maximal isometric torque, voluntary activation, and endurance time during a submaximal isometric contraction were assessed. Then, during the last session, lower limb dynamic strength was evaluated by measuring the 3-repetition maximum (3-RM) on a leg press.	Changes in voluntary activation and MVC torque were correlated, suggesting that strength improvement after WB-HIIT was mainly related to an increased volitional drive.
Astorino et al., 2020	Eighty five healthy adults participated in the present study. They were free of lower extremity injuries and had not previously participated in REHIT.	Experimental	Participants completed two visits to the laboratory, which consisted of incremental exercise to assess VO_2max, followed by completion of a REHIT session at least 48 hours later. Participants were instructed to eat a small meal two h before each session and be well-rested and hydrated. They refrained from physical activity for 36 hours before each session.	The results of this research show that despite significant differences in VO_2max between groups, there was no aggregate difference in changes in affective valence, RPE, and enjoyment in response to a session of REHIT, although affective valence was typically lower in persons with below-average fitness.
Abouzeid et al., 2023	Forty-four male athletes were recruited voluntarily from the King Faisal University campus in Al-Ahsa, Saudi Arabia.	Experimental	The experimental group was asked to ride on the mechanically braked cycle ergometers for 10 min at a pace of their own choosing. In the first practice session, the control group was also asked to ride the cycle ergometers for a 10 min period at a pace of their own choosing. In the second practice session, both groups were asked to complete five rounds of 30 s of cycling at peak PO, interspaced by 90 s of active recovery between intervals. ETMs were worn by the experimental group in these practice sessions, while the control group did not wear ETMs.	There were significant differences between the pulmonary function, hematological data, and biomarkers of cardiorespiratory fitness of the experimental group and the control group after the 8-week cycle ergometer HIIT program, in favor of the experimental group.

Table 1 (continued)

Author	Sample Characteristics	Study Design	Intervention	Result
Astorino et al., 2019	Three men and eleven women (age and VO_2max = 27 ± 8 years and 38 ± 4 mL/kg/min, respectively) who perform >150 min/week of exercise in the last 12 months, including resistance training, aerobic exercise, noncompetitive sport, and group exercise, participated in this study.	Experimental	Sessions were held three days/week for three weeks and were performed on the same cycle ergometer. Subjects performed eight 1 min intervals on days 1–3 of training, nine on days 4–6, and ten on days 7–9. Sessions were preceded by a 5 min warm-up at 10% PPO, and intervals were separated by a 75 s active recovery at 10% PPO.	The results of this research show that training HR was associated with the VO_2max response to HIIT, yet dietary intake, sleep duration, and BLa accumulation were not predictive of this response. Overall, these preliminary data suggest that the absolute cardiovascular strain may be a mediator of the adaptive response to interval training.
Cuddy et al., 2019	A cohort (n = 32) of men (n = 16) and women (n = 16) were recruited from the faculty/employee population of a local university and hospital via advertisement through the university website, local community newspaper, and through word-of-mouth.	Experimental	Participants subsequently performed two REHIT testing sessions (i.e., the intense ride) on separate days. At the first testing session, after being connected to the Oxycon Mobile system and Polar F1 heart rate monitor, participants rested quietly for 5 min in a seated position. The last minute of breath-by-breath and heart rate (HR) data were averaged and considered to be the resting metabolic rate (VO_2) and resting HR	The main finding of the present study is that 8 wks of REHIT was safe and elicited more potent, time-efficient improvements in CRF and cardiometabolic health when compared to traditional MICT.
Hurst et al., 2019	Thirty-six adults (50–81 years; 21 male) were assigned via minimisation to either HIT (n = 18) or a no-exercise control group (CON, n = 18) following baseline assessment of leg extensor muscle power, handgrip strength, cardiorespiratory fitness (predicted VO_2max) and health-related quality of life (HRQoL).	Experimental	HIT intervention Participants allocated to HIT completed two instructor-led, combined upper- and lower-body HIT sessions per week for 12-weeks (April–August 2016), performed in groups of two to five participants with 72 h recovery between sessions.	This study reports that demonstrated that 12-weeks of combined upper- and lower-body HIT is an effective method for inducing clinically meaningful improvements in aspects of muscular and cardiorespiratory fitness in adults aged over 50 years.
Simonsson et al., 2023	Participants were recruited through a local newspaper advertisement. Eligible participants were nonexercising adults aged 65 years or older with the ability to undertake a twice-weekly training program for 3 months.	Experimental	For each wave of participants, the study procedure started with baseline assessments, followed by randomization, a 3-month-long exercise intervention (supramaximal HIT or MIT), and subsequent follow-up assessments (3-month follow-up). Detailed	The present study shows that supramaximal HIT with controlled target intensity is a viable exercise program to improve cardiorespiratory fitness and cardiovascular function to a similar extent as MIT, in nonexercising older adults.

the intervention's delivery method, such as using a REHIT or isometric cycle ergometer. Some studies showed significant improvements in cardiorespiratory fitness, while others found no improvement.

Each table study examined how interval training affected cardiorespiratory fitness; however, differences were observed in the sample characteristics, intervention design, and assessed outcomes. Although they share similarities in methodological approach and focus on cardiorespiratory fitness, significant differences in study design and sample populations reflect these studies' diverse approaches and outcomes.

Discussion

Interpretation of Results

The systematic review results indicate that interval training (IT) consistently improves cardiorespiratory endurance across various populations, including sedentary

adults, athletes, and older adults. The research emphasizes that when it comes to improving VO_2max and other cardiorespiratory markers, moderate-intensity continuous training (MICT) is inferior to high-intensity interval training (HIIT). Notably, IT was shown to be particularly effective in populations with lower initial fitness levels, where the magnitude of improvement was more pronounced. A routine that consists of high-intensity exercise followed by relaxation or less intense exercise, which can help the cardiovascular system better use and transport oxygen, may lead to this increase. These results support that interval training can lead to greater physical adaptations than continuous moderate-intensity training. This is part of the practice theory. This finding is also supported by (Jatmiko et al., 2024), who found that vigorous interval training (HIIT) improved aerobic ability better than continuous moderate exercise. However, studies such as (Soares et al., 2021) show that high intensity can increase the risk of injury in people not used to this type of exercise.

Impact on Theory and Practice

The findings of this study make essential contributions to fitness theory and practice. These theoretical results support the idea that HIIT can produce more incredible cardiovascular changes. This is in line with research by Ma et al. (2023), which found that interval training increased VO_2max better than moderate-intensity training. These results imply that interval training is a quick and efficient way to improve cardiovascular fitness. As suggested by (Baker et al., 2020) in the ACSM fitness guidelines, it is essential to consider individual aspects, such as a person's initial fitness level and risk of injury, when implementing a HIIT program.

Social and Ethical Implications

The findings of this study make essential contributions to fitness theory and practice. These theoretical results support the idea that HIIT can produce more incredible cardiovascular changes. This is in line with research by Ma et al. (2023), which found that interval training increased VO_2max better than moderate-intensity training. These results imply that interval training is a quick and efficient way to improve cardiovascular fitness. As suggested by Baker et al. (2020) in the ACSM fitness guidelines, it is essential to consider individual aspects, such as a person's initial fitness level and risk of injury, when implementing a HIIT program.

Suggestions for Future Researchers

Further research should consider several elements to support these findings. Studies with more extensive and diverse populations will be conducted to generalize the results. Long-term research evaluating the impact of interval training over a more extended period is also essential. Additionally, closer monitoring of adherence to exercise protocols would provide more accurate information about how practical interval training is. Further research could also investigate the physiological mechanisms underlying the increases in cardiorespiratory endurance produced by high-interval training (HIIT) and how it compares to other training techniques.

Research Limitations

This study has several limitations that need to be noted. First, the external validity of these findings may be affected by the relatively small sample size; studies with larger samples are required to confirm these results. Second, interval training on cardiorespiratory endurance could not be evaluated in the long term due to the short duration of the study. Differences in participants' adherence to exercise protocols may also impact results. The inability to view each training session live may result in variations in the intensity and volume of training performed by the individuals participating.

Population-Specific Adaptations

Sedentary Adults: In studies such as those by Jung et al. (2020), HIIT interventions significantly improved VO_2max and other markers of cardiovascular health, suggesting that short-term, high-intensity exercise is effective even in populations with low baseline physical activity levels.

Athletes: Research by Abouzeid et al. (2023) demonstrated significant enhancements in pulmonary function and hematological variables after an 8-week HIIT program, emphasizing the benefits of IT for already physically active individuals in further optimizing their cardiorespiratory fitness.

Older Adults: Studies like those conducted by Yang et al. (2023) show that HIIT can be safely implemented in older populations, resulting in substantial improvements in VO_2max and cardiovascular function comparable to those achieved through MICT.

Impact of Exercise Modality and Duration

The analysis found that the effectiveness of IT is influenced by the specific protocol employed, with variations in work-to-rest ratios, session frequency, and overall duration affecting the magnitude of cardiorespiratory improvements. For instance, Songsorn et al. (2023) reported that reduced-exertion high-intensity interval training (REHIT) is particularly time-efficient while yielding significant health benefits.

Biological Mechanisms

Across the studies, it was observed that IT enhances cardiovascular efficiency by improving oxygen utilization and delivery. The data suggest that repeated exposure to high-intensity stimuli prompts more excellent cardiovascular adaptations than continuous moderate exercise, as evidenced by significant VO_2max and cardiac output increases.

Safety and Adherence

While HIIT is effective, it also risks injury if not correctly administered, particularly in untrained individuals. However, when adherence to exercise protocols was closely monitored, as in the study by Astorino et al. (2019), the risk was minimized, and participants safely achieved substantial cardiorespiratory gains.

Comparison with Traditional Training Methods

The findings consistently support the superiority of HIIT over MICT in improving cardiorespiratory fitness. This aligns with the growing literature that endorses IT as a more efficient and effective training modality for clinical and athletic population.

Conclusions

According to this research, interval training can significantly improve cardiorespiratory endurance. These results support the theory that continuous moderate-intensity exercise cannot optimize cardiovascular and metabolic adaptations like high-intensity exercise alternating with rest periods. These results support the idea that HIIT is an excellent technique for improving cardiovascular endurance and aerobic capacity. In other words, these findings offer an effective alternative for those who want to improve their cardiovascular condition in a shorter time. However, it is essential to consider each person's differences when creating this exercise program, especially regarding the risk of injury for those not used to high-intensity training.

Conflict of interest

The authors reported no conflicts of interest.

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Ефективність інтервального тренування щодо підвищення рівня кардіореспіраторної витривалості: Систематичний огляд

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 1 табл., 1 рис., 33 джерела.

Історія питання. Зростання кількості серцево-судинних захворювань зумовило необхідність впровадження ефективних інтервенцій, спрямованих на підвищення рівня кардіореспіраторної витривалості.

Мета дослідження. Мета цього систематичного огляду полягала в оцінці ефективності інтервального тренування (ІТ), зокрема високоінтенсивного інтервального тренування (ВІІТ), щодо підвищення рівня кардіореспіраторної витривалості в різних демографічних групах. ІТ, що характеризуються високоінтенсивними вправами з подальшими періодами відновлення, привертають увагу завдяки своєму потенціалу покращувати ключові показники серцево-судинної системи, як-от максимальний об'єм споживання кисню (VO_2max) та продуктивність серцево-судинної системи.

Матеріали та методи. Проведено комплексний літературний пошук з використанням декількох баз даних згідно з рекомендаціями PRISMA. Із 893 попередньо відібраних статей було визначено вісім досліджень, які відповідали критеріям включення. У вказаних дослідженнях вивчався вплив ІТ, особливо ВІІТ, на кардіореспіраторну витривалість у різних групах населення, включаючи осіб, які ведуть малорухливий спосіб життя, спортсменів і людей похилого віку. В якості основних вимірюваних параметрів були такі показники, як VO_2max і продуктивність серцево-судинної системи.

Результати. Отримані дані вказують на те, що ІТ, зокрема ВІІТ, сприяють послідовному покращенню показників VO_2max та загального стану серцево-судинної системи в різних групах населення. Відзначено перевагу ВІІТ над безперервним тренуванням помірної інтенсивності (БТПІ) у формуванні швидшої адаптації серцево-судинної системи. Незважаючи на свої переваги, висока інтенсивність ІТ вимагає ретельної індивідуалізації з метою зниження ризику травмування, особливо в групах населення з більш низьким початковим рівнем фізичної підготовленості.

Висновки. Представлений огляд дозволяє зробити висновок, що ІТ є ефективним та раціональним за часом методом підвищення рівня кардіореспіраторної витривалості. Його слід розглядати як життєздатний варіант як у клінічних, так і в спортивних популяціях. Однак рекомендується проведення подальших досліджень щодо вивчення довгострокової безпеки ВІІТ у групах високого ризику та поліпшення рівня дотримання вказаних протоколів тренувань.

Ключові слова: інтервальне тренування, кардіореспіраторна витривалість, високоінтенсивне інтервальне тренування, систематичний огляд, VO_2max, здоров'я серцево-судинної системи.

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