Bravo's: Journal of Physical Education and Sport Science
Volume 13 Issue 3, September 2025, pp: 526-540
E-ISSN: 2597-677X; P-ISSN: 2337-7674
DOI: http://dx.doi.org/10.32682/bravos.v13i3/174

Physiological concepts of high intensity interval training improving aerobic capacity: a systematic review

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Abstract

Enhancing athletes' physical capabilities is necessary to promote success. There is a strong correlation between a healthy body and the training performance that results. High-intensity exercise and recovery time are combined in the sport known as high intensity interval training (HIIT). The purpose of HIIT training is to improve an athlete's strength, speed, and physical stamina. Objective. This study sought to determine the effects of high-intensity interval training (HIIT) on athletes' VO2max. Additionally, this study offers a theoretical foundation for using HIIT training to enhance athletes' physical performance. Materials and methods. We looked through a number of literature databases for our systematic review study, including Pubmed, Web of Science, and Science Direct. Articles over the past five years that address athletes, HIIT training, and VO2max. Using the Web of Science, Pubmed, and Science Direct databases, 437 papers published in the last five years were located. For this systematic review, ten papers that satisfied the inclusion criteria were chosen and reviewed. Standard operating procedures were evaluated in this study using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Results. A systematic review has demonstrated that HIIT exercise increases athletes' aerobic capacity. HIIT training has been shown to significantly enhance athletes' physical condition. Conclusions. It has been demonstrated that HIIT training greatly raises athletes' aerobic capacity by raising their VO2max. In order to complement athletes' accomplishments, it is suggested that this be used as a training menu

Keywords: HIIT; Physical Exercise; Physical Fitness; VO2max

Received: 22 August 2025 Revised: 07 September 2025 Accepted: 10 September 2025

Authors' Contribution: A – Conceptualization; B – Methodology; C – Software; D – Validation; E - Formal analysis; F – Investigation; G – Resources; H - Data Curation; I - Writing - Original Draft; J - Writing - Review & Editing; K – Visualization; L – Supervision; M - Project administration; N - Funding acquisition

INTRODUCTION

Athletes today are always required to be able to pursue excellence in sports competitions. In addition, between athletes and coaches have a goal to be able to perform as well as possible during the competition in order to get achievements (Huang, Wang, Tang, Lei, & Koh, 2025). The ability of an athlete to compete during practice or competition is influenced by how optimized sports performance is (Xiao et al., 2021). Several factors can affect an athlete's performance such as technical ability, tactical ability, talent level, fitness level, and psychological condition (Fernandez, Sanz, & Mendez, 2009). Knowing the complex factors that comprehensively identify athlete performance is a must for athletes to optimize sports performance. Physical fitness is one of many factors that are most important in supporting athletes' skills (Koopmann, Faber, Baker, & Schorer, 2020). Health-related physical fitness (muscle strength, endurance, flexibility, body composition, and cardiorespiratory endurance) is associated with an individual's everyday activities, while physical fitness connected to skills (speed, power, agility, balance, coordination, and response time) is associated with the capacity

to carry out physical tasks effectively in relation to particular sports (Xiao et al., 2025). Furthermore, since technical performance and physical fitness are prerequisites and foundations for each other is the result of physical fitness, it is critical to comprehend the relationship between the two (Lago-Fuentes et al., 2018).

Numerous empirical studies have been carried out utilizing a variety of training techniques, including endurance training, in an effort to determine how efficient different training methods are at enhancing athletic performance. To improve athletic performance, sports scientists employ cutting-edge science, technology, and scientific training techniques (Behringer, Neuerburg, Matthews, & Mester, 2013), core strength training (Lago-Fuentes et al., 2018), plyometric training (Zquierdo, 2013), and functional training (Xiao, Bai, Geok, Yu, & Zhang, 2023). Athletes' performance can be enhanced by targeted training, which can recognize the natural relationship and transition between technical performance and physical fitness (Xiao et al., 2025), this is mostly due to the fact that these techniques are founded on the traits and regulations of athletic programs, which are used to pinpoint areas of weakness and create specialized training plans. Second, by concentrating on the nervous system's ability to coordinate human movement is demonstrated by these techniques, which also highlight the overall effects of different joints, the total coordination of the human movement chain, the dynamics of human movement, stability, and balance (Xiao et al., 2025). Traditional resistance training, which involves progressively The American College of Sports Medicine (ACSM) advises increasing the exercise load during training in order to improve sports performance (Feito, Heinrich, Butcher, & Carlos Poston, 2018). The foundation of optimal athletic performance is thought to be multijoint and multiplanar training, which is absent from the majority of conventional resistance training (Fernandez-Fernandez et al., 2020). To guarantee optimal transfer to sport, the training elements in the program should be in line with the athlete's requirements and program features (Xiao et al., 2021). To put it another way, certain guidelines should be adhered to while choosing workouts that correspond to the kind of activity that is a part of the sport. However, one training method that has garnered a lot of interest is functional training (Feito et al., 2018).

An alternate method for enhancing physical performance is HIIT training (Alves et al., 2021). High levels of anaerobic and aerobic fitness are necessary for HIIT training (Aschendorf, Zinner, Delextrat, Engelmeyer, & Mester, 2019). These new types of training such as HIIT are increasingly developing for new training methods that are effective in improving athletes' physical performance. Both aerobic and anaerobic mechanisms re-

synthesize adenosine triphosphate (ATP) during prolonged high-intensity exercise (Altinel et al., 2024). With a variety of training modalities, HIIT is also known to boost motivation and engagement. One further benefit of HIIT is that it requires less equipment. Teenagers who require moderate to intense physical activity can benefit from tabata, a type of HIIT (Tabata, 2019). Nevertheless, nothing is known about the physiological impacts of this type of HIIT in the literature.

It is known from previous research that HIIT training has been shown to enhance athletes' physical performance (Chellappa & Louis Raj, 2025). However, some previous reviews have not mentioned how the concept of physiological mechanisms and stages of HIIT training in increasing aerobic capacity through increasing VO2max. Consequently, this systematic review will go into great detail about how the effect of HIIT training in increasing aerobic capacity through increasing VO2max.

METHOD

To determine how training impacts on athletes' physical performance, this study was conducted by evaluating academic literature. Pubmed, Science Direct, and Web of Science were the search engines used to find scientific papers. HIIT training, athletes' physical performance, and aerobic capacity were the search terms used. The selection of articles was based on the following inclusion criteria: English language proficiency, research and experimental studies, and year of publication. In addition, articles that did not meet the inclusion criteria, including research samples that did not involve humans, research that was not an experimental study, and parameters that were not VO2max, were not included in our analysis and were included in the exclusion criteria

Table 1. Inclusion criteria

Web search engines	**Pubmed, Science Direct, and Web of Science**
Publishing period	2020 – 2025
Keyword	HIIT training, athletes' physical performance, and aerobic capacity
Language	English
Type of article	Original research article
Full Text	Articles matched the purpose and/or topic of the research.

Eligibility criteria

The first step in the eligibility criterion was to review publications from the last five years that addressed HIIT training and physical performance enhancement. Publications that did not fit the criterion for scientific validity or those were not listed in reliable search indexes like Web of Science, Pubmed, or Science Direct were also excluded from our research.

Procedure

Following evaluation and verification, the publications' titles, abstracts, and full texts were added to the Mendeley database. Using the databases Science Direct, Pubmed, and Web of Science, 473 papers were located in the first phase. Following title suitability screening, 257 papers that satisfied the criteria were chosen for the second screening stage. 112 papers were found in the third stage after the title, abstract, and keywords were read. After reading every article, we made the following decisions in this final step: the study must be original, the sample must be human, the parameter must be VO2max, and the exercise intervention must be HIIT exercise. We now arranged the products according to their general suitability. Following a rigorous review and observation process, ten papers that satisfied. For more details, the details of the prism analysis method are shown in Figure 1.PRISMA flowchart of the article selection process.

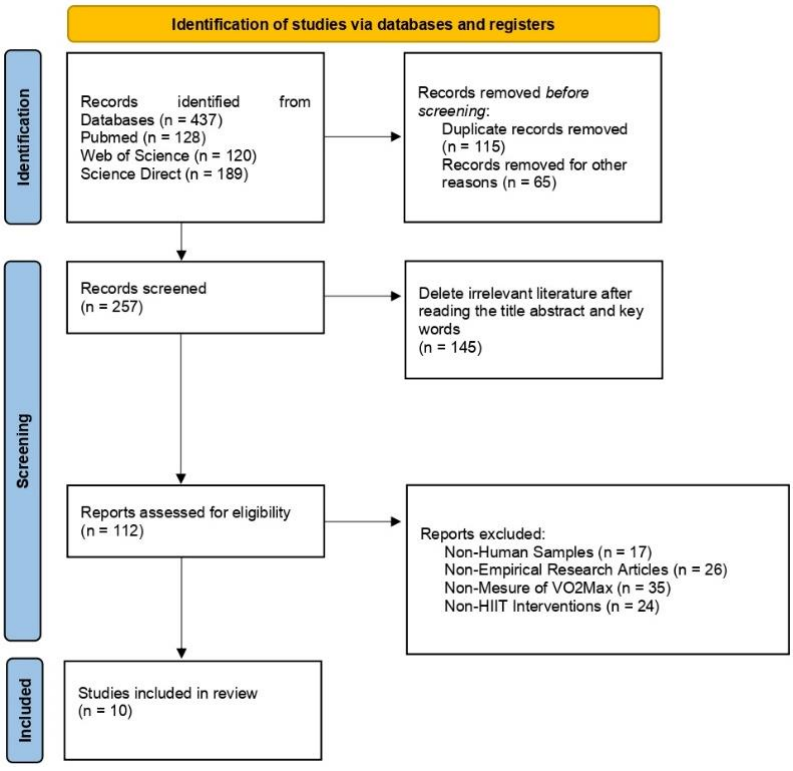

Figure 1. PRISMA flowchart of the article selection process

RESULT

Table 2. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
(Shamim, 2024)	Randomized controlled trial	40 male basketball players	18-25 years	HIIT 1. For eight weeks, exercise is done three times a week. 2. The workout began with low-intensity jogging and dynamic stretching for ten minutes. 3. Ten sets of 30 seconds of sprints, fast steps, or jumps comprised the primary workout. 4. The workout ends with 1 minute of active recovery. 5. The workout concludes with a 10-minute cool-down.	1. There was a significant increase in VO2max in the HIIT group $p<0.05$.
(Altinel et al., 2024)	Randomized controlled trial	22 sportsmen	14-16 years	HIIT 1. Exercise protocol using Tabata training. 2. For six weeks, exercise was done three times a week. 3. To increase fitness and motivation to play basketball, the workouts included squats, side jumps, commando dance, push-ups, squat jumps, crunches, jumping jacks, and burpees with a ball. 4. A cool-down concluded the workout.	1. The HIIT group experienced a notable rise in VO2max $p<0.05$.
(Atakan et al., 2021)	Randomized controlled trial	Twenty-eight healthy recreationally active male	20-30 years	HIIT 1. Exercise using an ergometer. 2. Training was	1. Following the HIIT intervention, VO2max

					conducted 6 HIIT sessions over 5 days for the double HIIT group. 3. Training was conducted 6 HIIT sessions for 2 weeks for the single HIIT group. 4. Exercise using a stationary bike in an all-out 10-minute cycle with 85% - 90% VO2Max. 5. And 10 min 60 sec cycling at 100% VO2Max interspersed with 75 sec cycling at 60 W. 6. Participants completed 10 high-intensity intervals per training session.	significantly increased $p<0.05$.
(Subekti, Raihan, Hafif, & Syaukani, 2023)	Randomized controlled trial	13 subjects were Pencak Silat athletes	19 years	HIIT 1. For four weeks, exercise is done three times a week. 2. Before the exercise, warm up first. 3. The HIIT protocol is a simulation of a martial arts match consisting of 3 minutes with 3 rounds with an interval of 1 minute, athletes perform a series of movements (punches, kicks, and falls) on the punch / target in accordance with the predetermined program. 4. The exercise is closed with a cool down.	1. There was a significant increase in VO2max after HIIT intervention $p<0.05$.

(Murawska-Cialowicz et al., 2020)	Randomized controlled trial	25 men	32 years	HIIT 1. 1. Exercise is done 2x a week for 8 weeks. 2. 2. Each 60-minute training session included a 10-minute warm-up, 40 minutes of high-intensity interval training, and a 10-minute cool-down. 3. 3. The exercises included oblique abdominal muscle exercises (side crunches), shoulder muscle exercises (military press with medicine ball), trapezius muscle exercises (chin-ups), straight abdominal muscle exercises (crunches), chest muscle exercises (push-ups), arm muscle exercises (triceps dips), and lower limb muscle exercises (squats with jumps).	1. There was a significant increase in VO2max after HIIT intervention $p<0.05$.
(Sá Filho et al., 2024)	Randomized controlled trial	25 men	26-28 years	HIIT 1. A six-minute warm-up precedes the workout. 2. Over the course of three weeks of treatment, participants attended two sessions per week for a total of six sessions. 3. At a 1% incline, participants started walking on the treadmill at a pace of 5 km/h. 4. The pace was maintained for six minutes after being progressively increased by 1.0 km/h per minute	1. There was a significant increase in VO2max after HIIT intervention $p<0.05$.

				until it reached 65% of heart rate reserve (HRRes). 5. After that, the pace was increased by 1.0 km/h every minute until the subject was unable to run any more. At that time, the VPeak and actual maximum HR (HRmaxR) were noted.	
(Lu, Wiltshire, Baker, & Wang, 2021)	Randomized controlled trial	Twenty healthy, untrained female university students	20 years	HIIT 1. Before beginning the intervention, warm up. 2. Exercises were performed 3x a week for 12 weeks of intervention. 3. The exercises included burpees, stepping, deep squat leaps, butt kickers, stepping, mountain climbers, stepping, side-to-side squats, stepping, jumping jacks, stepping, high knees stepping, and stepping.	1. Following the HIIT intervention, VO2max significantly increased $p<0.05$.
(Herrera-Valenzuela et al., 2021)	Randomized controlled trial	Sixteen boxers	28 years	HIIT 1. The workout starts with a warm-up. 2. For four weeks, exercise is done three times a week. 3. The HIIT protocol involved hitting a punching bag with force and speed while utilizing free combinations. The exercise was broken up into three blocks, each consisting of five repetitions lasting 30 seconds, followed by a 6-second rest period and a 1-minute recovery period in between.	1. There was a significant increase in VO2max after HIIT intervention $p<0.05$.
(González-Gálvez et al., 2024)	Randomized controlled trial	Forty-five adolescents	12 years	HIIT 1. A warm-up precedes the exercise. 2. For eight weeks, training is conducted twice a week.HIIT	1. There was a significant increase in VO2max after HIIT

				protocol which is repetitive sprint running with maximum intensity.	intervention p<0.05.
(Germano et al., 2022)	Randomized controlled trial	Fifty masters road cyclists	35-49 years	HIIT 1. A warm-up precedes the exercise. 2. Work out with an ergometer. 3. Exercise was performed for 12 weeks of intervention. 4. Gradual exercise using a bicycle ergometer at 80% rpm. 5. The exercise was closed with a cool down.	1. Following the HIIT intervention, VO2max significantly increased p<0.05.

DISCUSSION

This study's goal was to ascertain how high-intensity interval training affected increasing aerobic capacity through VO2max. Based on the analysis of papers that have been reviewed, it proves that physical exercise with the type of high internsity interval training is proven to increase VO2max. Drawing from earlier studies on basketball players who engaged in HIIT training three times a week for eight weeks using the main training menu involving 10 sets of sprints, fast steps, or jumps for 30 seconds and ending with active rest, it was found to significantly increase VO2max (Shamim, 2024). Other research results sportsmen who do HIIT using tabata training it is completed three times a week for six weeks with details of the types of exercises ranging from squats, exercises that have been shown to dramatically raise VO2max include side jumps, commando dance, push-ups, squat jumps, crunches, jumping jacks, and burpees (Altinel et al., 2024). This information is further supported by earlier studies that demonstrate how HIIT exercise can dramatically raise VO2max (Subekti et al., 2023). One reason HIIT increases VO2max is due to increased mitochondrial density. HIIT has been shown to increase mitochondrial density in skeletal muscle, resulting in increased aerobic energy production. This adaptation is crucial for improving VO2max and lactate threshold, as it allows athletes to produce energy more efficiently and sustain high-intensity efforts for longer periods.

According to other research, HIIT, which is performed for 60 minutes each session and consists of 10 minutes of warm-up, 40 minutes of hiit exercise, and 10 minutes of cooling, is proven to significantly increase VO2max. It is performed twice a week for eight weeks and includes exercises for the lower limb muscles (squats with jumps), the back muscles (back

extensions), the straight abdominal muscles (crunches), the chest muscles (push-ups), the arm muscles (triceps dips), the oblique abdominal muscles (side crunches), the shoulder muscles (military press with medicine ball), and the trapezius muscles (chin-ups) (Murawska-Cialowicz et al., 2020). Other research' findings support the notion that HIIT exercise, done twice a week for three weeks, significantly raises VO2max (Sá filho et al., 2024). Other studies demonstrate that hiit exercises, which include jumping jacks, stepping, high knee stepping, side-to-side squats, stepping, mountain climbers, stepping, forearm plank to high plank, burpees, deep squat jumps, stepping, butt kickers, and stepping, can significantly raise VO2max when performed three times a week for 12 weeks (Lu et al., 2021). Thus, HIIT exercise does, in fact, work wonders for raising VO2max.

The following study's findings show that HIIT training, which is done three times a week for four weeks, involves hitting a punching bag with strength and speed using free combinations. The workout is broken up into three blocks with 5 repetitions of 30 seconds for 6 seconds of rest, with a 1-minute recovery time between blocks proven to significantly increase vo2max after the intervention (Herrera-Valenzuela et al., 2021). Other data hiit protocol repetitive sprints with maximum intensity performed 2x a week for 8 weeks proved to significantly increase vo2max (González-Gálvez et al., 2024). So HIIT training is highly recommended especially for athletes in an effort to increase their aerobic capacity to support competition performance. The impact of which can improve athlete achievement. Because the athlete's physical ability is the main factor in improving the athlete's skill ability. However, the review so far has only known that HIIT is indeed the best in improving physical performance. It is not yet known for sure how the physiological response is when doing HIIT. Here we explain and examine in depth how the physiological response of hiit training is in increasing aerobic capacity through increasing VO2max. In our analysis review, the samples were not all athletes, so the hiit applied also had different effects depending on the duration, intensity, age, level of experience, and health status. So the physiological response is indeed different. However, in general, what we reviewed only focused on HIIT being proven to increase VO2max.

We can be certain that HIIT exercise has been demonstrated to raise VO2max considerably. The hormesis of the body is impacted by HIIT training. Hormesis is a quick biological process that generates ATP through two anaerobic and aerobic pathways. Because it uses both anaerobic and aerobic pathways, HIIT is an exercise that offers numerous advantages. (Wirawan & Griadhi, 2020). The formation of reactive oxygen species (ROS), which are substances engaged in bodily physiological processes and contribute to the body's

physiological adaptation, is influenced by intensity and interval. ROS will contribute to muscular growth, mitochondrial biogenesis, and even enhanced cognitive function (Gibala et al., 2012).

It has been demonstrated that HIIT increases skeletal muscle mitochondrial density, which raises aerobic activity's energy generation. Athletes can generate energy more effectively and maintain high-intensity workouts for longer thanks to this adaptation, which is essential for raising VO2max and lactate threshold (Shamim, 2024). Additionally, by promoting the glycolytic (anaerobic) and oxidative (aerobic) energy systems, HIIT raises the activity of crucial enzymes involved in energy synthesis. Because it improves both short-term sprinting performance and long-term endurance, HIIT is particularly helpful for sports like basketball that use both energy systems (Shamim, 2024).

While anaerobic exercise encourages improved ammonia removal and develops tolerance to lactic acid, high-intensity aerobic exercise can improve the body's ability to manage carbohydrates and glycogen levels. These alterations are linked to the adaptive effects of ROS on the body. Overtraining, which is typical of trained athletes, can also result in maladaptive oxidative damage to the body (Radak et al., 2017). Furthermore, HIIT's repeated high-intensity exercises may enhance neuromuscular efficiency and coordination, which are essential for carrying out specialized motions like jumping, sprinting, and rapid direction changes. The enhanced muscular endurance and sprinting performance seen in the HIIT group were probably influenced by these advancements in motor units and firing patterns (Shamim, 2024).

Numerous bodily changes can result in an increase in VO2max during HIIT. increased cardiac contraction and stroke volume. The heart adjusts to exercise by contracting more forcefully. The heart adjusts by raising cardiac output and stroke volume when the training load is continuously increased (Wirawan & Griadhi, 2020). Changes in cardiac remodeling, particularly in the left ventricle of the heart, are linked to this increase in stroke volume and cardiac output (Gibala et al., 2012). HIIT training has the potential to raise the cell's mitochondrial count. Additionally, this activity contributes to the activation of PGC-1α through phosphorylation, which is crucial for cellular metabolic homeostasis. More mitochondrial genes that create more mitochondrial proteins will have their transcription increased by the amount of PGC-1α. The body responds by increasing its oxygen utilization capacity, or VO2max, as the number of mitochondria grows the organelle that creates aerobic metabolism, which in turn raises the need for oxygen for metabolism (Putra, Al Ardha, Kinasih, & Aji, 2017). In the study we conducted, we know that from all the articles we reviewed, it is proven

that HIIT significantly impacts the increase in VO2max. However, further experimental studies are definitely needed to prove it. So in the next opportunity we are interested in conducting this experiment to prove it through experimental studies

CONCLUSIONS

The results of the study prove that there is an increase in VO2Max when doing HIIT that in the cells there is an increase in mitochondrial density and this occurs in skeletal muscles so that it triggers an increase in aerobic capacity and increases VO2Max. This systematic review's advantage is that it just examines randomized controlled trials, which eliminates the chance of unclear causal linkages and are the most trustworthy kind of scientific data. Furthermore, human subjects are the primary focus of the samples collected to ensure that all data are consistent and not mingled with samples from other categories, such as animal subjects.

On the other hand, we also convey the limitations of our research, including the small number of studies we reviewed, the lack of protocol heterogeneity and the still limited review of the physiological responses we conducted. And this is indeed a limitation of the research we conducted. Therefore, we are interested in conducting experimental studies on this in the future to prove it.

The dearth of discussion and debate over the physiological research that show HIIT training raises VO2max and the underlying mechanisms for doing so were the limits we faced. In order to improve understanding and knowledge regarding the impact of HIIT training on raising VO2max and the theoretical and scientific explanation of the underlying mechanisms, this study is thought to be crucial. The findings of the study can then be used to recommend that coaches use HIIT training to raise athletes' VO2max, which affects their physical performance during competition.

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