Physiological mechanisms of increasing maximal oxygen volume through small sided games training: a systematic review

Mecanismos fisiológicos del aumento del volumen máximo de oxígeno mediante el entrenamiento en juegos reducidos: una revisión sistemática

Authors

Muhammad Muhyi [1]
Suharti [1]
Puspodari [2]
Akhmad Syarif [3]
Baskoro Nugroho Putro [4]
Junian Cahyanto Wibawa [5]
Novadri Ayubi [6]

[1] Universitas PGRI Adi Buana Surabaya (Indonesia)
[2] Universitas Nusantara PGRI Kediri (Indonesia)
[3] Universitas PGRI Palangkaraya (Indonesia)
[4] Universitas Sebelas Maret (Indonesia)
[5] STKIP PGRI Trenggalek (Indonesia)
[6] Universitas Negeri Surabaya (Indonesia)

Corresponding author:
Muhammad Muhyi
muhyi@unipasby.ac.id

How to cite in APA

Muhyi, M., Suharti, Puspodari, Akhmad Syarif, Baskoro Nugroho Putro, Junian Cahyanto Wibawa, & Novadri Ayubi. (2025). Physiological mechanisms of increasing maximal oxygen volume through small sided games training: a systematic review. *Retos*, *69*, 1215–1225. https://doi.org/10.47197/retos.v69.116525

Abstract

Background. An athlete's maximal oxygen capacity, or VO2max, is a crucial measure of their aerobic performance. Since small-sided games (SSG) incorporate tactical, technical, and physical components all at once, they have gained popularity as a teaching tool. According to a number of studies, SSG can raise VO2max by inducing physiological stimuli including elevated heart rate and oxygen consumption. As a result, it's critical to thoroughly examine the physiological processes that underlie the rise in VO2max brought about by SSG training. Objective. This study sought to ascertain whether playing small-sided games increased VO2Max. Materials and methods. For our systematic review investigation, we examined several literature databases, such as Pubmed, Scopus, Web of Science, and Science Direct. We searched for literature published between 2020 and 2025 that discussed VO2Max and small-sided games. Another 664 published papers were found using the databases Scopus, Web of Science, Pubmed, and Science Direct. Ten papers that met the inclusion criteria were selected and reviewed for this systematic review. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were used in this study to assess standard operating procedures. Results. Ten studies that have been examined have demonstrated that training with small-sided games significantly raises VO2Max.
Conclusions. The results of this systematic study indicate that playing small-sided games has been demonstrated to raise VO2Max. For athletes and sportsmen, it can be an alternate suggestion in an attempt to raise VO2Max through small-sided game training.

Keywords

SSG; physical exercise; physical fitness; vo2max.

Resumen

Antecedentes. La capacidad máxima de oxígeno de un atleta, o VO2máx, es una medida crucial de su rendimiento aeróbico. Dado que los juegos reducidos (JRE) incorporan componentes tácticos, técnicos y físicos a la vez, han ganado popularidad como herramienta didáctica. Según diversos estudios, los JRE pueden aumentar el VO2máx al inducir estímulos fisiológicos, como una mayor frecuencia cardíaca y un mayor consumo de oxígeno. Por lo tanto, es fundamental examinar a fondo los procesos fisiológicos que subyacen al aumento del VO2máx provocado por el entrenamiento con JRE.
Objetivo. Este estudio buscó determinar si la práctica de juegos reducidos aumentaba el VO2máx. Materiales y métodos. Para nuestra revisión sistemática, examinamos diversas bases de datos bibliográficas, como Pubmed, Scopus, Web of Science y Science Direct. Buscamos literatura publicada entre 2020 y 2025 que abordara el VO2Max y los juegos en espacios reducidos. Se encontraron otros 664 artículos publicados utilizando las bases de datos Scopus, Web of Science, Pubmed y Science Direct. Se seleccionaron y revisaron diez artículos que cumplían los criterios de inclusión para esta revisión sistemática. En este estudio se utilizaron los Elementos de Informe Preferidos para Revisiones Sistemáticas y Metaanálisis (PRISMA) para evaluar los procedimientos operativos estándar.
Resultados. Diez estudios examinados han demostrado que el entrenamiento con juegos reducidos aumenta significativamente el VO2máx.
Conclusiones. Los resultados de este estudio sistemático indican que se ha demostrado que jugar a juegos reducidos aumenta el VO2máx. Para atletas y deportistas, puede ser una alternativa para intentar aumentar el VO2máx mediante el entrenamiento con juegos reducidos.

Palabras clave

SSG; ejercicio físico; aptitud física; VO2máx.

Introduction

Being physically active is crucial for preventing non-communicable diseases (Randers et al., 2024). A balanced lifestyle and consistent exercise are necessary to maintain physical fitness and excellent health. Because it can lower oxidative stress, boost antioxidant capacity, and activate antioxidant enzymes all of which have a protective effect on preventing cell damage regular exercise can enhance the body's general health (Wibawa et al., 2024). In the last several decades, physical activity has been identified as a preventive measure to enhance public health and ward against Parkinson's disease (Wibawa et al., 2025). However, nowadays physical exercise is not only a maintenance of the body in order to maintain health status, but also as a method in increasing physical capacity, especially for athletes.

Modified versions of official team sports, known as small-sided games (SSGs), are usually played on smaller or modified fields or courts with fewer players and frequently have unique rules (Clemente, 2025). These modifications could entail altering the objectives of the assignment or the way teams work together, such setting clear guidelines for interpersonal interactions or restricting individual behavior (Clemente et al., 2021). By encouraging more frequent decision-making, increasing player involvement, and providing more opportunities to practice technical and tactical skills in a game-like environment, SSG aims to preserve the ecological validity of practice (Davids et al., 2013). In order to foster dynamics akin to actual match situations in a more specialized setting, these games are frequently utilized in team sports including rugby, basketball, handball, volleyball, and soccer (Clemente, 2025). Simplifying or changing the game to accomplish a particular objective is the aim (Silva et al., 2016). The goal is to improve physical capacity and performance. One of the things that affects it is the ability of VO2Max, especially in athletes.

Compared to non-athletes, athletes are thought to have superior cardiorespiratory fitness measurements. VO2Max, a common metric for assessing cardiorespiratory fitness is maximum oxygen uptake. Exercise physiologists consider it to be one of the most accurate indicators of an athlete's degree of physical fitness and cardiorespiratory function (Srivastava et al., 2024). Success in endurance sports and increased cardiorespiratory fitness are predicted by VO2Max. It has been defined as the most oxygen that can be taken in during exercise, followed by an increase in the intensity of the activity does not result in any additional rise in oxygen intake (Crowley et al., 2022). Milliliters of oxygen per minute per kilogram of body weight or liters of oxygen per minute are used to measure VO2Max (Rocco et al., 2013). VO2Max is the global standard for physical capacity (Alok Kumar Yadav, 2017). To evaluate maximum oxygen intake, oxygen uptake must reach a saturation point, demonstrating the effective coordination of the metabolic, cardiovascular, and brain systems. A maximum effort incremental test's peak VO2 is most likely a reliable indicator of VO2Max because incremental exercise does not always lead to a saturation point (Scribbans et al., 2016). Maximal aerobic capacity has become a powerful indicator of adverse health outcomes and total mortality risk throughout the last forty years. Exercises at different intensities can be performed to increase VO2Max and overcome negative effects (Montero & Díaz-Cañestro, 2016).

Small sided games are identical to the type of high intensity interval training. SSG training on a small field and making this small game has an impact on players to continue doing high intensity activities and occasionally take a break and continue running again with high intensity. So this is identical to the type of HIIT training. The term "HIIT" describes a type of intermittent exercise training that alternates short bursts of high-intensity exercise, such as sprints that reach 90% of maximal heart rate (HR) and maximal oxygen consumption (VO2max), with rest or recovery intervals in between (Gibala et al., 2012). Because it saves time, this training approach has been selected as the top trend in health and fitness for 2018 (Thompson, 2023). Even though athletes have been using HIIT in their training since the early 20th century, its popularity has lately grown, and within the past ten years, the number of published research that are pertinent to HIIT has skyrocketed (Gibala et al., 2012).

According to research, HIIT training regimens that run anywhere from two weeks to eight months are a time-efficient way to achieve a number of health advantages, such as altered body composition and reduced visceral fat (Astorino et al., 2017). Additionally, HIIT enhances exercise performance, fat oxidation during submaximal activity, and cardiorespiratory fitness (Talanian et al., 2007). Higher skeletal muscle mitochondrial biogenesis and mitochondrial function, which show up as higher oxidative phosphorylation capability, may be one of the fundamental mechanisms behind these gains (Granata et al.,

2016). According to a published research study, the shortest duration of HIIT to date was two weeks, with six HIIT sessions. During that time, the study observed gains in skeletal muscle metabolic adaptations, fat burning during submaximal activity, and endurance capacity (Jacobs et al., 2013).

So far, athletes have done intensive training for what they want to achieve such as increasing physical capacity to support achievement. But how small sided games contribute to increasing physical capacity through VO2Max is still a little discussion. The physiological mechanism is still not much discussed in depth. Knowing in detail how the physiological mechanisms underlying small sided games in increasing VO2Max can be the basis of training in doing this exercise. Therefore, the purpose of this study is to determine how the mechanism of small sided games in an effort to increase VO2Max.

Materials and method

Study Design

Researchers conducted a comprehensive search for experimental studies in journal databases such as Pubmed, Science Direct, Web of Science, and Scopus. In the data search process, we selected high-quality scientific articles spread across these databases. These databases are considered the best in the world, which guarantees their validity and legitimacy. Duplicate entries were removed using this initial search strategy. To further narrow down the search results, inclusion criteria were set to guide researchers in data extraction. The inclusion criteria we have set include the article must be experimental, the research sample must be human and not animal, the intervention study must be small-sided games with any sport, and finally the parameter taken must be VO2Max. Criteria that are not included in the inclusion as set are then as exclusion criteria that are not included in our research analysis.

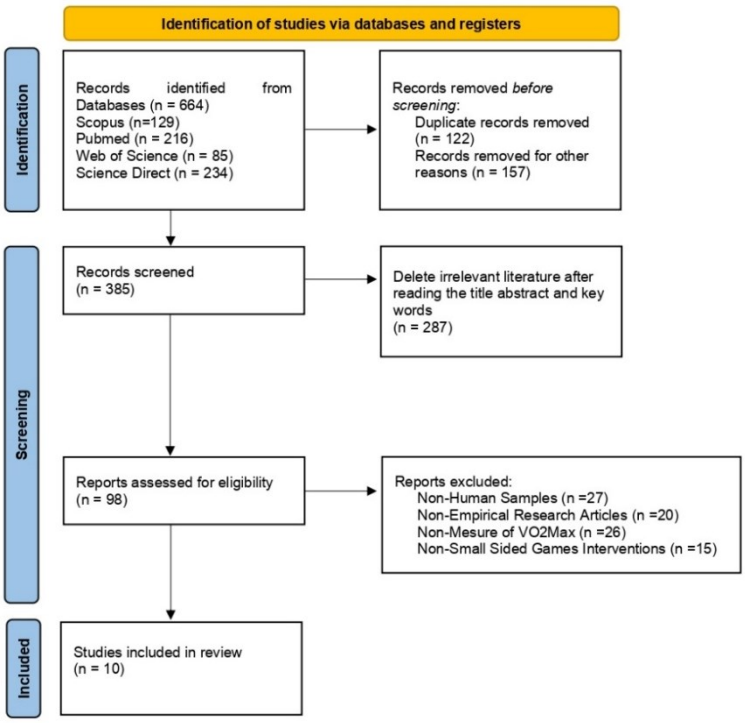
Eligibility Criteria

This study's inclusion criteria were developed by looking at papers from 2020 to 2025 that looked at how small-sided games affected VO2Max. Furthermore, our study excluded papers that did not meet scientific validity criteria or that were not found in trustworthy search indexes such as Scopus, Web of Science, Pubmed, or Science Direct.

Procedure

After initial review and validation, the full text, abstract, and title of the publications were added to the Mendeley database. Using the search databases Scopus, Science Direct, Pubmed, and Web of Science, 664 publications were found in the first stage. After reading the articles to adjust the appropriateness and compatibility of the title, 385 papers that met the requirements advanced to the second screening stage. In addition, 98 papers were selected for the third round after careful review and analysis of the appropriateness of the title, abstract, and keywords. After reviewing each publication, we had to decide that the study must be unique, that the parameter examined was VO2Max, that the intervention was a small-sided game, and that the sample was human to meet the inclusion conditions. After a rigorous review and observation process, ten papers that met the inclusion criteria were selected for analysis at this stage. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) served as the guideline for the research operation.

Figure 1. PRISMA flowchart of the article selection process



Results

Table 1 presents a summary of the design and intervention characteristics of the included studies.

Table 1. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
(Pratama et al., 2024)	Experimental	46 football athletes	15-17 years	Exercise: For two months, the Experimental Group (GE) engaged in four SSG football activities per week. The Control Group (GC) engaged in the same frequency of standard exercises as the experimental group, but without any equipment or movement modifications.	There was a significant increase in VO2Max in the SSG group.
(Norrahmah, Zalillah, Made, & Wijaya, 2025)	Experimental	36 young amateur league soccer players	20 years	Exercise: To enhance players' physical condition and abilities, the SSG+SET Training Program blends Sprint Endurance Training (SET) with Small-Sided Games (SSG). Another organization that solely uses SSG. Over the course of four weeks, both groups participated in 12 training sessions, three sessions per week.	It is proven that the group with the combination of SSG + SET is more effective in increasing VO2Max.
(Fitrian, Graha, Nasrulloh, & Asmara, 2023)	Experimental	16 individuals	15 to 18 years	Exercise: The treatment was administered 15 times, three times per week. A player of futsal and other little side games. A training program for small-sided games in 2v2, 3v3, and 4v4 forms served as the treatment.	There was a significant increase in VO2Max after SSG training.
(Setiakarnawijaya et al., 2022)	Experimental	20 Futsal Athletes	19 – 21 years	Exercise: The duration of the intervention was sixteen weeks. Exercise Methods for Interval	There was a significant increase in VO2Max after SSG training.

				Training and Futsal Modification, Small Side Games.	
(Zaharia et al., 2023)	Experimental	40 football players	17 years	Exercise: Goalkeepers in 4vs.4 football small-sided games (SSGs) (4vs.4+GK). For eight weeks, apply twice a week.	In the SSG experimental group there was a significant increase in VO2Max post intervention.
(Chandra, Kusuma, Artanayasa, & Agung, 2025)	Experimental	Sixty students of Undiksha Soccer Student Activity Unit	under 23 years	Exercise: Samples participated in training four times a week for four weeks, and they were divided into two groups: the small-sided games only (SSG) group and the combination group (SSG+RT).	There was a significant increase in VO2Max both after SSG+RT combination training and SSG alone.
(Karahan, 2020)	Experimental	Twenty-two male soccer players	15 years	Exercise: The training regimen is scheduled to begin eight weeks before the competitive season, four days a week, and for sixty minutes each day. In this study, soccer SSG players were partnered in 3 v 3 matches. Additionally, it was maximally intense skill-based training (SBT).	Both SSG and SBT groups had a significant increase in VO2Max after the intervention.
(Arslanoglu et al., 2024)	Experimental	60 football players	23 years	Exercise: The combined training group (CT) received maximal aerobic speed training with small-sided games in addition to regular football training. For 12 weeks, the maximum aerobic speed group (MAS) received only maximal aerobic speed training twice a week. The regular football training regimen was maintained by the normal training group (NT).	There was a significant increase in VO2Max after the exercise intervention.
(Ma, G, & Vinu, 2025)	Experimental	52 soccer players	14 to 16 years	Exercise: The experimental group trained five days a week for 12 weeks, playing small-sided games with floaters assistance. Each 90-minute practice included lead-up games, cooling down, small-sided games with floaters intervention, and warming up. The floaters training program was not practiced by the control group.	The findings showed that VO2Max was considerably increased by small-sided games with floaters intervention.
(Randers et al., 2024)	Experimental	Thirty-nine habitually active men	30 years	Exercise: Were randomized to either the inactive control group (CO) or the street football training group (ST) or grass football group (GR), which played small-sided games for 70 minutes, 1.5 and 1.7 times a week, respectively, for 12 weeks. Heart rate (HR) and GPS devices were used to measure exercise intensity. A battery of tests was done both before and after the intervention.	The grass football group proved to significantly increase VO2Max.

Discussion

This study sought to ascertain how playing small-sided games affected VO2Max. Considering the study's findings, it is proven that small sided games can increase VO2Max. The results of previous research show that small sided games football conducted 4x a week for 2 months proved to have a significant impact on increasing VO2Max (Pratama et al., 2024). The results of another study conducted on 36 soccer players aged 20 years who were given a combination training intervention combining short-sided games and training for sprint endurance conducted 12 training sessions for 4 weeks with a frequency of 3 sessions per week had a significant impact on increasing VO2Max (Norrahmah et al., 2025). The results of another study on 16 individuals who were given the intervention of small sided games futsal training

with a duration of 15 sessions with a frequency of 3x a week proved to significantly increase VO2Max (Fitrian et al., 2023).

Other research data also proved that 20 futsal players who were given modified small sided games training conducted for 16 weeks had a significant impact on increasing VO2Max (Setiakarnawijaya et al., 2022). The results of another study proved that 40 football players who were given small sided games training 2x a week for 8 weeks proved significant in increasing VO2Max (Zaharia et al., 2023). Other research data soccer players who were given a combination intervention of small sided games and resistance training or small sided games alone and carried out 4x a week for 4 weeks had a real impact on increasing VO2Max both combination training and small sided games alone (Chandra et al., 2025). So based on several studies this is indeed the basis for small sides games to have a real impact on increasing VO2Max.

The results of another study of 22 soccer players who were given a training program of 60 minutes per day, 4x a week for 8 weeks proved that there was a significant increase in VO2Max (Karahan, 2020). Further studies have shown that playing small-sided football twice a week for 12 weeks dramatically raises VO2Max increases (Arslanoglu et al., 2024). The results of another study of small sided games for soccer players conducted 90 minutes per session for 12 weeks proved significant in increasing VO2Max (Ma et al., 2025). Other data that small sided football games conducted for 12 weeks also had a significant impact on increasing VO2Max (Randers et al., 2024). So it clearly proves that small sided games training significantly increases VO2Max. This can be a recommendation for coaches as an alternative exercise to improve aerobic physical performance. But besides that we must study in depth how small sided games affect the increase in VO2Max.

Physiological Mechanisms of Small Sided Games in Increasing VO2Max

Small-sided games, as we all know, are simplified exercises that mimic real games. Over the past ten years, exercise-based activities like small-sided games (SSG) have gained popularity and prevalence in soccer training for players of all ages and skill levels. SSGs aid in enhancing technical and tactical abilities as well as physical condition (Halouani et al., 2014). SSG, which is played on smaller courts with fewer players, has gained popularity as a way to maximize training time and enhance match-winning abilities and fitness (Clemente et al., 2014), It allows people of all ages to combine strength training, high-intensity cardiovascular endurance, and a difficult, flexible, enjoyable, and social workout (Krustrup et al., 2016). Since there are fewer players and a smaller playing space, SSG can place more emphasis on player interaction while still enforcing high physical demands (Clemente et al., 2014). SSG calls for adjustments to the field size (Clemente et al., 2020a), utilizing updated regulations (Castellano, 2013) which has less participants (Selmi et al., 2020), crucial for achieving tactical, physiological, and technical outcomes (Hill-Haas et al., 2011). There are three types of SSG games: small (less than four versus four), medium (five versus five to eight versus eight), and large (nine versus nine) (Ma et al., 2025). Through the use of situational diversions and randomized scenarios, SSG aids in simulating the complex features of competitive matches (Ma et al., 2025).

For a number of reasons, people of all ages and ability levels employ small field games (SSGs), which are a common training aid (Hill-Haas et al., 2011). The numerous restrictions and regulations mentioned during SSG that impact physiological, physical, technological, and tactical characteristics have been examined in a number of reviews in the scientific literature (Clemente et al., 2021). For instance, a 2011 study of a small number of physiological indicators revealed that blood lactate concentration, heart rate, and subjective exertion evaluation all increased as the relative field size increased (Hill-Haas et al., 2011). But training intensity also rises as a result of fewer players and the corresponding increase in the field's relative size (Hill-Haas et al., 2011). The impact of soccer's Small-Sided Games (SSG) training paradigm on physical performance has been documented in earlier research (Xu et al., 2024). SSGs have been shown to have an impact on players' physical performance as well as their technical and tactical abilities (Badari et al., 2021).

Among the different SSG forms examined in earlier research, 4v4 (3v3+GK) and 5v5 (4v4+GK) are among the most extensively researched configurations (Sarmento et al., 2018). Task limitations, particularly the space allotted to each player, are the primary determinants of SSG's physical demands and have a big impact on the game's exterior intensity. Greater locomotor load, including greater overall

distance traveled, distance traveled at varying speeds, and higher maximum speeds attained, is associated with a larger area per participant (Riboli et al., 2023). Although all SSGs, regardless of the area per player used, showed larger mechanical loads (sum of accelerations and decelerations) (Lacome, 2018). By providing more options to use space, the expanded play area in SSG encourages greater action diversity and exploration, which may result in more movement and distance traveled (Clemente et al., 2020b). Thus increasing higher training patterns.

It is important to note that the majority of format comparisons among the included studies on this subject fail to take into account differences in the length-width ratio and the relative area increase per participant. Larger formats (4 vs. 4 + GK and 5 vs. 5 + GK) result in players being farther away when taking into account their own team centroid (i.e., the geometric center of the team, calculated based on the location of the players in Euclidean space), according to studies that do maintain the relative area per player (Aguiar et al., 2015) compared to the smaller ones (3 vs. 3 + GK and 2 vs. 2 + GK). In one of these studies, it was observed that movements were more orderly (measured by estimated entropy) in larger formats (4 vs. 4 + GK and 5 vs. 5 + GK) than in smaller formats (2 vs. 2 + GK and 3 vs. 3 + GK) (Aguiar et al., 2015). Other studies Bach Padilha et al., 2017 examined how the players' tactical conduct was affected by the use of extra players, known as floaters, who only assist the team with the ball and act on the sidelines. According to the findings, using exterior floaters greatly expanded the effective playing area and the objective of keeping the ball in possession. Meanwhile, the format without floaters is associated with a significant increase in the penetration principle (Bach Padilha et al., 2017), perhaps in an attempt to increase the chances of overcoming an opponent in a duel. In addition, there are other factors that influence the increase in aerobic capacity through small-sided games training.

The increase in distance traveled during the shuttle run test and the estimated maximal oxygen intake during SSG training demonstrated the improvement in aerobic performance. Results from earlier research on the influence of recreational soccer training regimens on inactive and overweight groups showed a significant improvement in aerobic performance (Hornstrup et al., 2020; Seabra et al., 2016; da Silva Soares et al., 2022; dan Vasconcellos et al., 2016). According to other research, SSG causes significant cardiovascular reactions, such as elevated heart rate and oxygen consumption (Hammami et al., 2017), which over time may lead to gains in aerobic fitness. Because SSG is dynamic, it necessitates quick transitions between anaerobic and aerobic energy systems, involving both glycolytic and oxidative mechanisms (Mendham et al., 2015). Because of this metabolic flexibility, the cardiovascular system must effectively supply oxygen to the working muscles, which improves cardiovascular responses. Additionally, SSG's variation in movement patterns and intensity encourages the recruitment of different muscle areas, resulting in extensive and intricate physiological changes (Li et al., 2023).

Regular involvement in small-sided games is associated with better aerobic performance, which is a result of this multidimensional approach that stimulates both the circulatory and muscular systems. As has been shown in recreational soccer, playing SSGs, particularly ones with fewer players and less space, causes particular neuromuscular changes linked to greater lower limb strength (Luo et al., 2018). Rapid and repetitive accelerations and decelerations are a feature of SSG's dynamic character, which poses difficulties for the neuromuscular system (Xu et al., 2024). These difficulties cause modifications to muscle recruitment patterns, which may result in more effective fiber recruitment. SSG's unique movement patterns, which are marked by abrupt changes in speed and direction, are very similar to how jumping works. Using force to overcome inertia and, in the case of vertical jumps, stretch-shortening cycles are both used in this replication (Xu et al., 2024). In order to improve lower limb power, the overload caused by the acceleration and deceleration demands in SSG may trigger physiological reactions. These include improved force production capabilities and a greater recruiting of motor units.

Strenght and Limitations

The benefit of this systematic review is that it only looks at randomized controlled trials, which are the most reliable source of scientific data and remove the possibility of hazy cause-and-effect relationships. Additionally, the samples show consistent data, are human-focused, and aren't mixed with samples from other categories, such as animal samples.

We solely concentrate on performing a thorough analysis of how training with small-sided games influences VO2Max improvement, and we are conscious of the limitations of the researchers in this systematic review. Although it could seem less thorough when talking about physiological reactions and their

causes, researchers are constrained by the intricacy of physiological processes that take place in the body. Consequently, more thorough research is required to evaluate VO2Max via experimental testing. Additionally, a thorough analysis of the differences in intensity between high and low small-sided games is required; consequently, more research is advised to address this problem.

Conclusions

Training with small sided games has been proven to increase VO2Max aerobic capacity. By increasing VO2Max, it will increase the oxygen supply to cells to increase energy production. So that the formation of ATP increases which has an impact on increasing physical capacity which will also increase which will support performance in competitions.

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Authors' and translators' details:

Muhammad Muhyi	muhyi@unipasby.ac.id	Author
Suharti	suharti@unipasby.ac.id	Translator
Puspodari	puspodari@unpkediri.ac.id	Author
Akhmad Syarif	syarifroeslan2018@gmail.com	Author
Baskoro Nugroho Putro	baskoro.np@staff.uns.ac.id	Author
Junian Cahyanto Wibawa	juniancahyanto96@stkippgritrenggalek.ac.id	Author
Novadri Ayubi	novadriayubi@unesa.ac.id	Author