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Global Trends in High-Intensity Interval Training Research Adolescents: A Bibliometric Analysis

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Abstract

Study purpose. This bibliometric study aims to map global trends in HIIT research focused on adolescents and identify the most influential authors, journals, countries, and keywords.

Materials and methods. Methods: A quantitative bibliometric approach was applied using data from the Scopus database (2003–2024). Seven hundred and sixty-nine publications met the inclusion criteria and were analyzed in RStudio using the Bibliometrix and VOSviewer.

Results. Results show a significant increase in publication trends since 2021, indicating the growing recognition of HIIT as a practical approach to improving adolescent health and performance. The United States was identified as the most productive country (143 publications; 5,065 citations), serving as a hub for global collaboration. The journal Strength and Conditioning Research published the most articles, with Alan R. Barker and David R. Lubans emerging as the most influential authors. Frequently appearing keywords included "High-Intensity Interval Training" (HIIT), "Exercise," "Adolescents," "Physical Activity," and "Obesity." This study highlights a research gap that needs further exploration, particularly in integrating the physiological and pedagogical dimensions of HIIT implementation for adolescents.

Conclusions. The contribution of this study to adolescents is that it demonstrates that High-Intensity interval Training (HIIT) is a highly effective, efficient, and enjoyable exercise method for improving physical fitness and cardio-metabolic health, as well as motivating them to engage in physical activity. Furthermore, the implementation of HIIT tailored to adolescents' developmental characteristics can foster healthy lifestyle habits, improve physical abilities, reduce the risk of obesity, and support adolescents' mental health and overall quality of life.

Keywords: High Intensity Interval Training; Adolescents; Exercise; Health

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Introduction

Adolescence is an important period for developing and supporting healthy behavioral styles, as these behaviors affect life expectancy and the risk of developing diseases later in life (Milas et al., 2019; Tabrizi et al., 2024). Period covers change significant and consistent physical, cognitive, emotional, and social (Galván, 2021; Mytton et al., 2024). Sport, consistent and systematic physical activity, greatly influences optimal health in adolescents, facilitating the development of healthy physical and mental health (Atmaja et al., 2025; Sampasa-Kanyinga et al., 2022). In addition, the lack of physical activity correlated with an increased risk of cardiovascular disease and an increased possibility of early death (Shilton et al., 2024; Torres-Villela et al., 2023). Regardless of ability, physical activity, and body type, regular physical activity helps prevent various health problems. Some studies have shown that teenagers often fail to meet the essential physical needs for health. Some studies have shown that teenagers meet the physical activity requirements (Regina et al., 2020). Most children and adolescents spend a lot of time inside or outside of school hours (Lee et al., 2021). This phase encompasses significant physical, cognitive, emotional, and social transformations, as well as rapid, dynamic growth.

The implementation of physical activity programs at school aims to improve health among teenagers, promote health maintenance, and prevent disease or to offer activity alternatives outside the school environment, including exercise-based classes (Manojlovic et al., 2023). Many studies show that implementing this strategy can increase system cardiometabolic and neuromuscular outcomes (Martin-Smith et al., 2020; Patricio Arturo et al., 2025). Bauer et al., (2022) many studies show that implementing this strategy can increase cardio metabolic and neuromuscular outcomes systems. In addition, this training strategy can also improve physical health and fitness in adolescents (Stanković et al., 2025). This matter can produce more pleasant experiences than prolonged low-intensity training in adolescents (Jovanović et al., 2024). Respond improvement focus on the fitness and health of teenagers, studies in the literature are very important for understanding development research in this field. Bibliometric strategies are ways that can be trusted and reliable for differentiating progress and relationships between contributing authors, institutions, and countries (Esmer & Dertli, 2024; Islam & Muti, 2026).

Research shows that High-Intensity Interval Training can effectively improve physical fitness as well as cardiometabolic and neuromuscular outcomes in adolescents (Mitić et al., 2024; Poon et al., 2023). Nevertheless, there is still ample room for further research due to several limitations in the existing literature. Most previous studies have focused only on short-term interventions and were often conducted under controlled conditions or with specific groups, making it difficult to generalize the findings and understand the long-term effects. Furthermore, attention to the pedagogical aspects and the application of HIIT in educational settings remains quite limited, particularly regarding how HIIT can be effectively integrated into school curricula and physical education programs (Liu et al., 2024).

As a result, there is still a lack of understanding of how to implement HIIT effectively and sustainably in adolescents' real lives. Furthermore, although research on HIIT in adolescents is growing rapidly worldwide, there remains a lack of comprehensive, up-to-date bibliometric analysis in this field, particularly regarding the mapping of trends in research collaboration publications and the contributions of countries, institutions, and authors, which remain relatively limited. This gap makes it difficult to understand the overall development and dynamics of HIIT research in adolescents over time. Studies show that High-Intensity Interval training (HIIT) is proven effective in increasing fitness, cardiometabolic, and neuromuscular fitness in adolescents; however, there is still much room for improvement due to the limited research. There is research that yields only short-term results and is conducted in groups or under specific conditions (Winn & Mackintosh, 2017). Although a number of studies have a

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examined the effects of HIIT on adolescents, research in this field continues to evolve worldwide. most previous studies have focused on the physical and physiological effects of HIIT, while bibliometric analyses assessing publication patterns , research collaboration, and contributions from various contries and intitutions remain relatively rare.

With this objective in mind, this study analyzes international landscape studies on High Intensity Interval Training in adolescents using bibliometric methods. It provides a comprehensive overview of progress in the field and potential directions for future research.

Materials and methods

Database Strategy and Research

This study uses a quantitative-bibliometric approach, utilizing the Scopus database. Search focused on 2003–2024 to get a description of the general trend study on intensity interval training height in adolescents. The main keywords used in the search process are "high intensity interval training" tall, and teens, which are later combined with the Boolean operators "OR" and "AND" and keywords related to other topics. To expand coverage and ensure results are relevant to the study topic (Plakias, 2025; Rahman & Islam, 2026).

Table 1. Keywords used for the search in the database

Keywords: processing of the results data
Scopus
Title, abstract, and keywords ((“high-intensity interval training” OR “HIIT” OR “sprint interval training” OR “high intensity interval exercise”) AND (adolescent OR youth))

Article Selection for Bibliometric Analysis

In the bibliometric analysis, this is the only article that studies the original article and includes reviews. Publications by others, such as letters, notes, papers, conference proceedings, book chapters, review articles, books, and retracted publications, are excluded from analysis because they are considered irrelevant to the objective research. There is no limitation on the year of publication, so that all published articles until December 30, 2024, are included in the analysis, including the period 2003 to 2024. Of the 816 documents from the beginning of the search, 769 articles met the inclusion criteria and were further analyzed.

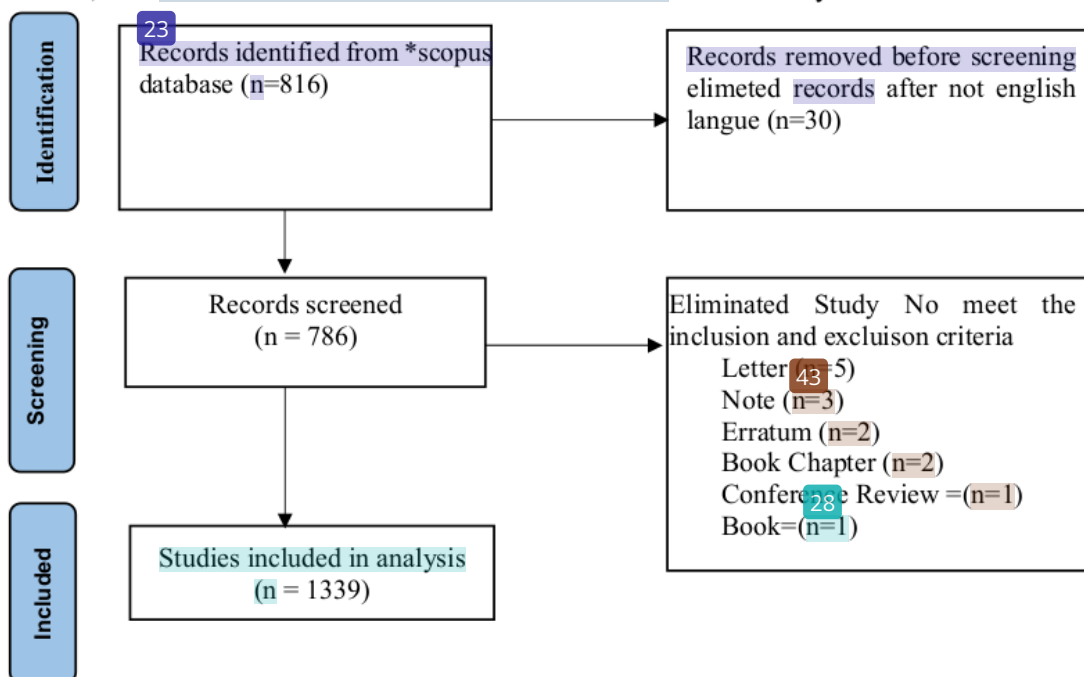


Figure 1. Search strategy flowchart

Bibliometric analysis

Analysis of the method literature. This uses a quantitative method for the study. Using Study bibliometrics with a web-based support system, an open tool for quantitative bibliometrics analysis using RStudio version 5.1.0 (2025-05-01 ucrt), Statistical Computing organization, Vienna, Australia. (Aria & Cuccurullo, 2017) VOSviewer software version 1.6.20 is also used to improve visualization results, which helps build and map network collaborations, relationships between keywords, and thematic studies (McAllister, Lennertz, and Atencio Mojica 2022). The variables analyzed covered source publication, author, country, and keywords, as shown in Table 2.

Table 2. Overview of bibliometric analysis techniques and applied parameters.

Criteria	Component	Study
Description	Key data related to the production of the scientific annual	RStudio/ Bibliometrix / Biblioshiny
Source	relevant journals	RStudio/ Bibliometrix / Biblioshiny
Writer	The most relevant authors	RStudio/ Bibliometrix / Biblioshiny
Countries	Production in scientific countries	RStudio/ Bibliometrix / Biblioshiny
Structure	Map of Collaboration Between Social Countries	VOSviewer
	Network collaboration writer	
	Network collaborative authors, the	RStudio/ Bibliometrix / Biblioshiny
Document	most articles quoted globally, and	
	Keywords writer	VOSviewer

Research results that have been analyzed based on three criteria: main: journal, author, and document. The analysis focuses on the ten most significant publications and authors, the most significant network collaborations between writers, the network collaborations between writers and countries, the ten most frequently viewed articles cited, the most active countries, and the keywords from the authors. In addition, journals and authors with a publication H index are most considered for their potential impact in gathering publications that will be analyzed.

Results

Analysis Descriptive

The following are the main points of this document, based on data from Scopus shown in Figure 2. The data to be analyzed covers the year, publication, article, study, and keywords. In addition, the analysis also displays the most productive journals. Analysis: This describes the number of publications by country and the countries with the most citations, with a focus on collaboration. Analysis results cover map collaboration between countries and network collaboration between the writers. Besides that, this analysis also confirms the most frequently cited articles, the most common keyword networks, and the study's trend.



Figure 2. Information important about data

Analysis: This found 789 works on the implementation of high-intensity interval training among teenagers, published between 2003 and 2024, with contributions from 256 publishers. Analysis shows annual growth of 24.64%, while the average age of articles is about 5.4 years. For 54 years, every article has received approximately 29.24 citations, and a total of 5,618 references have been used throughout the publication. Regarding the keyword author, 1,464 were recorded. The number of writers across all publications is 3,321, but only 9 articles were written by a single author, for an average of 5.79 authors per article. In addition, 38.27% of publications were produced through international cooperation.

Annual scientific production

Analysis shows that trend publications about the implementation method *intensity interval training tall* (HIIT) in adolescents have developed in three phases. From 2003 to 2011, research remained limited. The growth phase occurred rapidly from 2012 to 2018, with a significant increase in publications exploring the effectiveness of HIIT in adolescents. The period from 2019 to 2024 marks a phase of consolidation, with productivity stable and a peak in research publications in 2024 in [Figure 3](#).

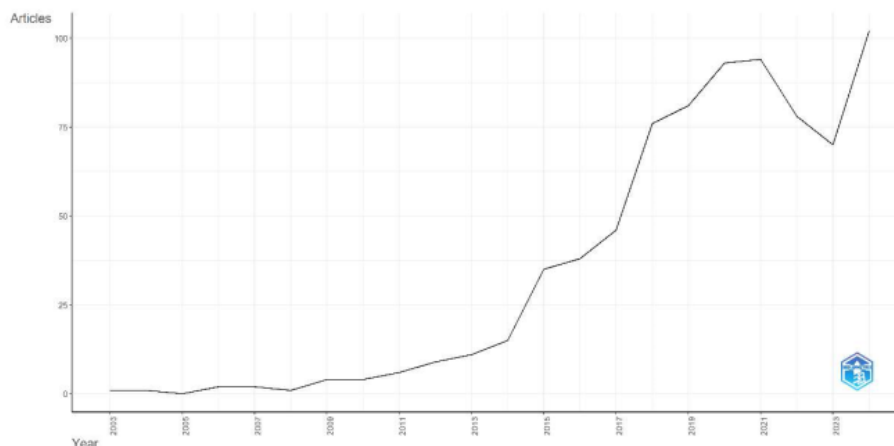


Figure 3. Annual Scientific Production

The most relevant journals

A total of 256 journals have published studies on the use of the intensity interval training method among teenagers, with 60% available in open format. This shows that studies on matter

are more easily accessible to the general public, especially in the field of physical education, because results are shared not only with scientists and researchers but also with teachers and educational institutions.

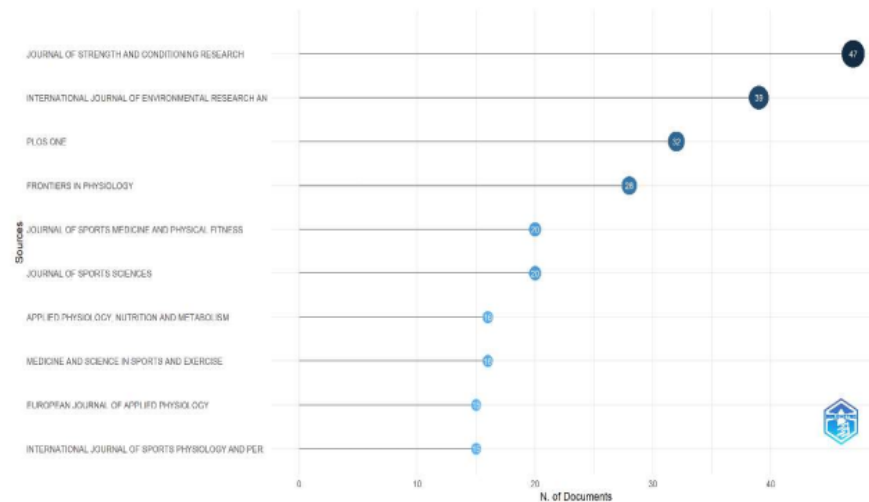


Figure 4. Most Relevant Sources

Figure 4. This table shows the 10 most active sources in published articles on implementation method intensity interval training in teenagers, all of which are publicly accessible. The journal with the most publications on the use of intensity interval training in adolescents is Strength and Conditioning Research, with 47 publications, followed by PLOS ONE with 39 articles and the International Journal of Environmental Research and Public Health with 32 publications.

Temporary, in Table 3, if seen from the H-Index, a measure of size and impact on citations, three journals with the highest performance are Journal of Strength and Conditioning Research (H-Index = 21), PLoS One (H-Index = 19), and International Journal of Environmental Research and Public Health (H-Index = 15).

Table 3. Local Impact of Sources According to the H Index

Source	HI	GI	MI	TC	NP
Journal Study Strength and Conditioning	21	32	1.105	1110	47
Plos One	19	32	1,357	2135	32
International Journal of Research Environment and Public Health	15	29	1.5	913	39
Physiology Applied, Nutrition, and Metabolism	13	16	0.765	647	16
Medicine and Science in Sports and Exercise	13	16	0.684	1103	16
Limitations in Physiology	12	22	1.2	498	28
Journal of Physiology Applied Europe	11	15	0.55	739	15
International Journal of Medicine Sport	11	14	0.647	531	14

Journal of Medical Sports and Physical Fitness	11	19	1	390	20
Journal of Knowledge Sport	11	20	0.647	413	20

HI: Number of cited publications at least the same as the number of publications; **GI:** Measure the impact of publications based on the total citations highest; **M- Index:** H-Index divided by the duration of the career publications; **TC:** Total citations; **NP:** Number of publications

The most relevant authors

41 In addition, the ten most influential writers in the topic study on the implementation method of high-intensity interval training in adolescents, sorted by the number of publications, are shown in Table 4. Three authors with the most publications are Barker, Alan R, with 28 publications, Williams, Craig A, with 25 publications, and Lubans, David Revalds, with 20 publications. Lubans, David Revalds, with 1026 citations, has the greatest local impact.

Table 4. Top ten Author with the tallest scientific output.

Author	Amount article	Quoting	Total Links Strength
Barker, Alan R.	28	565	81
Williams, Craig A.	25	516	75
Lubans, David Revalds	20	1026	84
Eather, Narelle	16	971	79
Bond, Bert O.	14	324	46
Domaradzki, Jaroslaw	13	146	21
Ramirez-Campillo, Rodrigo	13	303	20
Bouassida, Anissa	11	289	35
Hillman, Charles H.	11	669	56
Koźlenia, Dawid	11	103	20

An analysis network of the author's research on the intensity, interval, training, and height of implementation methods in adolescents produces a map visualization to understand interactions in the collaboration study. This map uses various colors to indicate different collaborations. Every point or knot represents every author involved in a publication in the analyzed dataset, and the size of the knot indicates the extent to which it influences writers in network collaboration (Mahyari et al., 2025; Newman, 2011). The lines connecting the authors represent collaborative connections, and thickness shows the strength of collaboration (van Eck & Waltman, 2010; Frey, 2022). After analyzing the pattern of author collaborations, 3,321 authors were identified, with a distribution of 1-7 authors per document.

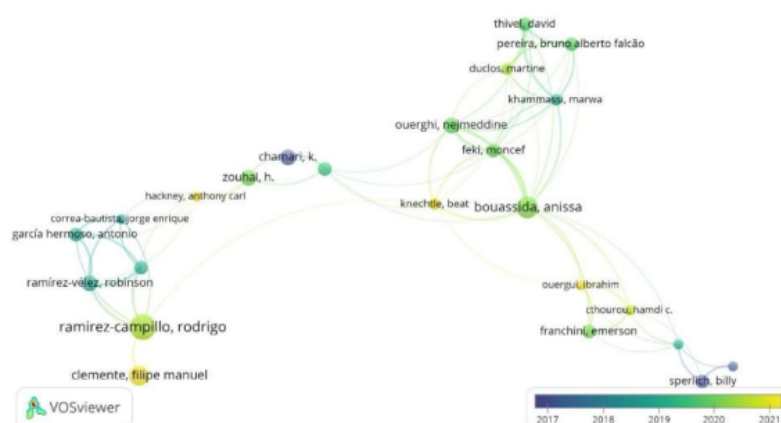


Figure 5. Collaboration Network Between Writers

Figure 5 shows a map of collaboration among writers, with 23 writers working together on two or more articles. The most dominant collaboration is Network Red, which consists of eight writers. Among them, Lubans and David Revalds occupy the most prominent position and have connections with other authors.

Production and Collaboration Between Countries

The results of the analysis in Table 5 show the number of publications by country. Collaboration between 42 countries shows the United States leads with 143 publications, followed by the UK (11) and Australia, with

Table 5. Production of those 10 countries with the highest amount quoted

Country	Amount article	Quoting	Strength total links
United States of America	143	5065	115
English	111	3683	89
Australia	95	4139	93
China	87	Tahun 1432	44
Brazil	70	tahun 1789	56
Canada	67	2751	78
Spanyol	66	year 1463	81
Perancis	44	tahun 2120	69
Jerman	44	tahun 1652	53
Tunisia	36	1234	82

Figure 6 shows that the United States holds the highest level of global collaboration, with 115 strong links, followed by Australia (93) and England (89).

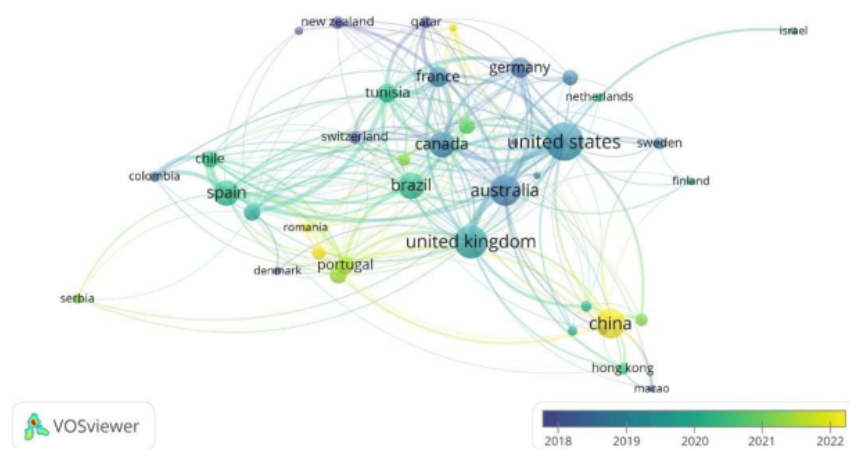


Figure 6. Collaboration between countries

Most Cited Articles

Continue review of the most frequently used documents referenced worldwide, found that work Milanović et al. (2015), with the title: "Effectiveness of High Intensity Interval Training (HIIT) and Resistance Training" Continuous For Increasing VO2max: An Overview Systematic and Meta-Analysis of Controlled Trials, published in the journal Sports Medicine. This article received 699 quotes.

Table 6. Top 10 articles with the highest citation

Writer	Year	Title	Source	Quoting	Average per Year
Milanović et al.,	2015	Intensity interval training performance to 4 Intensity (HIT) and Continuous Endurance Training for Increasing VO2max: An Overview, Systematic and Meta-Analysis of Controlled Trials	Medical Sport	699	63.55
Robinson et al.,	2017	Improvement Underlying Protein Translation Improvement Adaptation Metabolic and Physical Effects on Various Training Modes Exercise in Young and Old People	Cell Metabolism	404	44.89
Paolucci et al.,	2018	Sport reduces depression and inflammation, but intensity is important.	Psychology Biological	323	40.38
Whyte et al.,	2010	Influence 2 weeks of sprint interval training on results related to men who are	Metabolism	314	19.63

		overweight overweight/obese and not active.			
Huh et al., ⁶⁹	2014	Exercise-induced irisin secretion, regardless of age or fitness level, and increased irisin can, in turn, directly modulate muscle metabolism by activating AMPK.	Journal of Endocrinology and Metabolism Clinical	306	25.50
Costigan et al.,	2015	Interval training is effective for improving physical health in adolescents. Review a comprehensive and analytical combination.	Journal of Medical Sport English	302	27.45
Racil et al.,	Year 2013	Impact intensity interval training eight versus intensity on blood lipid and adiponectin levels in young obese women.	Journal of Physiology Applied Europe	284	21.85
Gillen et al.,	2016	Three months of sprint interval training improves the cardiometabolic health index to a level almost as high as that of regular exercise. However, the amount of practice and time spent is more than 5 times, 5 times.	PLoS ONE	282	28.20
Maillard et al.,	2018	Effect of High- Intensity Interval Training on Total, Abdominal, and Visceral Fat Mass: A Meta- Analysis	Medical Sport	254	31.75
Keating et al., ⁷⁶	2017	A systematic review of the effect of interval training on exercise intensity and body adiposity.	Review Obesity	249	27.67

Author keywords

The analysis shows that there are 1571 keywords in the research on this topic. that of the 50 most frequently used keywords used by the author with four group color, 10 most frequent keywords used Because frequency its use, namely "intensity interval training height (n=195)", "Sports (n=103)", "Teenagers (n=78)", activity physical (n=53) and "Obesity (n= 49)", and the least frequent keywords appear is "Concept self (n=14)", "Learning (n=15)", "education health (n= 5)" and "Elementary School (n=16)". In addition to the keyword dominant, the analysis identified several high-frequency keywords, indicating an area of research that has not been explored. have been explored. Ten keywords with frequency lowest includes "capacity aerobics" (n=11), "agility" (n=11), " disease cardiovascular " (n=11), "inflammation" (n=11), "insulin resistance" (n=10), "exercise intensity currently sustainable" (n=10), "exercise physical" (n=10), "school" (n=10), "strength" (n=10), and "sports team" (n=10) in Figure 7.

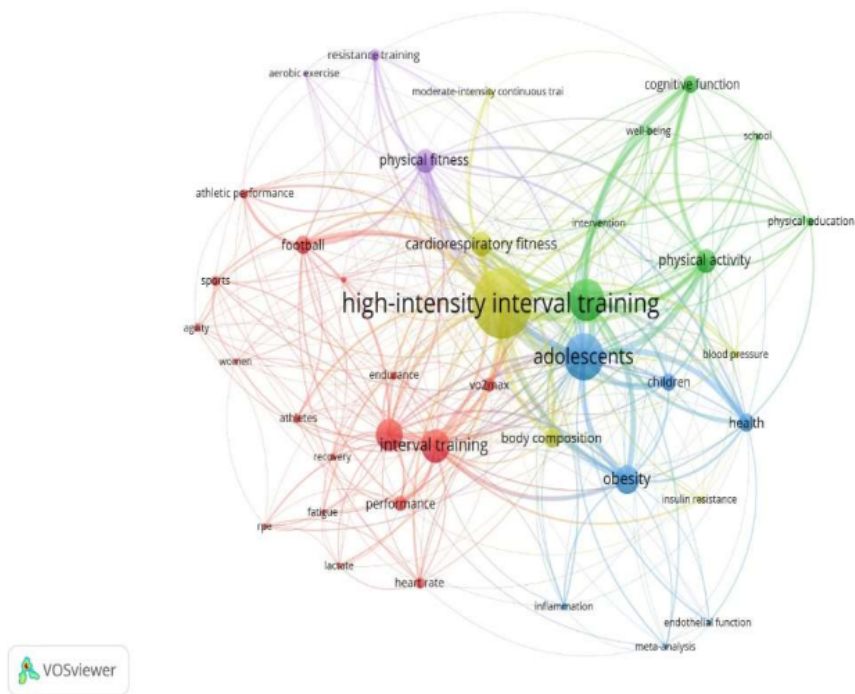


Figure 7. Keywords writer

Analyze more details that emerge alongside visible keywords from the average year publication, showing keywords colored yellow, like “Education Physical” and “Soccer Ball”, and keywords colored purple, like “power hold” and “exercise interval”. in Figure 8.

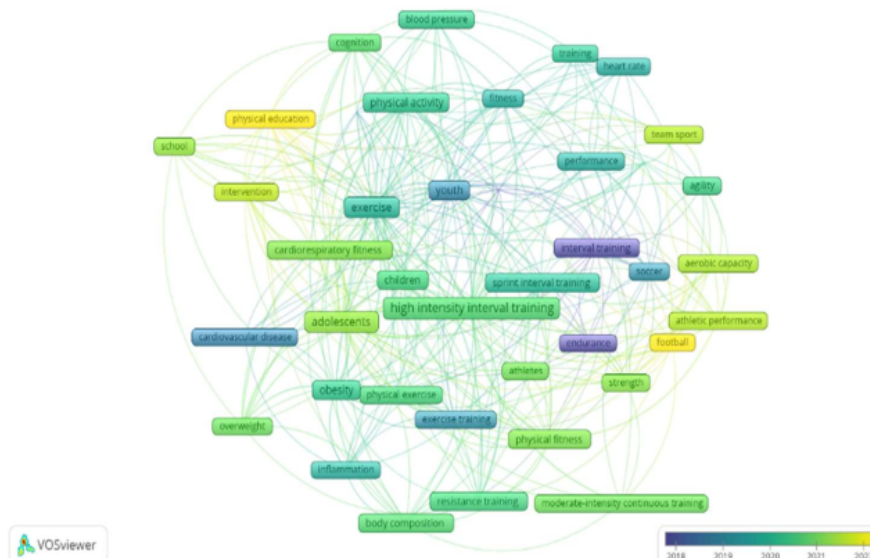


Figure 8. Keywords writer based on the average year of publication.

Discussion

Intensity Interval Training (HIIT) in Adolescents. Analysis shows that issues being researched have developed through three main stages. In the early phase (2003–2011), publications were very few, with only 0–6 articles per year, indicating the early exploration of HIIT's effectiveness in adolescents. The second phase (2012–2018) was marked by rapid growth, with the number of articles increasing from 9 publications in 2012 to 76 in 2018. The third phase (2019–2024) shows the existence of the topic globally in research, with publications stable at 81–94 per year and reaching a peak of 102 in 2024. Improvement in publication amount. This is driven by the widespread adoption of HIIT in education and in physical and sports competitions among teenagers. This trend is also supported by empirical evidence that shows the effectiveness of HIIT in increasing cardiorespiratory fitness, body composition, and metabolic health in adolescents (Berisha et al., 2025; da Silva Bento et al., 2022; Engel et al., 2018; Poon et al., 2024). In addition, advances in the observation and measurement of physiology have increased researchers' interest in understanding the impact of HIIT training on physiological adaptation (Chen et al., 2024; Quindry et al., 2020). Analysis of a highly respected and influential journal on the implementation of high-intensity interval training in adolescents shows that the *Journal of Strength and Conditioning Research* has the highest publication volume, confirming its position as a reference in high-intensity interval training (HIIT) research among teenagers.

Next, the analysis of network collaboration between writers shows that 3,321 authors contribute to publications on this topic, with the number of collaborators changing from 1 to 7 per document. A visualization of network collaboration shows that Lubans and David Revalds occupy the most central positions, with extensive network connections. In addition, three writers with publications are Barker, Alan R (28), Williams, Craig A (25), and Lubans, David Revalds (20). Based on the analysis, locally, Lubans and David Revalds also identified the strongest influence on science, with 1,026 citations. Analysis based on country revealed that 42 countries contributed to the publication of HIIT research in adolescents. The United States had the most publications, namely 143, followed by England with 111 and Australia with 95. From a scientific perspective, the United States also excels, with 5,065 citations, reflecting its dominant role in the field. In addition, in the international collaboration network, the United States holds the top position with the strongest link, namely 115, followed by Australia (93) and England (89). These results explain the role of the United States as an important center for global network collaboration, which diverts knowledge and strengthens cross-boundary collaboration in HIIT.

Next, keyword analysis uses VOS viewer to generate 1,571 keywords, of which 40 are the main keywords, grouped into four research areas. Ten keywords with frequency highest are: "High Intensity Interval Training" (n=222), "Physical Exercise" (n=112), "Adolescents" (n=130), "Interval training" (n=83), "training" (n=77), "obesity" (n=69), "fitness cardiorespiratory" (n=57), "fitness physical" (n=54), "activity physical" (n=53). And "composition body" (n=40) Keyword dominance This show that study about topic This especially focus on factors physiological and health physical, especially in effort For increase capacity cardiorespiratory, composition body, and indicators fitness metabolic in adolescents (Meng et al., 2022; Srisuk, 2025).

Temporary that is the keyword with frequency The lowest is "Aerobic exercise" (n=8), "function endothelial" (n=8), "meta-analysis" (n=8), and "Women" (n=8), "fatigue" (n=9), "curse" (n=9), "rpe" (n=9), "insulin resistance" (n=10), "school" (n=10), "power" (n=10). This shows that related topics, including psychosocial aspects, education, health, and the application of HIIT in a formal learning environment, are rarely examined. This shows the existence of a significant gap in research, especially in understanding how HIIT can contribute to the

development⁴ of character, motivation, learning, and self-concept in students at the school age. This result in line with research by Poon et al. (2023), which found that part big HIIT research in adolescents Keep going focused on results physiological, while dimensions psychological and pedagogical Not yet Lots explored (Leahy et al. 2020) With thus, the direction future research must adopt approach interdisciplinary that integrates HIIT does not only as intervention physique but also as a learning and educational strategy health For increase welfare teenagers in the neighborhood school.

The trend publication on emergence together shows a shift toward studies on High Intensity Interval Training. Keywords such as “Physical Education”⁶² “Football” have emerged as relatively new topics and attracted attention in recent years. This is supported by Rockey et al. (2023), who showed that the direction of research on High Intensity Interval Training has expanded from a focus on physiology to applications in education, physical, and learning sports. Changes This shows a shift in the scientific paradigm, where HIIT is no longer viewed as a method of training to increase physical capacity but also as a pedagogical approach that can support active learning (Patricio Arturo et al., 2025). In addition, the keyword²⁰ “Football” has been identified as a relatively new topic and has show⁷⁴ increasing interest in recent years. Phenomenon This reflects the expanding application of High Intensity Interval Training in sports teams, especially football, which emphasizes the development of aerobic capacity, speed, and decision-making skills in situational games (Thomakos et al., 2024). This trend also shows the integration of the HIIT approach into the training model based on games, which are considered more relevant and effective for improving the performance of young technical athletes (Prasad et al., 2025).

This study has many necessary limitations considered. One of them lies in the database used. This study uses only one database, Scopus, and does not include others such as Google Scholar or Web of Science. Limitations²⁴ This can create bias in analysis and evaluation results, especially when comparing field-like institutions or states (Echchakoui, 2020; Mongeon & Paul-Hus, 2016). In fact, an article on a 2024 research topic, limited only² to Web of Science, shows different approaches but potentially complements each other in coverage of relevant publications, journal¹⁹ and authors. A single database selection can also influence results, especially regarding⁶⁶ number of citations and the coverage of research analyzed.

Research on High-Intensity Interval Training (HIIT) in adolescents has shown rapid growth, especially in 2021. p This marked that it started to be recognized as an effective method of exercise for increasing health and performance in teenagers. Besides, it is dominated by developed countries like the United States, as well as many that focus on physical activity, sports, and obesity. Besides that, research still shows a gap in results, such as the physical benefits of HIIT, its health benefits, and its effects on fitness and weight loss. While other aspects that are not lost important covering the method (HIIT) is taught (approach pedagogical) and how physiological conditions of teenagers influence the effectiveness of practice, are still not much studied intensely. Besides that integrated research aspect, physiological, like (response of the body of a teenager to practice), with the aspect of learning or training. (How HIIT is applied in the context of education or exercise sports), It is still very limited.

With this gap, there is an opportunity for researchers to review HIIT in detail, particularly for women. Another limitation of the study is that the methodology search uses only two main keywords, which may lead to the potential to miss some studies. Thus, the results provide a comprehensive description of the connections among authors, countries, and institutions with the highest scientific productivity in the intensity interval training height in adolescents, as well as the most influential journals and keywords. Furthermore, it is recommended that the coverage search be expanded to include more keywords and that they be approached more analytically in depth. In addition, exploration continues to discipline sport;

certain requirements are necessary to understand the implementation of HIIT in the context of physiological, pedagogical, and performance of teenage athletes.

Research on High-Intensity Interval Training (HIIT) among adolescents has grown rapidly over the past two years, reflecting a significant paradigm shift in the understanding of physical activity during adolescence. Physical activity is no longer viewed merely as a biological necessity for improving physical fitness, but also as an essential component of physical literacy, which encompasses motivation, self-confidence, movement competence, knowledge, and understanding required to sustain an active lifestyle. Within this framework, HIIT has emerged as one of the most effective, efficient, and relevant training interventions for adolescents, both in sports settings and educational environments.

Bibliometric analysis indicates that the development of HIIT research among adolescents can be classified into three major phases. During the initial phase (2003–2011), the number of publications remained relatively limited, ranging from only 0–6 articles per year. This condition suggests that HIIT research in adolescents was still in its early exploratory stage and primarily focused on the physiological effectiveness of high-intensity exercise on aerobic capacity, cardiovascular health, and metabolic responses in adolescents. In the second phase (2012–2018), there was a substantial increase in publications, rising from 9 studies in 2012 to 76 studies in 2018. This rapid growth was driven by increasing global concern regarding adolescent obesity, sedentary lifestyles, and the demand for time-efficient training methods. Entering the third phase (2019–2024), HIIT research evolved into a global research topic, with publication numbers remaining consistently high at approximately 81–94 articles per year and reaching a peak of 102 publications in 2024. This trend demonstrates that HIIT has gained widespread recognition as an effective training strategy for improving adolescent health and performance, both in sports settings and physical education contexts.

The increase in the number of publications has been supported by various empirical studies demonstrating that HIIT is effective in improving cardiorespiratory fitness, body composition, insulin sensitivity, and metabolic health among adolescents (Berisha et al., 2025; da Silva Bento et al., 2022; Engel et al., 2018; Poon et al., 2024). Furthermore, advances in physiological measurement technologies have encouraged researchers to further investigate the body's adaptive mechanisms to HIIT, including neuromuscular, metabolic, and cardiovascular responses (Y. Chen, Xu, dan Wang 2024; Quindry, Williamson-Reisdorph, & French 2020). These developments reinforce the continued dominance of HIIT research that primarily emphasizes physiological aspects and physical performance.

This pattern is clearly reflected in the keyword analysis conducted using VOSviewer, which identified 1,571 keywords, including 40 major keywords grouped into four research clusters. The most frequently occurring keywords were “High-Intensity Interval Training” (n = 222), “Adolescents” (n = 130), “Physical Exercise” (n = 112), “Interval Training” (n = 83), “Training” (n = 77), “Obesity” (n = 69), “Cardiorespiratory Fitness” (n = 57), “Physical Fitness” (n = 54), “Physical Activity” (n = 53), and “Body Composition” (n = 40). The prominence of these keywords indicates that HIIT research involving adolescents continues to concentrate heavily on improving physical fitness, enhancing metabolic health, and reducing obesity (Jovanović et al., 2024; Meng et al., 2022; Srisuk, 2025).

Nevertheless, the strong emphasis on physiological aspects reflects a limited paradigm in understanding adolescent physical activity. Adolescent health challenges are not solely associated with physical conditions, but are also influenced by motivation, educational environments, self-perception, and the ability to recognize the importance of physical activity. In this context, the concept of physical literacy becomes highly relevant. Physical literacy is regarded as a fundamental basis that encourages individuals to engage in regular physical activity throughout their lives. Previous studies have demonstrated that physical literacy, physical activity, and learning motivation are positively and significantly associated with

students' learning outcomes. Adolescents with higher levels of physical literacy tend to show greater participation in physical activity, stronger academic motivation, and more active involvement in physical education learning.

The integration of HIIT with physical literacy has become increasingly relevant because HIIT is characterized by short, varied, and enjoyable exercise sessions, making it well suited to the needs of adolescents in school environments where instructional time is often limited. In this context, HIIT is no longer viewed solely as a physical training method, but also as a pedagogical strategy capable of enhancing student engagement, learning motivation, and meaningful movement experiences. This paradigm shift is reflected in the emergence of new keywords such as "Physical Education" and "Football," which have begun to receive greater attention in recent studies. Rockey et al., (2023) explained that the direction of HIIT research is gradually shifting from a predominantly physiological focus toward applications in physical education and sports learning. Similarly, Patricio Arturo et al., (2025) emphasized that HIIT is increasingly being recognized as a pedagogical approach that supports active learning and student participation.

Furthermore, the emergence of the keyword "Football" indicates that HIIT is increasingly being implemented in team sports, particularly soccer. HIIT is considered highly compatible with the demands of soccer, which requires repeated high-intensity activities, aerobic endurance, speed, agility, and rapid decision-making abilities (Thomakos et al., 2024). The integration of HIIT into game-based training models is also regarded as more effective and enjoyable for adolescents because it combines physical conditioning with the development of technical and tactical sport skills (Prasad et al., 2025). This approach aligns closely with the concept of physical literacy, as students are not only trained physiologically but are also encouraged to develop cognitive abilities, decision-making skills, and self-confidence through movement activities.

On the other hand, the findings also reveal a paradox within educational environments regarding adolescent physical activity and health. Research has shown that students in public schools tend to demonstrate higher levels of physical activity and greater muscular strength, yet they also exhibit a higher risk of obesity compared to students in Islamic boarding schools (Adi et al., 2020). In contrast, students in boarding schools generally present more normal body mass index levels despite lower physical activity participation, while also showing better concentration and stronger learning interest (Firmansyah et al., 2022). These findings suggest that adolescent health is shaped by a complex interaction of environmental factors, activity patterns, lifestyle habits, and educational approaches. Therefore, the implementation of HIIT based on physical literacy in schools may provide an effective strategy for balancing physical health, learning motivation, and adolescents' psychological development.

Although HIIT research has developed rapidly, the bibliometric analysis reveals several significant research gaps that remain insufficiently explored. Keywords with relatively low frequencies, such as "Women" (n = 8), "School" (n = 10), "Fatigue" (n = 9), and "RPE" (n = 9), indicate that psychosocial, pedagogical, and gender-related aspects continue to receive limited attention. Most existing studies still emphasize short-term physiological outcomes, while issues related to motivation, self-concept, emotional well-being, and the psychological responses of adolescent girls to HIIT remain underrepresented in the literature (Leahy et al., 2020). In fact, previous research has shown that adolescent girls generally exhibit lower levels of physical activity and are more vulnerable to increased body fat accumulation and obesity (Adi et al., 2020). These findings highlight the need for more inclusive and gender-sensitive research approaches in the implementation of HIIT among adolescents.

In addition, this bibliometric study has several methodological limitations. The analysis relied solely on the Scopus database, which may not fully capture all relevant publications available in other databases such as Web of Science and Google Scholar. The use of a single

database may introduce citation bias and limit the overall research coverage (Echchakoui 2020; Mongeon & Paul-Hus 2016). Furthermore, the use of only two primary keywords in the search process may have reduced the ability to identify all studies related to HIIT among adolescents comprehensively.

Overall, the development of HIIT research among adolescents demonstrates a paradigm shift from a predominantly physiological perspective toward a more holistic and interdisciplinary approach. HIIT is no longer viewed merely as an exercise method for improving physical fitness, but also as an educational strategy that can support physical literacy, learning motivation, character development, and the overall well-being of adolescents. Therefore, future studies should integrate physiological, pedagogical, psychological, and social dimensions to ensure that the implementation of HIIT provides more comprehensive benefits for adolescent health and educational outcomes. Such an approach is also essential for creating movement experiences that are more inclusive, enjoyable, and sustainable, thereby contributing to improved quality of life among adolescents while simultaneously reducing global rates of obesity and sedentary behavior.

However, despite growing evidence of HIIT's benefits among adolescents, several limitations remain in current research. Most studies still focus primarily on short-term physiological outcomes, such as body composition, cardiovascular fitness, and metabolic responses, while paying limited attention to the long-term sustainability of HIIT participation, psychological adaptation, and social influences among adolescents. In addition, many studies involve relatively small sample sizes, specific populations, male adolescents, overweight participants, or short intervention durations, which may limit the generalizability of findings across diverse adolescent groups.

Another limitation is the inconsistency in HIIT protocols, including variations in intensity, duration, recovery periods, and frequency, making it difficult to establish standardized recommendations for school or community settings. Furthermore, broader educational and psychosocial outcomes such as motivation, enjoyment, adherence, and emotional well-being are still underexplored in comparison to physiological indicators. Therefore, future studies are encouraged to adopt longitudinal and multidisciplinary approaches that integrate physical, psychological, social, and educational dimensions to better understand the comprehensive impact of HIIT on adolescent development and health outcomes.

Conclusions

Consistent improvement shows significant attention from researchers to the effectiveness of HIIT in increasing cardiovascular fitness, body composition, and health among teenagers. The United States, the United Kingdom, and Australia have contributed to and influenced the scientific field at the highest level, which shows their important position in the network. The same international findings from bibliometric analysis also indicate changes in research focus and aspects of physiology related to the application of HIIT in Physical Education and improving fitness. However, there is still a lack of research to be done to pay attention, especially regarding the physiological and pedagogical mechanisms that underpin HIIT for teenagers. Therefore, future research is recommended to explore the long-term effects of HIIT Interventions on various adolescent populations, including variations in age, gender, Physical fitness levels, and sociocultural backgrounds. Further studies should also investigate the optimal duration, intensity, and frequency of HIIT programs implemented in school-based Physical education settings to maximize physiological adaptation and student engagement.

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5 Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article. All authors confirm that they have no financial, personal, or professional relationships that could have influenced the research, analysis, interpretation of the results, or the writing of this manuscript.

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