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Review Article

Analyzing Research Trends on High Intensity Interval Training and Oxidative Stress: A Bibliometric Analysis (2003-2024)

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

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Abstract

Background. Exercise-induced oxidative stress, often resulting from high-intensity interval training (HIIT), can cause short-term declines in performance due to alterations in cellular and DNA function. Therefore, oxidative stress markers have gained increased attention for their potential role in reducing risks and improving individual performance.

Objectives. This study aimed to assist researchers and practitioners in grasping current research trends and exploring future research directions in the field of oxidative stress and HIIT.

Materials and methods. This paper presents a comprehensive bibliometric overview and visualization of research on oxidative stress in HIIT, analyzing 192 publications from the Scopus database. Scopus was chosen for data extraction due to its prominence as Elsevier's citation database, high-quality peer-reviewed works, and four metrics: h-index, CiteScore, SCImago Journal Rank (SJR), and Source Normalized Impact per Paper (SNIP).

Results. By employing various visualization tools to analyse influential authors, organisations, and keywords, the paper identifies leading publications and key research clusters related to oxidative stress in HIIT.

Conclusions. Through performing citation and reference co-citation analyses, the study highlights central research topics and emerging trends pertaining to oxidative stress in HIIT.

Keywords: high-intensity interval training, oxidative stress, exercise, bibliometrics.

Introduction

High-intensity interval training (HIIT) is recognized as a highly effective and time-efficient method for enhancing cardiorespiratory and metabolic functions, significantly contributing to optimizing physical performance across different domains (Sarkar et al., 2021). In general, High-intensity interval training offers several benefits. It is distinguished by short periods of vigorous physical activity (approximately 85–90% of VO_2max), usually lasting one to four minutes, followed by intervals of lower-intensity exercise or rest (Alansare et al., 2018). This training program was rated top in the health and fitness trends because of its time-saving nature (Petersen et al., 2016; Thompson, 2018). Moreover, this methodology capitalizes on the efficiency of workout time and contributes to a broad spectrum of fitness improvements, embodying a multifaceted approach to physical conditioning (Laursen and Jenkins, 2002). HIIT is a promising alternative to traditional endurance training, achieving similar or better improvements in physiological, performance, and health outcomes across both healthy and diseased populations (Gibala et al., 2008). It also helps manage oxidative stress, a key factor in cellular damage and overall health, highlighting its effectiveness in boosting fitness, supporting cellular health, and fostering resilience.

Oxidative stress represents a fundamental biological phenomenon characterized by an imbalance between the generation of reactive oxygen species (ROS) and the organism's capacity to neutralize them through antioxidant defenses (Sies, 2020). This imbalance can lead to significant cellular damage, affecting proteins, lipids, and DNA. Such damage is implicated in various health conditions, including chronic diseases and the aging process (Oxidative Stress, MODRN, n.d.). In 1956, Denham Harman introduced the free radical theory of aging, highlighting the detrimental effects of free radicals (Harman, 1956). According to this theory, the production of ROS, which are oxygen-containing

molecules that can form free radicals, is a byproduct of metabolic processes. Although ROS are naturally produced during normal metabolism (Forsberg et al., 2001), excessive accumulation of these species can inflict harm on cellular macromolecules, including proteins, DNA, and lipids (Gutteridge et al., 1996; Halliwell, 1996). To counter such damage, the body relies on an array of antioxidants—metabolites and enzymes that counteract the detrimental effects of ROS by neutralizing free radicals, thereby safeguarding cellular components (Pham-Huy et al., 2008; Cooper et al., 2002).

Understanding the relationship between oxidative stress and high-intensity interval training (HIIT) is critical because HIIT is known to reduce oxidative stress and enhance overall health outcomes. Bibliometric analysis, which involves the statistical examination of research publications, can provide valuable insights into the evolving body of knowledge on this topic. Given the increasing volume of research on both oxidative stress and HIIT in recent years, there is a pressing need for a comprehensive review. The current study aims to address this gap by conducting a bibliometric analysis using the Scopus database, summarizing and evaluating the research landscape concerning oxidative stress and HIIT.

The structure of the paper is organized as follows: Part 2 outlines the study methods, Part 3 presents the analysis results, Part 4 provides an in-depth discussion of the results, and Part 5 presents the study's conclusion and provides guidance for future research.

Material and Methods

Development of Research Questions

This study's main objective was to conduct a bibliometric analysis of HIIT and Oxidative Stress manuscripts that were published in the Scopus database. Some research questions have been formulated to help achieve this goal. Table 1 shows these questions and their significance.

Data Extraction

Selecting the appropriate search engine for data extraction is essential. In this study, Scopus was chosen for data extraction due to its prominence as Elsevier's citation database, high-quality peer-reviewed work, and four metrics: h-index, Cite Score, SCI Imago Journal Rank (SJR), and Source Normalized Impact per Paper (SNIP) (Sidhu et al., 2020).

The total number of papers published in Scopus in the field of oxidative stress and HIIT were 229. The following method were used to search for publication topic word = ("High Intensity Interval Training" OR "High-Intensity Interval Training" OR "High Intensity Intermittent Training" OR "High-Intensity Intermittent Training" OR "High Intensity Intermittent Exercise" OR "High-Intensity intermittent Exercise" OR "High Intensity Interval Exercise" OR "High-Intensity Interval Training" AND "Oxidative Stress" OR "Oxidative Stresses" OR "Oxidative Damage") time period = 2003 to 2024. In our review of previous bibliometrics literature (You et al., 2021) we only included articles and reviews that were written in English. Therefore, any works not in English were excluded from our analysis.

Table 2. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Language	English	Other than English
Time period	2003-2024	<2003
Literature	Articles, Reviews	Book chapter, short survey, Note and Editorial
Publication stage	Final	Article in press
Subjects	Human	Animals

Analysis Tool

The study used VOSviewer to analyze literature on the relationship between oxidative stress and HIIT. The

Table 1. Research questions and their importance

Research Questions (RQ)	Importance
RQ1: What is the annual Trend oxidative stress and HIIT?	It is important to determine the yearly volume of publications on oxidative stress and HIIT, as this can help predict future trends.
RQ2: Which author contributed more to oxidative stress and HIIT research?	It would assist researchers in locating specific studies, authors, and their link for conducting high-quality research on oxidative stress and high-intensity interval training.
RQ3: Which Subject area published more research work on oxidative stress and HIIT?	It will help to identify the Main Subject area on oxidative stress and high-intensity interval training in various areas and types of documents.
RQ4: What is the topmost publication with citations for oxidative stress and HIIT?	It would be beneficial for researchers studying oxidative stress and high-intensity interval training to carefully select conferences, universities, and journals to publish their research work. This decision could potentially impact the future citations of their papers.
RQ5: Which are the leading countries in the publication of oxidative stress and HIIT?	It would help researchers and practitioners understand which countries are focusing more on oxidative stress and high-intensity interval training. This will enable them to contribute their research work in those countries for future publications.
RQ6: What is the keyword network of oxidative stress and HIIT?	It will be an easy method of searching for future research. This will assist researchers in pinpointing future research directions.

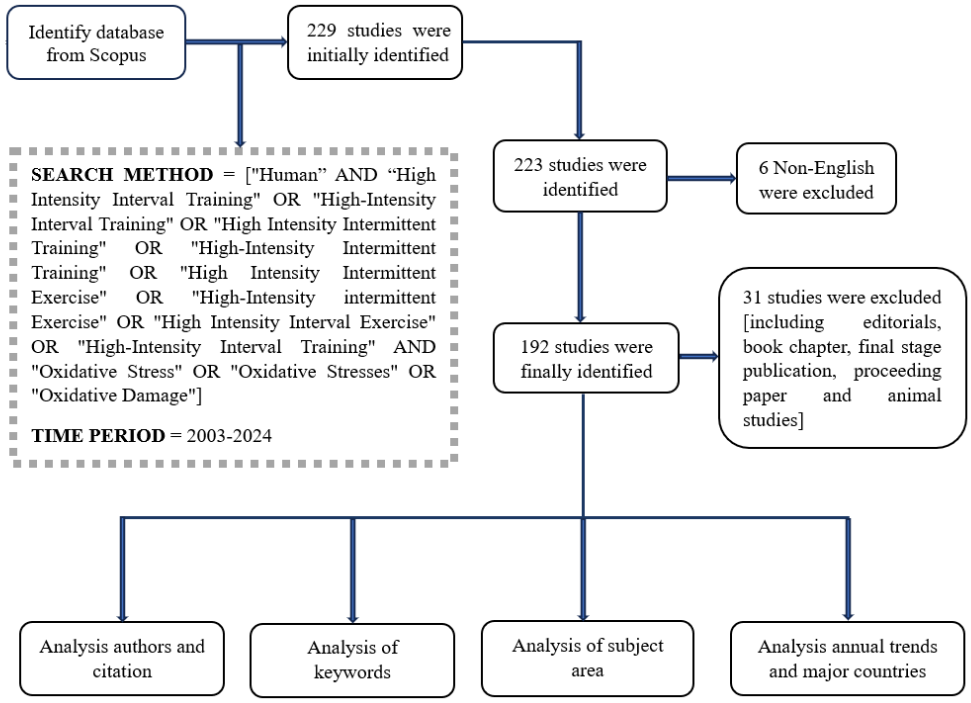

Fig. 1. Flow Diagram with the stages of the methodology for selecting manuscripts

visualizations revealed key authors, influential publications, and key research areas. VOSviewer also analyzed citations to identify the most frequently cited papers. The analysis helped identify critical developments, influential studies, and emerging research directions in the field. The visualizations provided a clear understanding of the major themes and focus areas within the research. Overall, VOSviewer's analytical capabilities provided valuable insights into the evolving research landscape of oxidative stress and HIIT.

Results

Citation Analysis

The study "Analyzing Research Trends on HIIT and Oxidative Stress: A Bibliometric Analysis (2000-2023)" provides a comprehensive analysis of research trends, including annual publications, key referenced documents, influential authors, major journals, and prominent countries in the area.

Table 3 presents a summary of the top 10 most cited publications in the field of high-intensity interval training (HIIT) and oxidative stress. This information provides an overview of the leading publications across various journals and addresses the research gaps concerning oxidative stress and HIIT. The study conducted by Gibala and McGee (2008) has received the most citations, totalling 523, in the Journal of Exercise and Sports Sciences Review. The study concluded that HIIT can significantly enhance skeletal muscle oxidative capacity, endurance performance, and metabolic control during aerobic-based exercise, even with just six sessions over two weeks. Ramos et al. (2015) performed a systematic review and meta-analysis comparing HIIT to moderate-intensity interval training on vascular function; this publication has garnered 488 citations and is published in Sports Medicine. The paper titled "The Effects of High-

Table 3. Analysis of citations among various authors

S. No.	Authors	Source/Journal	Total Citations
1	Gibala (2008)	Exercise and sports sciences review	523
2	Ramos (2015)	Sports Medicine	488
3	Jelleyman (2015)	Obesity Review	409
4	Papadopoulou (2020)	Nutrients	217
5	Malinowski (2019)	Nutrients	157
6	Mahalakshmi (2020)	International Journal of Molecular Science	143
7	Bogdanis (2013)	Food and Chemical Toxicology	135
8	Flockhart (2021)	Cell Metabolism	119
9	Hull (2020)	The Lancet Respiratory Medicine	117
10	Huang (2019)	Nutrients	105

Intensity Interval Training on Glucose Regulation and Insulin Resistance: A Meta-Analysis" by Jelleyman et al. (2015) has received 409 citations in the Obesity Review Journal. The study by Papadopoulou (2020), published in Nutrients, received 217 citations. Additionally, Papadopoulou's (2020) study on intermittent fasting and cardiovascular disorders, also published in Nutrients, has gathered 157 citations. Furthermore, the study conducted by Mahalakshmi et al. (2020), published in the International Journal of Molecular Sciences, received 143 citations.

Likewise, Bogdanis et al. (2013) investigated the effects of short-term HIIT on oxidative stress and antioxidants in healthy individuals. Their research received 135 citations and is published in the Journal of Food and Chemical Toxicology. Additionally, research by Flockhart et al. (2021) received a total of 119 citations and is published in Cell Metabolism. Furthermore, the study by Hull et al. (2020), published in The Lancet Respiratory Medicine, received 117 citations. Huang et al. published a scholarly article entitled "The Beneficial Effects of Lactobacillus plantarum PS128 on High-Intensity, Exercise-Induced Oxidative Stress, Inflammation, and Performance in Triathletes" in the Journal of Nutrients, which received a total of 105 citations. This citation analysis highlights the most impactful research and authors in the field of high-intensity interval training and oxidative stress.

Yearly Publications

The graph depicted in Figure 2 illustrates the annual number of publications on high-intensity interval training and oxidative stress that have been published or indexed in Scopus from 2003 to 2024. Between 2003 and 2014, the number of yearly publications ranged from 0 to 4, indicating minimal emphasis on this topic. The number of publications has shown a clear upward trend since 2015, with a range of 3 to 24 from 2015 to 2020. In 2021 and 2022, there was a slight reduction, with 22 and 21 publications respectively. However, in 2023, there was a significant increase, reaching a peak of 35. In 2024, there is a positive trend, with 18 articles published so far, and it is expected to approach the publication numbers of 2023. Overall, the data shows that the number of publications has been increasing over the last 20 years, although there are annual variations in the publication numbers.

Subject Area Analysis

Figure 3 depitics the prominent subject area in the field of HIIT and Muscle Damage. The fields of Medicine and Biochemistry have the highest number of publications, with 133 and 79, respectively. This indicates that the medical field is particularly prominent in the study of HIIT and oxidative stress. The field of Nursing and Health Profession contributed 23 and 22 publications respectively, showing a valuable focus on health parameters of an individual. The subject area of Agricultural and Biological Sciences is having less publications amounted by 17. Furthermore, subjects contribute little less are Chemistry, Pharmacology, Toxicology and Pharmaceutics, and Neuroscience documents amounted 8, 8, and 7 respectively, indicating less emphasis on the neuron and biochemical parameters.

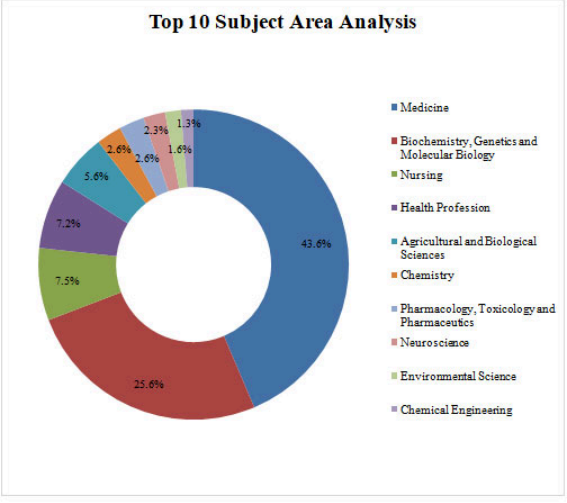

Fig. 3. Subject area analysis

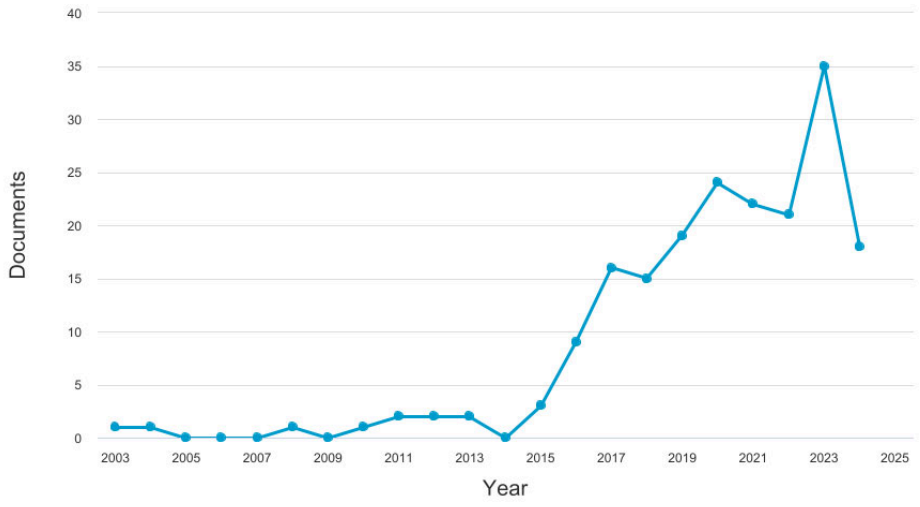

Fig. 2. Yearly publications

The field of Environmental Science and Chemical Engineering each contributed 5 documents, suggesting that researchers from diverse fields are also being involved in the study of HIIT and Oxidative Stress. In general, the data indicate that HIIT and oxidative stress are interdisciplinary topics involving multiple domains. A thorough understanding of this concept requires integrating knowledge from various fields.

Co-occurrence of Keywords

Figure 4 demonstrates keyword clustering based on co-occurrence. An appropriate method was deployed to analyze the co-occurrence of keywords related to HIIT and oxidative stress. A total of 3056 keywords were extracted from 192 research articles, with 346 keywords occurring a minimum of 5 times. The selected keywords were classified into 4 clusters. Cluster one consists of 111 items. In general, a larger circle indicates more frequent use of that keyword in scholarly work. The study reveals that keywords such as "oxidative stress", "High intensity interval training", "tumor necrosis factor", "human", "exercise intensity", "male", and "metabolism" are more frequently used in comparison to "obesity", "body mass", "insulin", and "dietary supplement". Future research should explore these keywords and current trends in relation to HIIT and oxidative stress, aiming to provide a more comprehensive understanding.

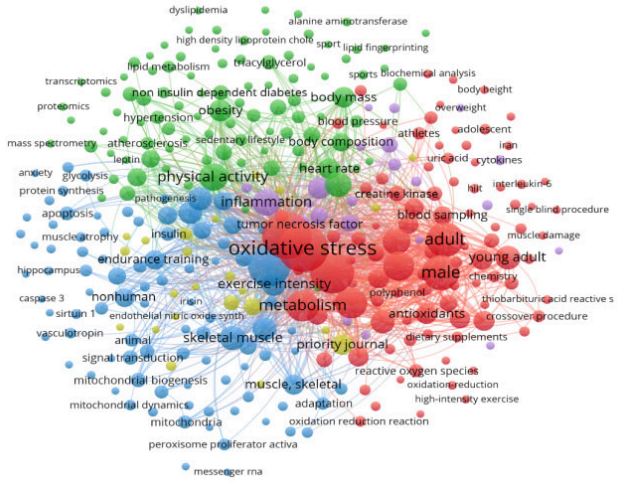

Fig. 4. Co-occurrence of keywords

Country Analysis

From 2003 to 2024, the United States ranked highest in HIIT and oxidative stress publications, with 26 documents, attributed to its advanced technology and research infrastructure in sports sciences, according to Figures 5 and 6. China follows closely with 24 documents, reflecting significant advancements in research. The United Kingdom and Brazil have published 22 and 18 documents, respectively, indicating substantial contributions to the field of HIIT and oxidative stress. Canada, Iran, and Australia have contributed 15, 13, and 12 documents, respectively. Additionally, Denmark, Spain, and Poland have 10, 9, and 8 publications, respectively, demonstrating growing

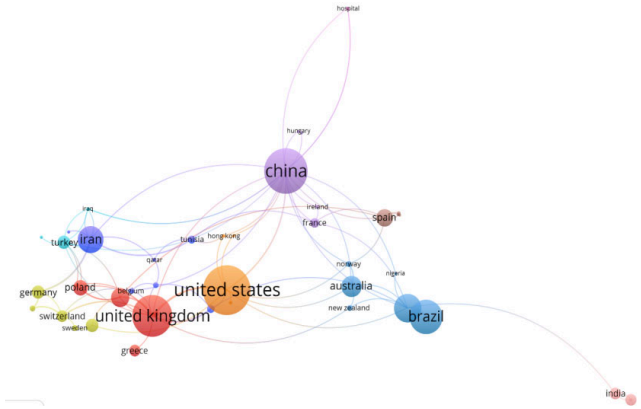

Fig. 5. Top most contributed countries

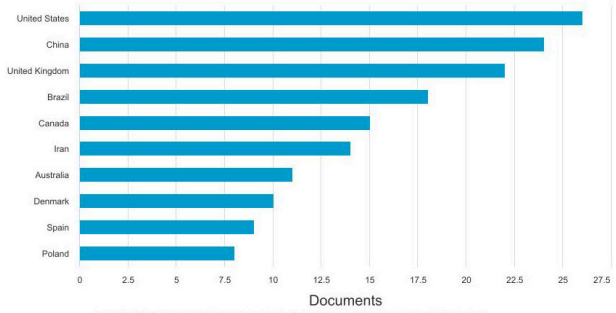

Fig. 6. No. of document published by top 10 countries

investments in sports sciences and research. These nations are characterized by advanced technology and substantial research investments, which have positioned them at the top of this research area.

Top Authors

Figure 7 displays the top authors and their publications in HIIT and oxidative stress. The top seven authors each have published four articles, reflecting a high level of competition within the field. Among them, the leading author is Candow, D.G., who has published four papers, followed by Davison, G.W., with an equal number of publications. Additionally, Dehghan, P., Levinger, I., Parker, L., Shaw, C.S., and Stepto, N.K. have each contributed four papers. Bangsbo, J. has published three articles, closely followed by Chatzinikolaou, A. and Deli, C.K., each with three publications. Figure 8 illustrates the clusters of authors who are actively involved in this research area, highlighting their significant contributions to the field of high-intensity interval training and oxidative stress.

Discussion

This study aims to analyze research collaboration and associations in HIIT and oxidative stress from 2003 to 2024 using the Scopus database. It extracts 192 publications and 5,555 citations, including studies involving human subjects, review articles, and original research articles, from 2003 to 2024.

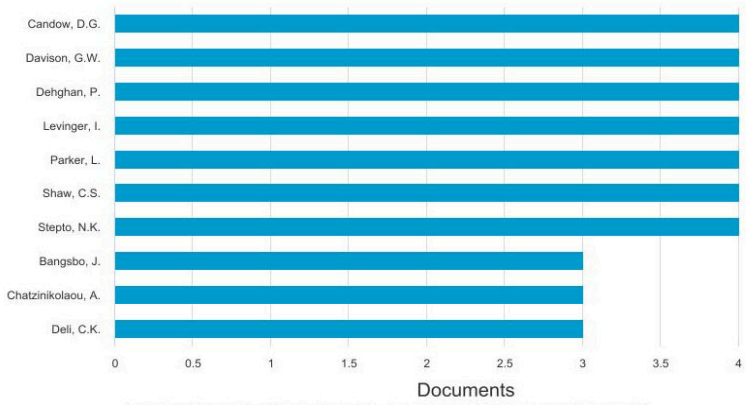

Fig. 7. Top Authors and their publication counts

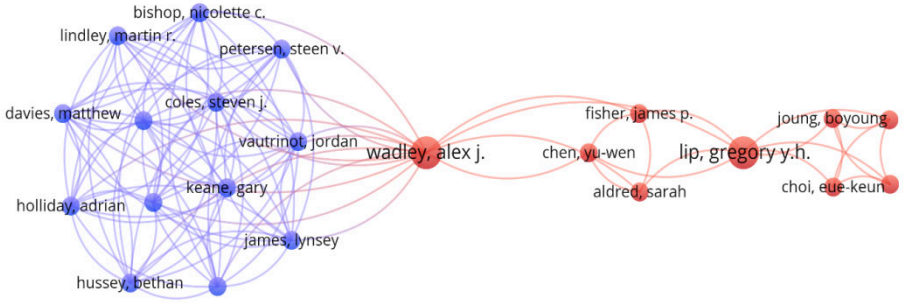

Fig. 8. Co-authorship between authors

RQ1: What is the annual trend in research on oxidative stress and HIIT?

The publication trend for research on HIIT and oxidative stress is illustrated in Figure 2, which provides valuable insights. From 2003 to 2014, the number of publications remained relatively stable, ranging from 1 to 4 per year. From 2014, there was a marked increase, continuing until 2020. In 2021 and 2022, there was a slight decline in the number of publications; however, in 2023, the number of publications surged again, reaching a peak with 35 publications.

RQ2: Which authors have contributed most to research on oxidative stress and HIIT?

Result revealed that Candow, D.G, Davison, G.W., Dehghan, P., Levinger, I., Parker, L., Shaw, C.S., and Stepto, N.K. are the most prominent authors, having published 4 papers each, as shown in figure 7.

RQ3: Which subject areas have published the most research on oxidative stress and HIIT?

Figure 3 illustrates that the field of Medicine has produced the highest number of papers on HIIT and oxidative stress, with 133 publications. Biochemistry ranks second with 79 publications. Nursing and Health Professions are ranked fourth and fifth, respectively. Other prominent subject areas include Agricultural and Biological Sciences, Chemistry, Pharmacology, Toxicology and Pharmaceutics, and Neuroscience.

RQ4: Which countries are leading in the publication of research on oxidative stress and HIIT?

Figure 6 shows the leading countries in terms of publication output. The United States holds the top position with 26 papers, closely followed by China with 24 publications. Other notable countries include the United Kingdom, Brazil, Canada, and Iran.

RQ5: What are the key terms associated with oxidative stress and HIIT?

In the final network analysis, 3,056 keywords were selected. These keywords were categorized into four clusters: Cluster 1 contains 111 keywords, Cluster 2 contains 108 keywords, Cluster 3 includes 101 keywords, and Cluster 4 consists of 25 keywords. The most frequently used keywords are "oxidative stress," "high intensity interval training," and "human," while less common keywords include "obesity," "body mass," "insulin," and "dietary supplement."

RQ6: Which publication has the most citations in the field of oxidative stress and HIIT?

Table 3 highlights the most cited publications in the field. Gibala and McGee (2008) are identified as the most influential authors with their study titled "Metabolic Adaptations to Short-Term High-Intensity Interval Training: A Little Pain for a Lot of Gain?" This publication has received 523 citations. Additionally, Ramos et al. (2015) has received 488 citations, while Jelleyman et al. (2015) has been cited 409 times.

Theoretical Implications

The present study makes the following contributions:

This study provides the first bibliometric analysis of HIIT and oxidative stress within the Scopus-indexed literature.

The outcomes of this bibliometric analysis will offer significant benefits to the academic community by guiding future researchers in exploring novel areas of inquiry and establishing a comprehensive foundation for diverse and impactful research projects.

Limitation of the Study

Despite the objective and comprehensive nature of the data analysis in this study, several limitations should be acknowledged. First and foremost, this bibliometric analysis is limited to articles indexed in the Scopus database, excluding other major databases such as Web of Science and PubMed. Second, the analysis is confined to studies published between 2003 and 2024, thereby excluding research conducted prior to 2003. Finally, this study only includes publications in English, omitting research published in other languages.

Conclusion

The study presents a bibliometric analysis of 192 studies on HIIT and Oxidative Stress from 2003 to 2024 based on the scopus database, revealing a significant increase in research activity since 2014, with a peak in 2023. Key contributors include Candow and Davison, with the Medicine field dominating with the highest number of publications. Geographically, the United States and China are the top contributors, followed by the United Kingdom, Brazil, Canada, and Iran. Keyword analysis highlights core terms like "oxidative stress," "HIIT," and "human," while less frequent terms include "obesity" and "dietary supplement." Gibala and McGee (2008) publication is the most cited, indicating its substantial impact on the field. These findings highlight the growing interest and diverse contributions to HIIT and oxidative stress research.

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Conflicts of Interests

The authors declared no conflicts of interest regarding the study.

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Аналіз дослідницьких тенденцій щодо вивчення високоінтенсивних інтервальних тренувань та оксидативного стресу: Бібліометричний аналіз (2003-2024)

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

Реферат. Стаття: 9 с., 3 табл., 8 рис., 25 джерел.

Історія питання. Оксидативний стрес, індукований фізичними вправами, який часто виникає внаслідок виконання високоінтенсивних інтервальних тренувань (ВІІТ), може викликати короткострокове зниження результативності через зміни у функціонуванні клітин та ДНК. Враховуючи цей факт, маркери оксидативного стресу привертають підвищену увагу через їхню потенційну роль у зниженні ризиків та поліпшенні показників індивідуальної результативності.

Мета дослідження. Дослідження мало на меті сприяти дослідникам і практикам у розумінні сучасних наукових тенденцій та вивченні подальших напрямків досліджень у галузі оксидативного стресу та ВІІТ.

Матеріали та методи. У статті представлено комплексний бібліометричний огляд та візуалізацію досліджень з вивчення оксидативного стресу під час виконання ВІІТ, що включає аналіз 192 публікацій з наукометричної бази даних Scopus. З метою отримання даних було обрано базу даних Scopus з огляду на її авторитетність як бази даних цитування Elsevier, високу якість рецензованих робіт та чотири метрики: h-індекс, CiteScore, SCImago Journal Rank (SJR) та Source Normalized Impact per Paper (SNIP).

Результати. Використовуючи різні інструменти візуалізації для аналізу робіт авторитетних науковців, організацій та ключових слів, у статті визначено провідні публікації та ключові дослідницькі кластери щодо вивчення оксидативного стресу в умовах ВІІТ.

Висновки. Шляхом проведення аналізів цитування та коцитування посилань, дослідження висвітлює основні теми наукових робіт та новітні тенденції, пов'язані із оксидативним стресом під час виконання ВІІТ.

Ключові слова: високоінтенсивне інтервальне тренування, оксидативний стрес, фізичні вправи, бібліометрія.

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