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The impact of high-intensity interval training on women's health: A bibliometric and visualization analysis

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Abstract

Background: High-intensity interval training (HIIT) can significantly improve health indicators such as cardiopulmonary function, metabolic efficiency, and muscle strength in a short period. However, due to significant physiological and metabolic differences between males and females, the effects of HIIT vary between genders. Therefore, exploring the specific impacts of HIIT on women's health is crucial. Although there is a considerable amount of individual research on the impact of HIIT on women's health, a systematic bibliometric analysis is still lacking.

Methods: Publications related to HIIT in women's health were retrieved from the Web of Science Core Collection database, and tools like Microsoft Office Excel 2021, VOSviewer, and Citespace were used to create visualized tables and views.

Results: The study included 808 publications distributed across 1234 institutions in 61 countries, authored by 3789 researchers. The United States, Australia, and Canada lead in this domain. Researchers like Astorino TA and Gibala MJ are notably influential in this field. The research has been prominently published in specific academic journals and widely cited by high-impact journals. Highly cited and bursting documents primarily discuss the effects of HIIT on metabolic adaptation, muscle adaptation, cardiovascular health, insulin sensitivity, and exercise performance. Frequent keywords include "aerobic exercise," "sprint interval training," "resistance training," "obesity," "body composition," "aging," and "insulin resistance." Keyword burst analysis reveals that early studies focused primarily on basic concepts and training models, which then expanded to specific physiological responses, applications in particular populations, and impacts on specific diseases.

Conclusion: This field has emerged as a research hotspot with international characteristics and extensive academic productivity. Journals and cited journals hold high academic influence, with highly cited and bursty references laying a solid theoretical and practical foundation for the field. In the rapid development of the past decade, research hotspots and frontier directions such as metabolic adaptation, muscle adaptation, cardiovascular health, exercise performance, and personalized training plans have been formed.

Abbreviation: HIIT = high-intensity interval training.

Keywords: bibliometric, high-intensity interval training, HIIT, women, women's health

1. Introduction

High-intensity interval training (HIIT) involves short bursts of intense exercise alternated with low-intensity recovery periods, including activities such as sprinting, jumping, and strength training. This method is often used to enhance cardiopulmonary function, metabolic efficiency, and muscle strength.[1,2] Due to its significant health benefits within a short duration, HIIT has garnered extensive attention and application in the fields of exercise science and public health. However, there are notable physiological and metabolic differences between men and women, leading to varying effects of HIIT in these groups. For instance, women often exhibit more pronounced psychophysiological responses to HIIT compared to men, particularly under conditions involving blood flow restriction, where women show higher perceived exertion and heart rate responses.[3] Moreover, women's recovery rate post-HIIT differs from men's, potentially due to gender differences in energy metabolism, muscle fiber type distribution, and hormonal levels.[4] In terms of metabolic adaptation, research suggests that men have a stronger response in muscle protein synthesis and mitochondrial biogenesis, indicating that men may experience better muscle adaptation to HIIT.[5] Additionally, there are significant gender differences in fatigue resistance and performance

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

No ethical approval is required because this study is a bibliometric analysis

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improvements during HIIT.[6,7] These differences suggest that men and women may have distinct training adaptations and performance enhancements during HIIT. Thus, examining the specific impacts of HIIT on women's health is of paramount importance. Studies indicate that HIIT not only improves women's cardiopulmonary and metabolic health but also positively affects weight management and psychological well-being.[8–10] However, despite numerous individual studies on the impact of HIIT on women's health, there is a lack of systematic bibliometric analysis.

This study aims to comprehensively review and assess the current research status, hotspots, and frontiers of HIIT's impact on women's health through bibliometric analysis. Specifically, this research will collect publications from the Web of Science database; subsequently, using Excel, VOSviewer, and Citespace, it will perform statistical analysis on the annual distribution of publications, countries/regions, institutions, authors, journals and cited journals, cited documents, and keywords to provide visualized tables and views that comprehensively describe the state of research in this field. Finally, based on the analysis of cited documents and keywords, this study will explore the research hotspots and frontiers in this domain.

2. Materials and methods

2.1. Data sources and search strategy

This study uses the Web of Science Core Collection's Science Citation Index Expanded and Social Sciences Citation Index as data sources. The search was conducted on June 29, 2024, with the search formula TS=("High Intensity Interval Training*" OR "High Intensity Intermittent Exercise*" OR "Sprint Interval Training*") AND TS=("women" OR "female*" OR "girl*"). There was no date restriction, language was restricted to English, and publication types were limited to articles or reviews. Publications irrelevant to "HIIT's impact on women's health" and those with limited translational potential, such as animal studies, were excluded to ensure uniformity in analysis and interpretation of results. Clinical trial protocols and research designs were also excluded. Ultimately, this study included 808 publications, comprising 739 articles (91%), and 69 review articles (9%).

2.2. Data analysis

This study employs Microsoft Office Excel 2021, VOSviewer, and Citespace for data management, analysis, and visualization. Specifically, Microsoft Office Excel 2021 is used for data processing and creating views of the annual distribution of publications. VOSviewer generates visual networks for co-authorships among countries/regions, authors, and keyword co-occurrences. Citespace is utilized to create dual-map overlays of journals, views of highly-cited references, keyword clustering timelines, and views of highly-bursting keywords. Additionally, data such as publication counts, citation numbers, collaboration nodes, centrality, and total link strength are gathered and analyzed using VOSviewer and Citespace. The integrated use of these tools enables the study to present data analysis results comprehensively and accurately, offering valuable visual information.

3. Results

3.1. Analysis of annual publication volume

The trend of publication output over time in a specific research field can reflect the vitality and dynamic changes of research activities, helping researchers gauge the continuity and stability of research themes in that field.[11] Figure 1 shows the annual distribution trend of publications in this field from 1978 to 2024, noting that the publication count for 2024 is not yet complete and thus not included in the data comparison. From 1978 to 2009, the annual publication count was generally one or none, with only a few years seeing slightly more, indicating minimal academic attention and research still in its nascent stages. The second phase, from 2010 to 2015, saw a gradual increase in publication numbers. There were 4 publications in 2010 and 6 in 2011, increasing to 7 in 2012 and 13 in 2013. In 2014 and 2015, the numbers significantly rose to 25 and 23 publications respectively, indicating growing interest and emerging research in this field. From 2016 to 2023, the field entered a period of rapid development with a sharp increase in publication numbers, averaging about 82 publications per year, with the highest annual count reaching 118. This indicates widespread attention and extensive research in this area, suggesting that the field has become a hotspot. Moreover, a trend line obtained from regression analysis suggests that the number of publications in this field may continue to grow in the future.

3.2. Analysis of country/region and institution

The number of publications and collaborative relationships across different countries/regions reflect the research activity, productivity, and the structure of international scientific

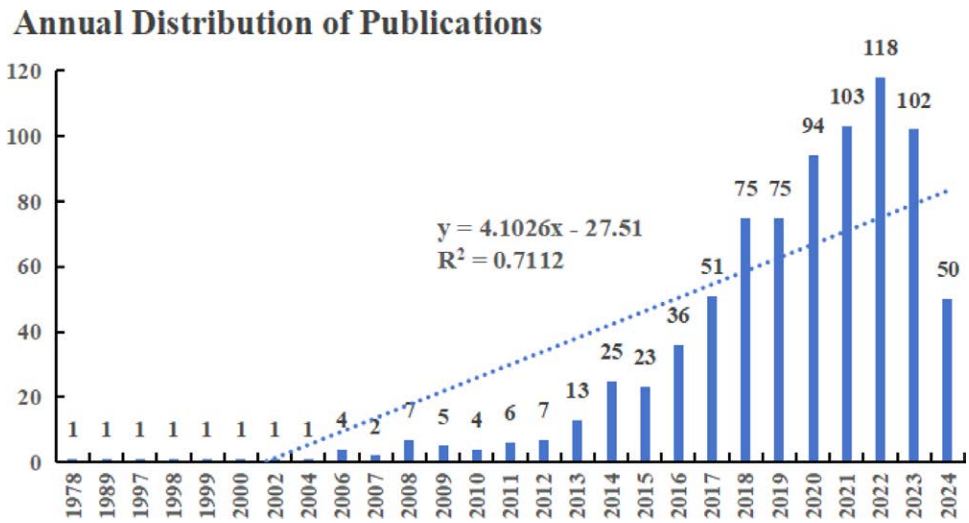

Figure 1. Annual distribution of publications.

collaboration networks in this field.[12] The publications included in this study are distributed across 61 countries. Table 1 lists the top 10 countries/regions in terms of publication counts, where the number of collaboration nodes represents the number of collaborating countries/regions or institutions, centrality values indicate the importance of a node's position in the network, and the total link strength reflects the intensity of interconnections between nodes.

The top 10 countries/regions with the highest number of publications are primarily concentrated in North America, Europe, and the Asia-Pacific region. The United States ranks first with 184 publications (cited 4585 times), and it leads in terms of collaboration nodes (32), total link strength (136), and centrality (0.25), indicating the strongest research capabilities and international cooperation abilities in this field, making it a key player in the international research network. Australia and Canada rank second and third, respectively, with 107 and 104 publications, demonstrating high research impact with average citations of 33 and 37 respectively. The United Kingdom (82 publications), Spain (77 publications), and China (72 publications) also show prominent performance in the field, especially Spain and the United Kingdom, which have high centrality (0.24 and 0.23), indicating their important positions in the international research network. Additionally, Brazil, Norway, Germany, and Iran, although having fewer publications, have also made significant contributions to the field. Figure 2 displays the collaboration network of at least 40 countries with a minimum of 5 publications each, centered around the United States, Australia, Canada, and the United Kingdom, which have closely-knit cooperation networks.

On the other hand, the publications included in the study involved 1234 institutions, and Table 2 lists the top 10 institutions by publication count. The Norwegian University of Science and Technology (36 publications) and the University of Queensland (26 publications) lead the list, hailing from Norway and Australia, respectively. The high citation counts for these institutions (1300 and 792 citations, respectively) highlight their significant research impact. California State University San Marcos (USA, 19 publications) and the University of British Columbia (Canada, 19 publications) also perform well. Notably, the University of Copenhagen (Denmark, 19 publications) and McMaster University (Canada, 18 publications) have fewer publications but boast high average citation counts of 45 and 113, respectively, indicating high research quality. The University of Granada (Spain, 18 publications), Karolinska Institutet (Sweden, 15 publications), and both the University of Macau and Macau Polytechnic Institute (China, 15 and 14 publications, respectively) also hold significant influence in the field.

3.3. Analysis of author

By analyzing the publication volume, citation counts, and collaboration patterns of authors, it is possible to identify prolific authors within the field and understand their collaborative networks.[13] The field comprises 3789 authors, with Table 3 listing the top 10 by publication count. The h-index is utilized to assess the quantity and level of academic output of researchers.[14] Astorino TA, with an h-index of 14, has authored 27 relevant publications, amassing a total of 870 citations, averaging 32 citations per publication, highlighting his significant standing in the field. Additionally, Castillo MJ, with an h-index of 12, stands out with his research garnering 1809 citations in total, averaging 129 citations per publication, indicating his exceptional contributions to the field. Other authors such as Kong Z, Nie J, and Amaro-Gahete FJ have also published extensively in this area and have established strong collaborative ties with other researchers. Figure 3 illustrates the collaboration network among 39 authors with at least 6 publications each. A closely-knit team involving Kong Z, Nie J, Zhang H, Shi Q, and others exhibits a high degree of collaboration strength.

3.4. Analysis of journal and cited journal

The analysis of journals and cited journals based on their citation counts and impact factors helps identify the main academic journals in the field and evaluate their academic influence.[15] The publications included in this study are spread across 241 journals, with Table 4 listing the top 10 journals by publication count. Frontiers in Physiology leads with 49 publications, serving as a primary platform for dissemination. The European Journal of Applied Physiology, with 45 publications totaling 1471 citations, holds considerable influence in the field. PLOS ONE, with 19 publications averaging 51 citations each, demonstrates the high academic quality of the articles it publishes. These journals have an average impact factor of approximately 3.2, with a total of 305 publications and 7101 citations.

The publications cited 4472 different journals, with Table 5 listing the top 10 cited journals. The most cited journal is Medicine & Science in Sports & Exercise (2416 citations), followed by the Journal of Applied Physiology (1810 citations) and Sports Medicine (1421 citations). These cited journals have an average impact factor of approximately 7.9, totaling 11,178 citations. Notably, Medicine & Science in Sports & Exercise, European Journal of Applied Physiology, PLOS ONE, and the Journal of Strength and Conditioning Research appear in both Tables 4 and 5, indicating that these journals are not only major publication platforms but also crucial mediums for scholarly communication.

Dual-map overlay, which combines citation and cited data, visually represents the citation relationships between journals, aiding in revealing the positions and relative influence of different journals within the research network.[16] As shown in Figure 4, citing and cited journals form distinct clusters on the left and right sides of the map, respectively.[17] Identifying 2 main citation pathways: green and gray. The green pathway denotes frequent

Table 1

Top 10 countries/regions by publication count.

Rank	Country/region	Count	Citation	Average citation	Cooperative node	Centrality	Total link strength
1	United States	184	4585	25	32	0.25	136
2	Australia	107	3560	33	24	0.14	120
3	Canada	104	3825	37	23	0.11	88
4	United Kingdom	82	2192	27	26	0.23	106
5	Spain	77	1104	14	28	0.24	87
6	China	72	721	10	16	0.16	29
7	Brazil	65	849	13	23	0.08	63
8	Norway	46	1537	33	14	0.02	58
9	Germany	42	958	23	20	0.05	54
10	Iran	40	375	9	15	0.05	28

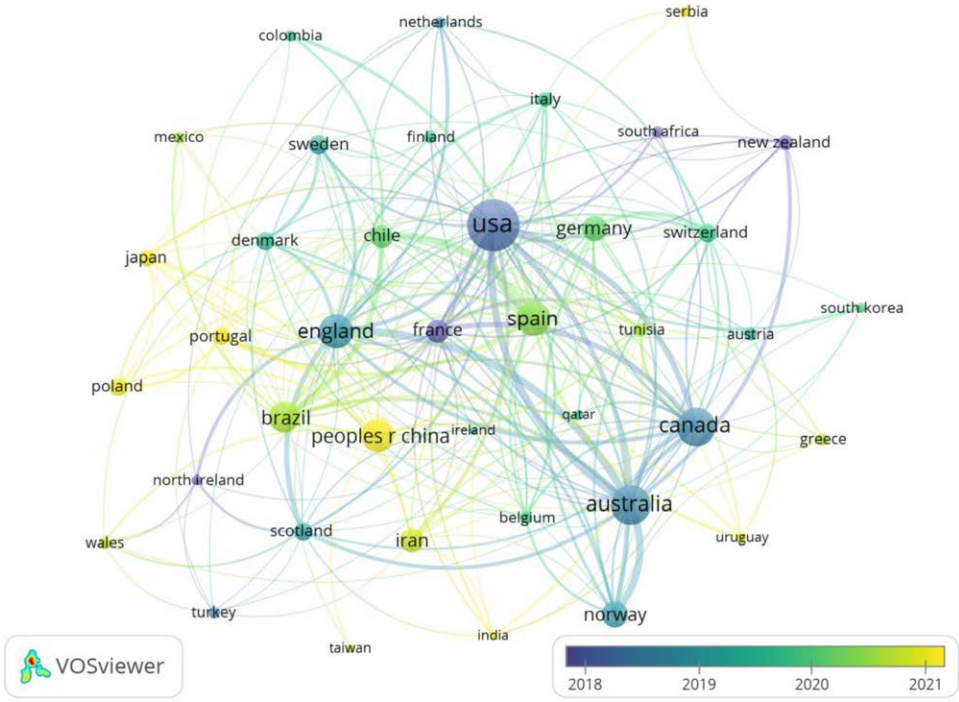

Figure 2. Co-authorship network of countries/regions.

Table 2

Top 10 institutions by publication count.

Rank	Institution	Country/region	Count	Citation	Average citation
1	Norwegian University of Science & Technology	Norway	36	1300	36
2	University of Queensland	Australia	26	792	30
3	California State University San Marcos	United States	19	538	28
4	University of British Columbia	Canada	19	255	13
5	University of Copenhagen	Denmark	19	862	45
6	McMaster University	Canada	18	2030	113
7	University of Granada	Spain	18	226	13
8	Karolinska Institutet	Sweden	15	626	42
9	University of Macau	China	15	323	22
10	Macao Polytechnic University	China	14	298	21

Table 3

Top 10 authors by publication count.

Rank	Author	Count	Citation	Average citation	H-index	Total link strength
1	Astorino, Todd A.	27	870	32	14	106
4	Kong, Zhaowei	15	329	22	9	86
3	Nie, Jinlei	15	310	21	9	87
2	Amaro-gahete, Francisco J.	14	214	15	8	69
5	Castillo, Manuel J.	14	214	15	8	69
6	Gibala, Martin J.	14	1809	129	12	72
7	Ramirez-campillo, Rodrigo	14	338	24	9	81
8	Zhang, Haifeng	13	279	21	8	79
9	Shi, Qingde	12	285	24	8	66
10	Wisloff, Ulrik	11	419	38	9	127

citations from journals in the Medicine/Medical/Clinical fields to journals in the Molecular/Biology/Genetics (z = 1.9849463, f = 752) and Health/Nursing/Medicine (z = 2.8472044, f = 1021) fields. The gray pathway indicates that journals in the Neurology/Sports/Ophthalmology fields frequently cite journals in the Molecular/Biology/Genetics (z = 4.013978, f = 1385), Health/Nursing/Medicine (z = 4.356958, f = 1492), and Sports/Rehabilitation/Sport (z = 3.1292818, f = 1109) fields. Here, "z" values represent standardized citation strength, with higher values indicating greater contributions to the citation pathways; "f" values represent the frequency of citations, with higher numbers indicating more frequent appearances.[14]

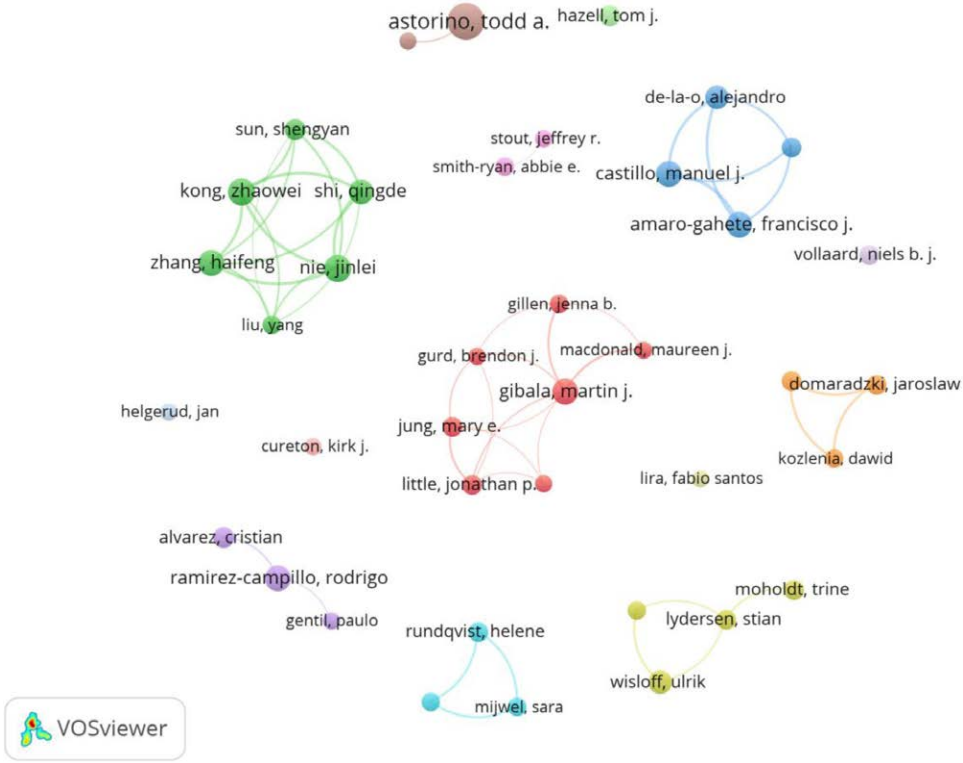

Figure 3. Co-authorship network of authors.

Table 4

Top 10 journals by publication count.

Rank	Journal	Count	Citation	Average citation	Impact factor (2023)
1	Frontiers in Physiology	49	753	15	3.2
2	European Journal Of Applied Physiology	45	1471	33	2.8
3	Journal of Strength And Conditioning Research	42	1056	25	2.5
4	International Journal of Environmental Research and Public Health	37	254	7	7.3
5	Medicine & Science In Sports & Exercise	36	1236	34	4.1
6	Applied Physiology Nutrition and Metabolism	27	709	26	2.4
7	PLOS ONE	19	973	51	2.9
8	Journal of Sports Medicine And Physical Fitness	18	230	13	1.2
9	Journal of Sports Science and Medicine	16	236	15	2.4
10	Scandinavian Journal of Medicine & Science In Sports	16	183	11	3.5

Table 5

Top 10 co-cited journals by citation count.

Rank	Journal	Citation	Impact factor (2023)
1	Medicine & Science In Sports & Exercise	2416	4.1
2	Journal of Applied Physiology	1810	3.3
3	Sports Medicine	1421	9.3
4	European Journal of Applied Physiology	1130	2.8
5	PLOS ONE	956	2.9
6	Journal of Strength and Conditioning Research	887	2.5
7	Journal of Physiology-London	838	4.7
8	Circulation	614	35.5
9	British Journal of Sports Medicine	591	11.6
10	International Journal of Sports Medicine	515	2.0

3.5. Analysis of cited reference

Analyzing cited references helps identify foundational studies and seminal literature in the field, understanding the knowledge base and the most influential research outputs.[18] The study includes 24,257 cited references, with Table 6 listing the top 10 by citation count. Weston KS and others published a systematic review and meta-analysis in the British Journal of Sports Medicine in 2014, titled "High-intensity interval training in

patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis," which, with 117 citations, ranks first, indicating its authoritative and foundational status in studying HIIT's impact on cardiometabolic diseases. Following that, Gibala MJ and others published "Physiological adaptations to low-volume, high-intensity interval training in health and disease," which has received 108 citations, second overall, revealing the physiological adaptability of low-volume HIIT in both health and disease, significantly influencing the understanding of HIIT's basic mechanisms and applications. Borg GA's 1982 article, "Psychophysical bases of perceived exertion," cited 97 times, demonstrates its pivotal role as a foundational study of the psychophysical basis of perceived exertion within HIIT research. These highly-cited references not only showcase the depth and breadth of HIIT research in women's health but also reveal the core content and key discoveries in the field, providing a solid theoretical and practical foundation for subsequent studies.

Figure 5 displays the top 25 cited references with the highest burst strengths, indicating significant and sudden increases in citation volume over specific periods.[19] Weston KS's 2014 article reached its highest burst strength (17.37) from 2014 to 2019, underscoring its critical role in understanding HIIT applications in cardiometabolic diseases. Similarly, Gibala MJ's 2012 article and Borg GA's classic 1982 article showed high citation bursts, with strengths of 16.13 (2013–2017) and 9.86 (2014–2018), respectively, providing foundational theoretical support for HIIT's physiological adaptability and subjective perception. Multiple articles by Gillen JB in 2014, 2015, and 2016, such as "Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans," demonstrated high burst strengths from 2015 to 2019, indicating swift recognition of their findings on metabolic adaptability in HIIT. These articles cover a wide range of content from theoretical foundations to practical applications, offering important references for future research and establishing a classic status and crucial role within the field through their frequent citations.

3.6. Analysis of keyword

The frequency and co-occurrence of keywords can reflect the main research hotspots and the connections between different

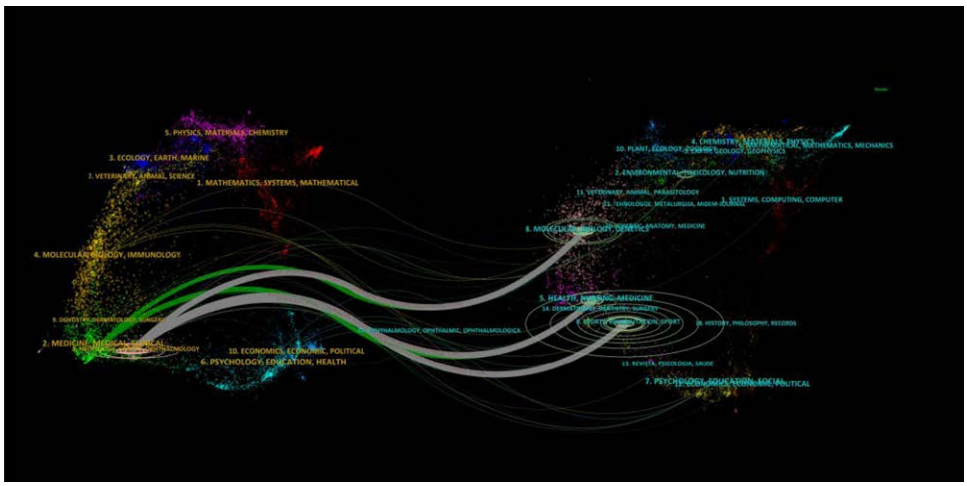

Figure 4. Dual-map overlay of journals.

Table 6

Top 10 references by citation count.

Rank	Title	Authors and publication year	Citation	Journal	Impact factor (2023)
1	High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis	Weston, K. S., et al 2014	117	British Journal of Sports Medicine	11.6
2	Physiological adaptations to low-volume, high-intensity interval training in health and disease	Gibala, M. J., et al 2012	108	The Journal of Physiology	4.7
3	Psychophysical bases of perceived exertion	Borg, G. A., 1982	97	Medicine & Science In Sports & Exercise	4.1
4	Similar metabolic adaptations during exercise after low-volume sprint interval and traditional endurance training in humans	Burgomaster, K. A., et al 2008	95	The Journal of Physiology	4.7
5	High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis	Buchheit, M., Laursen, P. B., 2013	89	Sports Medicine	9.3
6	Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance	Gibala, M. J., et al 2006	85	The Journal of Physiology	4.7
7	Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study	Wisløff, U., et al 2007	82	Circulation	35.5
8	Aerobic high-intensity intervals improve V˙ O2max more than moderate training	Helgerud, J., et al 2007	80	Medicine & Science In Sports & Exercise	4.1
9	Statistical power analysis for the behavioral sciences	Cohen, J., 1988	76	New York: Routledge	N/A
10	Aerobic interval training versus continuous moderate exercise as a treatment for the metabolic syndrome: a pilot study	Tjønna, A. E., et al 2008	76	Circulation	35.5

research themes within the field.[20] Table 7 lists the top 15 most frequently occurring keywords. While terms directly related to this research topic such as "high-intensity interval training," "exercise," "women," and "interval training" appear frequently, it is the relationships and network structures between these and other keywords that merit closer attention. "Obesity" (57 occurrences, centrality 0.16) is significantly associated with HIIT, indicating its importance as a research direction in the studies. Additionally, "aerobic exercise" (39 occurrences, centrality 0.12) and "sprint interval training" (37 occurrences, centrality 0.13) also highlight the importance of different training methods within HIIT research. "Cardiorespiratory fitness" (38 occurrences, centrality 0.10) and "body composition" (37 occurrences, centrality 0.08) reflect the multifaceted impact of HIIT on health outcomes. The high frequency and centrality of these keywords underscore their importance in the research network and researchers' focus on these health indicators. Figure 6 displays a co-occurrence network of 40 keywords appearing at least 11 times, revealing close associations between different keywords, such as strong connections between "high-intensity interval training" and "obesity," "body composition," "aging," and "cardiorespiratory fitness," indicating high interdisciplinarity and mutual influence among these research areas. This type of associative analysis sheds light on the application and impact of HIIT across various training methods, health outcomes, and specific populations.

Figure 7 presents a timeline of keyword clustering, showing the evolution of research themes and changes in focus areas over different periods.[21] Cluster #0 "Physical Activity" is the earliest and longest-lasting, representing the field's ongoing attention to physical activity and exercise. This theme has held a significant place in early research and has gradually developed into more refined research directions over time. Clusters #1 "Metabolic Syndrome" and #2 "Obesity" follow, highlighting the attention to metabolic syndrome and obesity issues, closely related to HIIT's applications in improving metabolic health and weight management. Clusters #3 "Interval Training" and #6 "High-Intensity Interval Training" reflect the focus on interval training, especially HIIT, concentrating on the effects and mechanisms of training methods, contributing significantly to optimizing training programs and enhancing performance. Clusters #7 "Female"

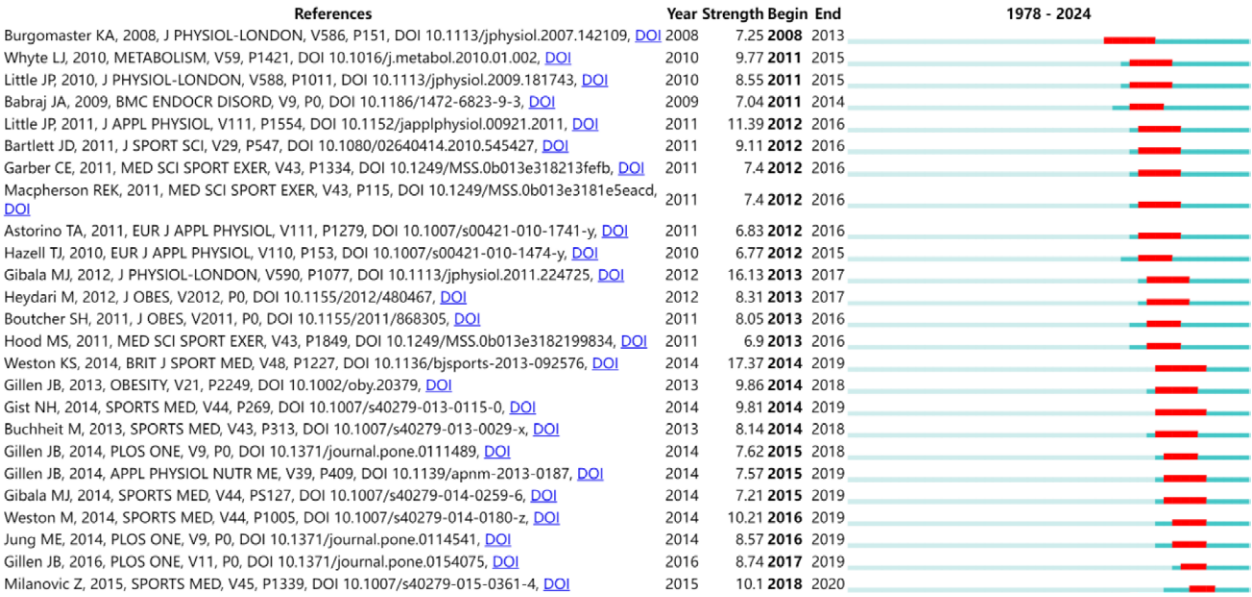

Figure 5. Top 25 references with the strongest citation bursts.

Table 7

Top 15 keywords by occurrences count.

Rank	Keyword	Occurrence	Centrality
1	High-intensity interval training	340	0.22
2	Exercise	133	0.34
3	Interval training	67	0.29
4	Obesity	57	0.16
5	Aerobic exercise	39	0.12
6	Cardiorespiratory fitness	38	0.10
7	Body composition	37	0.08
8	Sprint interval training	37	0.13
9	Women	32	0.10
10	Physical activity	31	0.11
11	Resistance training	28	0.06
12	Aging	23	0.05
13	Exercise training	22	0.07
14	Physical fitness	22	0.05
15	Insulin resistance	21	0.04

and #9 "Menopause" indicate research on women, especially menopausal women in HIIT, showing researchers' attention to the specific needs and responses of different genders and physiological stages. Clusters #10 "Inflammation" and #16 "Adiponectin" reveal studies on inflammatory responses and biomarkers like adiponectin, emphasizing HIIT's impact on health biological mechanisms.

Burst analysis of keywords can reveal shifts in research focus over specific periods, understanding current and future research priorities.[22] Figure 8 displays the 25 keywords with the highest burst strengths and their periods of burst. "Interval training" had the highest burst strength from 1997 to 2016, with a strength of 4.96, indicating early and sustained interest in interval training, continuously influencing the field's research. From 2008 to 2012, "fatigue" emerged as a key focus with a burst strength of 2.16, highlighting its importance in studies of high-intensity interval training during this period. "Adolescents" gained significance from 2022 to 2024, with a burst strength of 2.04, marking an increased focus on HIIT research among teenagers. These bursting keywords reveal several important directions and focal points in HIIT research.

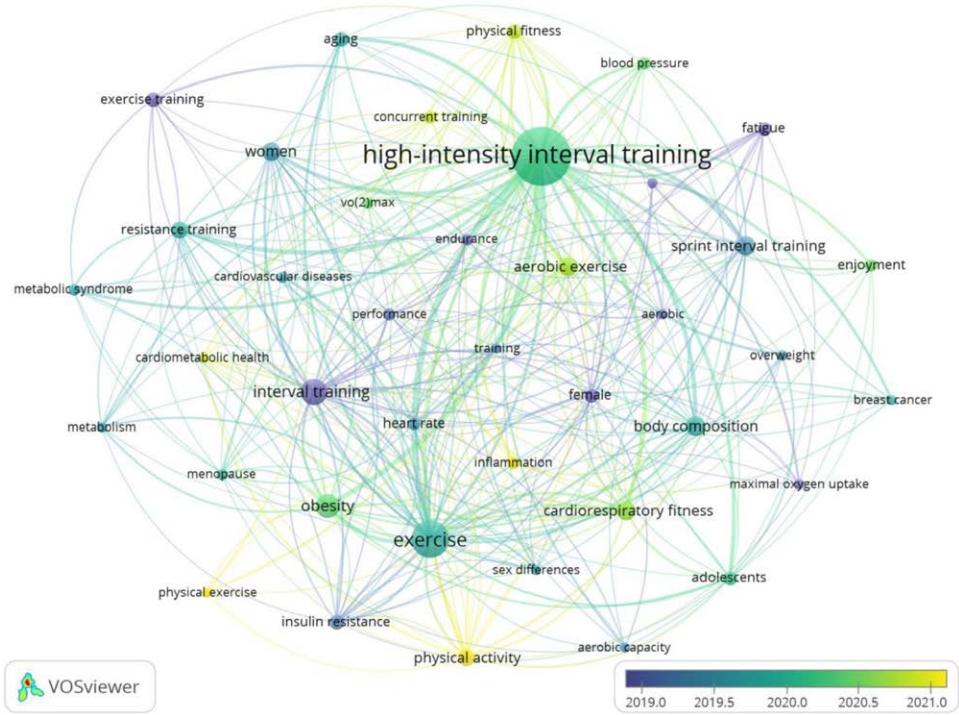

Figure 6. Co-occurrence network of keywords.

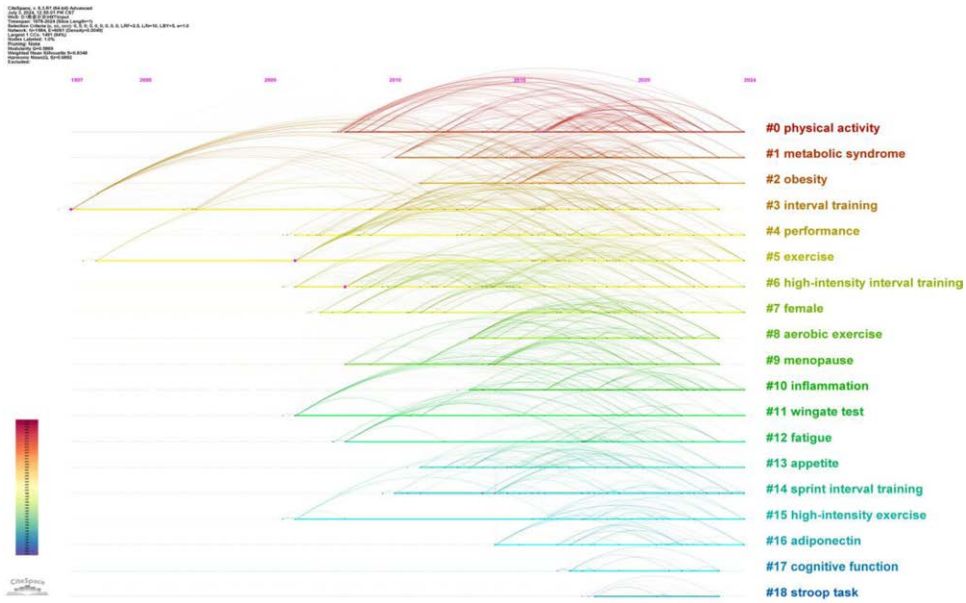

Figure 7. Clustering timeline of keywords.

4. Discussion

4.1. General information

This study incorporates 808 publications pertaining to the impact of HIIT on women's health, spanning from 1978 to 2024. Over 4 decades of research and application, this field has emerged as a focal point of scholarly interest, with potential for continued growth and significant research value. These publications are distributed across 1234 institutions in 61 countries, demonstrating the field's international character and extensive academic productivity. The United States, Australia, and Canada lead in this domain, with strong scientific contributions also from Norway, Denmark, and China. Key researchers such as Astorino TA and Gibala MJ have notably influenced this field, with Kong Z and others forming a robust research team through close collaboration.

Journal and cited journal analysis reveals that the related research is not only published extensively in specific academic journals but also widely cited by high-impact journals. Publications in "Medicine & Science in Sports & Exercise," "European Journal of Applied Physiology," and "PLOS ONE" serve as both major dissemination platforms and vital mediums for academic exchange, playing crucial roles in advancing research in this field. The analysis of cited literature helps identify foundational research and seminal documents. Highly cited and bursting cited documents mainly discuss HIIT's effects on metabolic adaptation, muscle adaptation, cardiovascular health, insulin sensitivity, and exercise performance, covering extensive theoretical and practical aspects, thus providing critical references for future research. These documents not only demonstrate the depth and breadth of HIIT research in women's health but also unveil the core content and key discoveries in the field, establishing a solid theoretical and practical foundation for ongoing studies.

Frequent keywords such as "aerobic exercise," "sprint interval training," and "resistance training" highlight the significance of various training methods in research. "Obesity," "body composition," "aging," and "insulin resistance" reflect the primary health issues and target populations in HIIT studies. Keyword burst analysis further reveals dynamic shifts in research hotspots. Early studies focused primarily on basic concepts and training models (e.g., "interval training"), gradually expanding to specific physiological responses (e.g., "fatigue," "endurance"). In recent years, applications in specific populations (e.g., "aging," "adolescents") and impacts on particular diseases (e.g., "breast cancer," "PCOS") have become research hotspots. Additionally, studies on HIIT's effects on women's psychological health and quality of life are gaining attention, reflecting the academic community's growing focus on holistic health for women.

4.2. Research hotspots and frontiers

Over the past decade, research on the effects of HIIT on women's health has rapidly evolved, establishing several research hotspots. Metabolic health is one significant focus, particularly the effects of HIIT on obesity, insulin resistance, and metabolic syndrome. Numerous studies have explored the impact of HIIT on women's body fat distribution, insulin sensitivity, and metabolic rate, demonstrating its potential for improving metabolic health.[23–25] Additionally, the influence of HIIT on women's cardiovascular health has emerged as another research hotspot. These studies primarily focus on the improvement of cardiovascular functions, endothelial function, and cardiac metabolic health, with results indicating that HIIT can effectively enhance cardiac function, increase maximal oxygen uptake, and improve cardiovascular health indicators.[26,27]

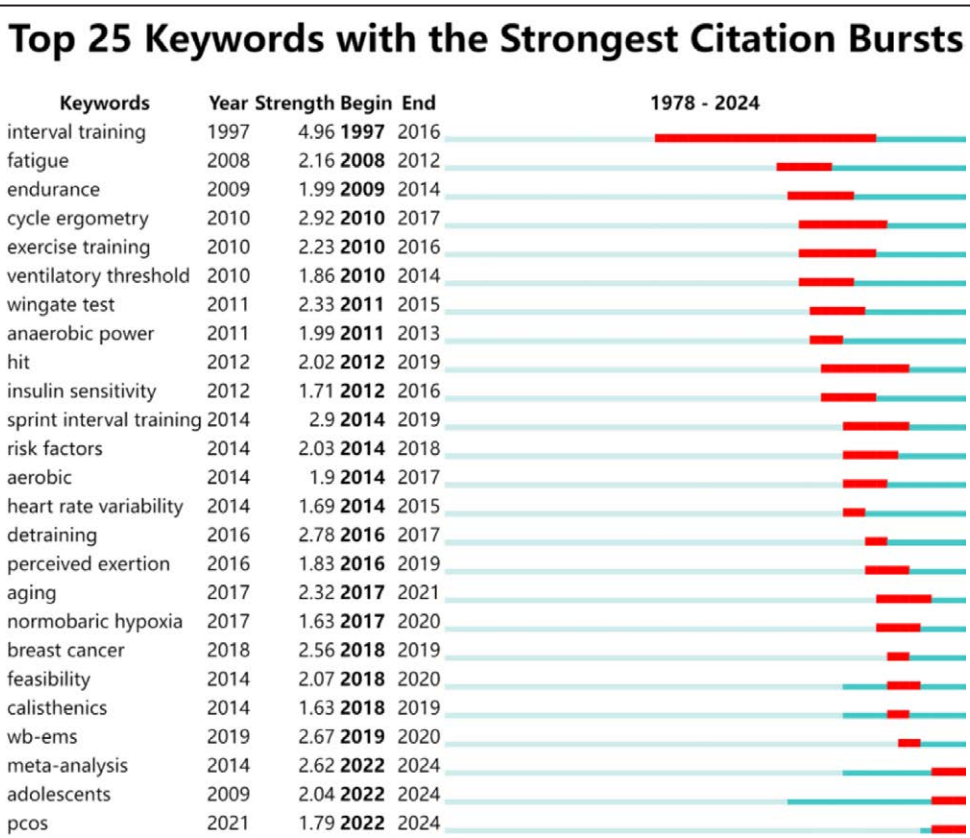

Figure 8. Top 25 keywords with the strongest citation bursts.

HIIT's role in enhancing women's muscular function and physical fitness has also attracted extensive attention. Research indicates that HIIT significantly boosts women's muscle strength, endurance, and overall athletic performance.[28,29] In the realm of psychological health, HIIT has shown positive effects on alleviating depression, anxiety, and enhancing the quality of life for women, particularly during the COVID-19 pandemic, where it has been utilized extensively to improve mental health due to its convenience.[30–33]

In recent years, research has shifted towards more specific and in-depth directions. Researchers have recognized that the effects of HIIT may vary due to individual differences, making personalized training programs and efficacy assessments a frontier in the field. For women of different ages or physical conditions, the intensity, frequency, and methods of HIIT need personalized adjustments to maximize health benefits.[34–36] Another research frontier is the impact of HIIT at the cellular and molecular levels. An increasing number of studies are investigating the effects of HIIT on gene expression, signaling pathways, and cellular functions, aiming to unveil its mechanisms at the molecular level.[37,38] These studies not only aid in understanding the biological basis of HIIT but also guide future intervention strategies and health management.

Additionally, studies combining HIIT with other forms of exercise, such as endurance training, strength training, and aerobic exercises, have become cutting-edge topics.[39,40] These studies aim to optimize training protocols and provide more comprehensive health intervention strategies. Lastly, with technological advancements, the application of digital health technologies in HIIT research has become a frontier topic. Using wearable devices, mobile apps, and online platforms for personalized training guidance and efficacy monitoring not only enhances the convenience and accuracy of research but also offers new tools and methods for public health management.[41–43]

In summary, the research hotspots and frontiers in HIIT for women's health not only reflect the current depth and breadth of research but also provide a rich theoretical and practical foundation for future studies. Future research should continue to focus on personalized interventions, cellular and molecular mechanisms, integrated training programs, and the application of digital health technologies to advance the field.

4.3. Limitations

This study has some limitations. Firstly, while the data encompasses studies from 61 countries, it only includes English-language articles and reviews from Science Citation Index Expanded and Social Sciences Citation Index sources. This might result in an underrepresentation of research from certain countries or regions, leading to an unbalanced global research distribution. Secondly, although the research spans from 1978 to 2024, the limited number of early documents may affect the comprehensive analysis of research trends. Lastly, due to the large volume of literature, the automated extraction and analysis of keywords and themes may miss some data or introduce bias, impacting the thorough identification of research hotspots and frontiers.

5. Conclusion

Through bibliometric analysis, this study has illuminated the current state, hotspots, and frontiers of research on the impact of HIIT on women's health. Over 4 decades, this field has emerged as a research hotspot characterized by international collaboration and extensive academic productivity, with some researchers forming robust teams through close collaboration. The journals of publication and cited journals possess significant academic influence, and highly cited and bursting documents cover a wide range from theoretical foundations to practical applications, establishing a solid theoretical and practical foundation in this field. In the rapid development over the past decade, multiple research hotspots and frontier directions have formed. Studies indicate that HIIT has significant positive effects on women's metabolic health, cardiovascular function, muscle strength, and psychological health, particularly showing great potential in interventions for obesity, insulin resistance, and metabolic syndrome. Recently, research has further delved into personalized training programs, cellular and molecular mechanisms, and the application of digital health technologies. Future research should continue to focus on these frontier areas to advance the application of HIIT in women's health and provide more precise and comprehensive health intervention strategies.

Author contributions

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Investigation: Youyou Li.
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