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Aerobic exercise and catecolamine: A bibliometric analysis

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Abstract

This study performed a bibliometric analysis of scientific literature on aerobic exercise and catecholamines to map the evolving knowledge structure in this important field, which has implications for both physical health and neurochemical regulation. Using data from the Web of Science and Scopus databases, publications published between 2000 and 2024 were analyzed. VOSviewer software was employed to visualize co-authorship, keyword co-occurrence, and citation patterns. The analysis focuses on publication trends, disciplines, keyword networks, authors, institutions, countries, and journals. The findings revealed that the number of publications showed a significant increase after 2010, while the number of citations peaked in 2015, exceeding 700 in 2021, but started to decline after 2022. Sports Sciences (102 publications) and physiology (74 publications) were the most dominant disciplines, while Endocrinology and Metabolism and Neurosciences also made significant contributions. Keyword networks showed that 'catecholamines' and 'exercise' were central concepts, linked to themes such as cardiovascular responses and insulin sensitivity. McMorris, T. (850 citations) and Kindermann, W. (839 citations) lead among authors, the University of Chichester (981 citations) leads among institutions, and the USA (5263 citations) leads among countries. Journal analysis revealed that the Journal of Applied Physiology has 1738 citations. The discussion emphasized the interdisciplinary nature of the field and its academic impact while highlighting the lack of local contributions, such as in Turkey. These results suggest that aerobic exercise and catecholamines offer a rich research area for both basic science and clinical applications. Suggestions include expanding the scope of bibliometric analyses using new analytical methods, focusing on underrepresented disciplines, and mapping the local literature. By mapping the current state of literature, this study aims to guide future research in this field.

Keywords: *Aerobic exercise, bibliometric analysis, catecholamine, sport sciences*

Aerobik egzersiz ve katekolamin: Bibliyometrik bir analiz

Öz

Bu çalışma, aerobik egzersiz ve katekolaminler üzerine yapılan bilimsel literatürün bibliyometrik analizini gerçekleştirmeyi amaçlamıştır. Web of Science ve Scopus veri tabanlarından elde edilen verilerle, 2000-2024 yılları arasındaki yayınlar incelenmiştir. Analiz, yayın trendleri, disiplinler, anahtar kelime ağları, yazarlar, kurumlar, ülkeler ve dergiler üzerine odaklanmıştır. Bulgular, yayın sayısının 2010 sonrası belirgin bir artış gösterdiğini, atıf sayısının ise 2015'ten itibaren 2021'de 700'ü aşarak zirve yaptığını, ancak 2022'den sonra düşüşe geçtiğini ortaya koymuştur. Spor Bilimleri (102 yayın) ve Fizyoloji (74 yayın) en baskın disiplinler olurken, Endokrinoloji ve Metabolizma ile Nörobilimler de önemli katkılar sunmuştur. Anahtar kelime ağları, "catecholamines" ve "exercise"in merkezi kavramlar olduğunu, kardiyovasküler yanıtlar ve insülin duyarlılığı gibi temalarla bağlantılı olduğunu göstermiştir. Yazarlar arasında McMorris, T. (850 atıf) ve Kindermann, W. (839 atıf), kurumlar arasında Chichester Üniversitesi (981 atıf), ülkeler arasında ABD (5263 atıf) lider konumdadır. Dergi analizi, Journal of Applied Physiology'nin 1738 atıfla önde olduğunu ortaya koymuştur. Tartışma, alanın disiplinler arası doğasını ve akademik etkisini vurgularken, Türkiye gibi yerel katkının eksikliğini öne çıkarmıştır. Sonuçlar, aerobik egzersiz ve katekolaminlerin hem temel bilimler hem de klinik uygulamalar açısından zengin bir araştırma alanı sunduğunu göstermektedir. Öneriler, bibliyometrik analizlerin kapsamının genişletilmesi, yeni analitik yöntemlerin kullanılması, az temsil edilen disiplinlere odaklanılması ve yerel literatürün haritalanması yönündedir. Bu çalışma, literatürün mevcut durumunu haritalandırarak alandaki gelecek araştırmalara yön vermeyi hedeflemektedir.

Anahtar Sözcükler: *Aerobik egzersiz, bibliyometrik analiz, katekolamin, spor bilimleri*

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INTRODUCTION

Aerobic exercise is a type of exercise that includes prolonged and rhythmic physical activities that improve cardiovascular endurance by increasing oxygen utilization (American College of Sports Medicine, 2018). Activities such as running, cycling, swimming and brisk walking strengthen heart and lung capacity by working large muscle groups. The main characteristic of aerobic exercise is that it relies on oxidative metabolism for energy production, making it ideal for endurance-based activities (Wilmore & Costill, 2004). This type of exercise is widely practiced around the world, providing far-reaching positive effects on physical health.

The health benefits of aerobic exercise have been documented by numerous scientific studies. Regular aerobic exercise reduces the risk of cardiovascular disease, regulates blood pressure and contributes to the prevention of type 2 diabetes by improving insulin sensitivity (Warburton, Nicol & Bredin, 2017). Furthermore, aerobic exercise supports mental health and has been shown to be effective in reducing symptoms of depression and anxiety (Dunn, Trivedi & O'Neal, 2001). These benefits may vary depending on the intensity and duration of exercise and the health status of the individual.

The physiological effects of aerobic exercise are not limited to the cardiovascular and metabolic systems. Regular exercise slows physical decline in the aging process by increasing muscle strength, flexibility and bone density (Garber et al., 2011). Furthermore, aerobic exercise can strengthen the immune system and increase resistance to infections (Nieman, 1994). These multifaceted effects make aerobic exercise an important strategy for both individual health and public health.

Catecholamines are organic compounds containing catechol and amine groups and are biochemical substances that function as both neurotransmitters and hormones in the human body. The major catecholamines are epinephrine (adrenaline), norepinephrine (noradrenaline) and dopamine (Goldstein, 2010). These molecules are synthesized by the adrenal medulla and sympathetic nervous system and are derived from the amino acids tyrosine or phenylalanine. Catecholamines play a central role in vital processes such as stress response, energy metabolism and cardiovascular regulation (Eisenhofer, Kopin & Goldstein, 2004).

The physiological effects of catecholamines are critical in maintaining the body's homeostasis. Epinephrine and norepinephrine trigger the "fight or flight" response, increasing heart rate, raising blood pressure and accelerating the mobilization of energy substrates (glucose and fatty acids) (Cryer, 2001). Dopamine is more associated with the reward system, motor

control and emotional regulation in the brain (Beaulieu & Gainetdinov, 2011). Catecholamines act on target tissues through alpha and beta adrenergic receptors and these interactions enable rapid adaptation of organ systems (Tank & Lee Wong, 2015).

The regulation of catecholamines is an important research topic in health and disease states. Catecholamine synthesis and release are tightly controlled by sympathetic nervous system activity and stress factors (Kvetnansky, Sabban & Palkovits, 2009). Abnormal catecholamine levels have been associated with various pathological conditions such as hypertension, anxiety disorders and neurodegenerative diseases (Goldstein, 2010). Therefore, the biochemical pathways and physiological effects of catecholamines have been intensively studied in medical and scientific research.

Aerobic exercise activates physiological systems by meeting the body's energy demands through prolonged and oxygen-dependent activities (Haskell et al., 2007). In this process, catecholamines - namely epinephrine, norepinephrine and dopamine - play a fundamental role in the body's adaptation to exercise. Catecholamines support performance during exercise by regulating metabolic rate and circulation (Goldstein, 2010). Therefore, the interaction of aerobic exercise and catecholamines requires a holistic approach to understand the biological effects of exercise.

Catecholamine release during exercise ensures efficient utilization of energy resources and increases the body's capacity to cope with stress. For example, epinephrine accelerates glucose production in the liver, while norepinephrine regulates blood vessel tone, facilitating adequate oxygen delivery to the muscles (Eisenhofer, Kopin & Goldstein, 2004). These dynamic responses are directly linked to the intensity and duration of exercise; therefore, the role of catecholamines in this process is critical for exercise physiology (Chrousos, 2009). Understanding how aerobic exercise affects catecholamine levels provides fundamental information for the optimization of training programs.

The combined study of aerobic exercise and catecholamines enables not only the elucidation of physiological mechanisms but also the development of innovative approaches in clinical and sports sciences. Regulation of catecholamine responses by exercise has potential applications in areas such as metabolic disease management and performance enhancement (Tank & Lee Wong, 2015). This interaction necessitates an interdisciplinary perspective in scientific research and offers important clues to the future of exercise science. In this context, bibliometric analysis emerges as a useful tool for mapping scientific output, identifying

influential works, and visualizing collaboration networks and research trends within a specific field.

Despite the growing number of studies examining the effects of aerobic exercise on catecholamine levels, the scientific literature remains fragmented, lacking a comprehensive overview of research trends, influential contributions, and collaboration patterns in this interdisciplinary field. This study aims to evaluate the scientific literature on the relationship between aerobic exercise and catecholamines through bibliometric analysis. It aims to reveal the intellectual structure of the field by systematically analyzing the publication trends, citation networks, and thematic focus of studies examining the interaction of aerobic exercise and catecholamines (Aria & Cuccurullo, 2017). This analysis aims to guide future studies in the fields of exercise physiology and neuroendocrinology by identifying leading research, influential publications, and research gaps (Bornmann & Daniel, 2010). Moreover, this study contributes to the literature by offering a consolidated scientific mapping of the field, helping to bridge fragmented knowledge and highlighting underexplored research themes. The bibliometric method was specifically chosen for its ability to quantitatively and visually analyze large volumes of scientific data, allowing for the identification of hidden patterns and collaborative structures that traditional reviews may overlook.

METHODS

This study used bibliometric analysis to systematically review the scientific literature on aerobic exercise and catecholamines. Bibliometric analysis offers a quantitative approach to assess the volume, citation structures and thematic trends of publications (Pritchard, 1969). This method was chosen to reveal the intellectual structure of the field, identify influential studies and identify research gaps. By focusing on peer-reviewed scientific publications, the analysis provided a reliable and comprehensive data set. The data collection process was based on publications from the Web of Science (WoS) database. This database was chosen for its multidisciplinary coverage and high-quality indexing (Mongeon & Paul-Hus, 2016). The search strategy was designed to include keywords such as “aerobic exercise”, “catecholamine”, “epinephrine”, “norepinephrine” and “dopamine” and their synonyms. English-language articles, book chapters and conference proceedings from 2000–2025 were included; editorials and gray literature were excluded. This language-based inclusion criterion may have limited the scope of the analysis by excluding potentially relevant studies published in other languages. In total, publications that met the inclusion and exclusion criteria were prepared for analysis after data cleaning (Aria & Cuccurullo, 2017). The analysis was conducted using VOSviewer

software. VOSviewer was used to visualize co-citation networks and thematic clusters (Van-Eck & Waltman, 2010). The analysis process included the distribution of the number of publications by year, the most cited studies, leading authors and institutions, and keyword co-occurrence analysis. These indicators were evaluated to identify the evolution of scientific production and key research foci in the field of aerobic exercise and catecholamines. In the study, double-blind screening was applied to improve data quality and inconsistencies in the dataset (e.g. duplicate publications) were manually corrected. Furthermore, the limitations of bibliometric analyses, especially the database coverage and the impact of keyword selection, were taken into account in the interpretation of the results (Bornmann & Daniel, 2010). This method provides a solid basis for objectively mapping the past and current state of the field.

FINDINGS

The distribution of scientific publications on aerobic exercise and catecholamines over time showed a significant increase between 2000 and 2024. Histogram analysis reveals that an average of 5-8 publications were produced annually between 2000 and 2010, but there has been a fluctuating increase in the number of publications since 2011 (Figure 1). In particular, the years 2019-2021 marked the period of highest productivity with 9-11 publications per year, while the number of citations increased rapidly after 2015, reaching over 700 in 2024. This trend shows that academic interest in the field has intensified in the last decade and that citation accumulation has outpaced publication growth (Garfield, 2006).

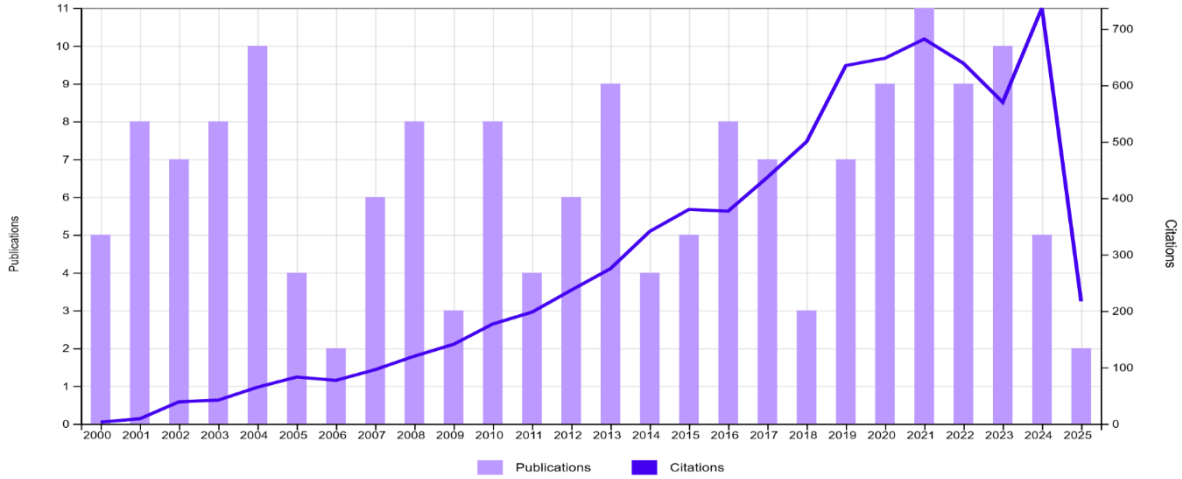

Figure 1. Distribution of publications and citations by year

The distribution between disciplines was evaluated by treemap analysis. Sports Sciences is the most dominant discipline with 102 publications, followed by Physiology with 74 publications. Other leading fields are Endocrinology and Metabolism (28 publications), Neurosciences (26 publications) and Cardiovascular Systems (22 publications). Less represented disciplines include Pharmacology (9 publications) and Internal Medicine (9 publications). This diversity confirms that aerobic exercise and catecholamines are a cross-cutting research topic in different scientific fields (Moed, 2005).

Figure 2. Distribution by research areas

Table 1. Authors' Citation and publication distribution

	Authors	P.	C.
1	Mcmorris, T.	5	850
2	Kındermann, W.	6	839
3	Lambourne, K.	1	772
4	Tomporowski, P.	1	772
5	Boobıs, Lh.	1	701
6	Brooks, S.	1	701
7	Gaıtanos, Gc.	1	701
8	Wılliams, C.	1	701
9	Hale, Beverley J.	2	607

Among the authors, McMorris, T. is the most influential with 5 publications and 850 citations, followed by Kindermann, W. with 6 publications and 839 citations. Lambourne, K. and Tomporowski, P. stand out with 1 publication and 772 citations each. Boobis, L. H., Brooks, S., Gaitanos, G. C. and Williams, C. also have 1 publication and 701 citations each.

Hale, Beverley J. received 607 citations with 2 publications. These results demonstrate individual contributions and impact in the field (Small, 1999).

Table 2. Publication and citation distribution of institutions

	Organizations	P.	C.
1	Chichester University	6	981
2	Georgia University	2	792
3	Copenhagen University	5	715
4	Loughborough Tech University	1	701
5	Giessen University	1	556
6	Munster University	1	556
7	Rennes University	3	418
8	Balamand University	1	376

Among the institutions, the University of Chichester is the leader with 6 publications and 981 citations. University of Georgia has 792 citations with 2 publications and University of Copenhagen has 715 citations with 5 publications. Loughborough Tech University received 701 citations with 1 publication, while Giessen and Munster Universities received 556 citations with 1 publication each. Rennes University received 418 citations with 3 publications and Balamand University received 376 citations with 1 publication. This distribution shows the influence of institutions in the field (Bornmann & Daniel, 2010).

Table 3. Publication and citation distribution of countries

	Countries	P.	C.
1	USA	80	5263
2	England	17	1939
3	Canada	36	1923
4	Germany	22	1480
5	Denmark	7	824
6	France	19	804
7	Japan	18	675
8	Italy	15	448
9	Libya	1	376

The geographical map and table analysis reveals that the USA leads with 80 publications and 5263 citations. The UK follows with 17 publications and 1939 citations, Canada with 36 publications and 1923 citations. Germany with 22 publications and 1480 citations, Denmark

with 7 publications and 824 citations, France with 19 publications and 804 citations. Japan has 18 publications and 675 citations, Italy has 15 publications and 448 citations, and Libya has 1 publication and 376 citations (Glänzel, 2001).

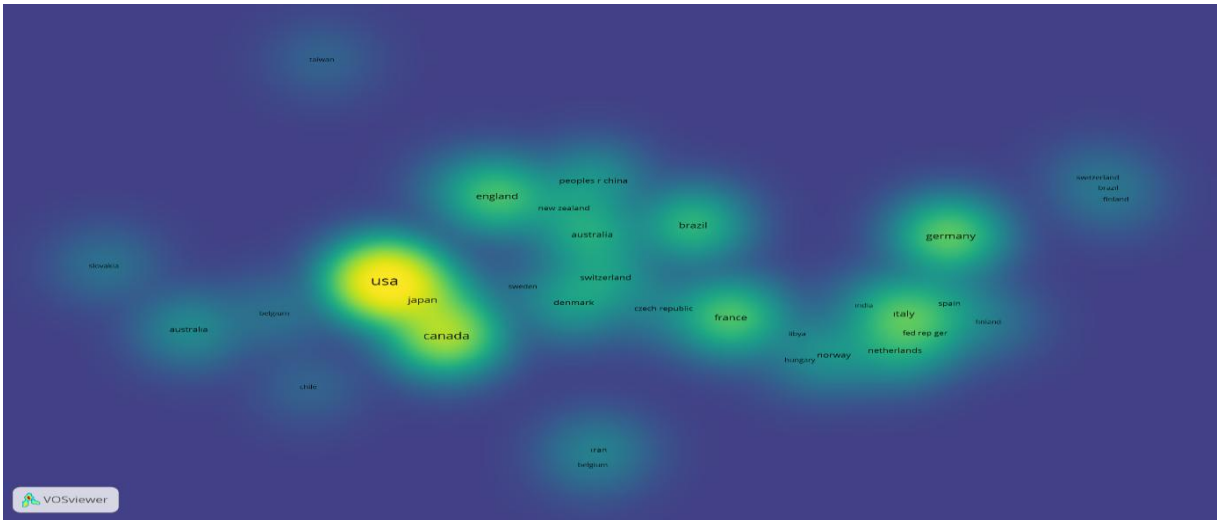

Figure 3. Density graph by country

Table 4. Publication and citation distribution of journals

	Journals	P.	C.
1	Journal of Applied Physiology	17	1738
2	Sports Medicine	7	1078
3	Medicine And Science In Sports And Exercise	19	912
4	Journal of Experimental Biology	6	779
5	Brain Research	1	772
6	Neurobiology of Learning and Memory	1	556
7	European Journal of Applied Physiology	12	545
8	Clinical Physiology	1	483
9	Physiology & Behavior	6	480
10	Hypertension	4	446

The journal analysis showed that Journal of Applied Physiology is the leader with 17 publications and 1738 citations. Sports Medicine is in second place with 7 publications and 1078 citations. Medicine and Science in Sports and Exercise received 912 citations with 19 publications, while Journal of Experimental Biology gained 779 citations with 6 publications. Brain Research received 772 citations with 1 publication and Neurobiology of Learning and

Memory received 556 citations with 1 publication. European Journal of Applied Physiology received 545 citations with 12 publications (Leydesdorff, 2009).

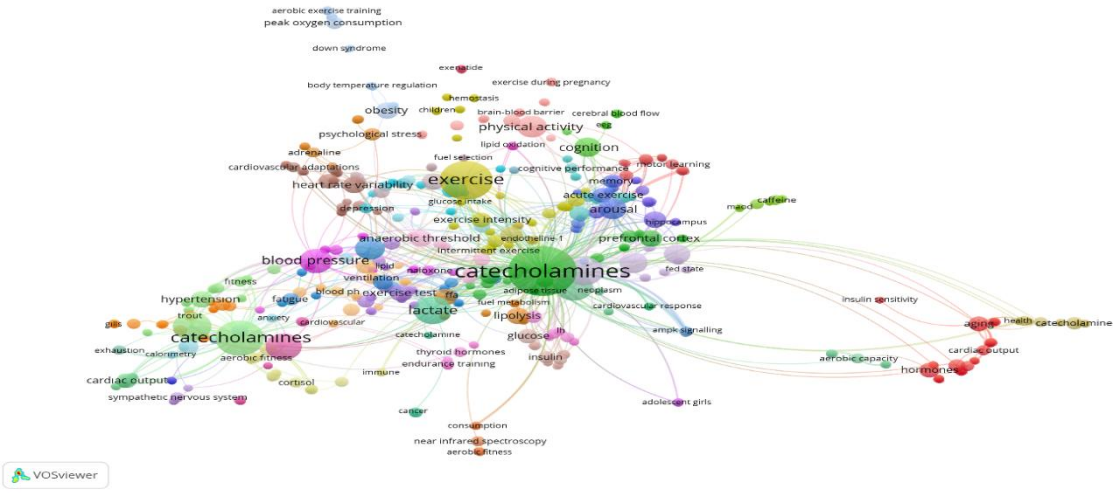

Figure 4. Network map of keywords

Keyword network analysis with VOSviewer showed that the terms “catecholamines” and “exercise” were central. These concepts exhibited strong links with “cardiovascular response”, “insulin sensitivity” and “aerobic exercise”. Thematic clusters focused on neuroendocrine effects of exercise, metabolic regulations and cardiovascular outcomes. Furthermore, terms such as “physical activity” and “blood pressure” emphasize the clinical and applied aspects of the field (Van Eck & Waltman, 2010).

DISCUSSION AND CONCLUSION

The increasing trend of publications on aerobic exercise and catecholamines between 2000 and 2024 shows that this field is gaining more and more attention in the scientific community. As seen in Figure 1, the rise in the number of publications, especially after 2010, and the increase in citations from 2015 onwards, exceeding 700 in 2021, reveals that the academic impact of this topic is deepening. However, the decline in citations after 2022 may suggest that new research has less impact or that the literature has reached saturation (Garfield, 2006). This may indicate that the field needs innovative approaches.

The interdisciplinary distribution confirms the leadership of fields such as Sports Sciences (102 publications) and Physiology (74 publications) (Figure 2). However, the contribution of disciplines such as Endocrinology and Metabolism (28 publications) and Neurosciences (26 publications) shows that aerobic exercise and catecholamines are not only related to physical performance, but also to neuroendocrine and metabolic processes. This

diversity highlights the importance of interdisciplinary collaboration in the literature and suggests the need for more integrated studies in the future (Moed, 2005). The keyword analysis (Figure 3) showed that "catecholamines" and "exercise" were central and linked to concepts such as "cardiovascular response" and "insulin sensitivity". This supports the metabolic and cardiovascular effects of exercise via catecholamines as a priority area of research (Van Eck & Waltman, 2010).

Author and institutional analysis reveals leadership in the field. Authors such as McMorris, T. (5 publications, 850 citations) and Kindermann, W. (6 publications, 839 citations), together with the University of Chichester (6 publications, 981 citations) have made significant contributions (Tables 1 and 2). In terms of countries, the USA's leadership with 5263 citations (Table 3) reflects the interest in this field on a global scale, while Turkey's absence in the data set suggests that local research should be increased (Glänzel, 2001). The journal analysis showed that the Journal of Applied Physiology leads with 1738 citations (Table 4), indicating that the field is discussed in high-impact platforms (Leydesdorff, 2009).

In conclusion, the study of aerobic exercise and catecholamines has emerged as a growing interdisciplinary research area, particularly gaining momentum over the past 15 years. This bibliometric analysis provides a unique lens through which the development of this field can be observed in terms of citation structures, institutional collaborations, and thematic clusters. The findings are consistent with prior research highlighting increasing scientific interest in the neuroendocrinological effects of exercise, yet they go further by identifying underexplored areas—such as the role of dopamine in endurance performance and the neuroadaptive response of catecholamines to long-term aerobic training.

Unlike traditional narrative reviews, the bibliometric approach allows a data-driven mapping of intellectual trends and research gaps. This perspective offers valuable insights into how the field has evolved and where it may be headed. The results suggest that the field holds rich potential for both basic science and clinical applications. Future studies are encouraged to integrate bibliometric insights with experimental data, promote interdisciplinary collaboration—especially among sports science, neuroscience, and public health—and support contributions from underrepresented regions and methodologies. By mapping the current state of the literature, this study lays a solid foundation for future catecholamine-focused research in exercise science.

Recommendations

This bibliometric analysis mapped the current state of the literature on aerobic exercise and catecholamines and revealed some gaps. In this context, the following recommendations are offered for future research:

Our study focused on Web of Science and Scopus databases. Future bibliometric analyses could cover a broader cross-section of the literature by including additional databases such as PubMed or Google Scholar. This may provide a better understanding of the diversity of publications in the field (Mongeon & Paul-Hus, 2016).

Instead of focusing only on citation and keyword networks, bibliometric analyses can use methods such as machine learning or text mining. These methods can reveal hidden trends and thematic connections in the aerobic exercise and catecholamines literature (Aria & Cuccurullo, 2017).

Our analysis showed that some disciplines such as Pharmacology are underrepresented. Bibliometric studies examining the relationship of catecholamines to exercise from a pharmacological perspective should be increased. This could close interdisciplinary gaps in the field (Moed, 2005).

No publications from Turkey were found in our study. Bibliometric analyses examining local studies on aerobic exercise and catecholamines in countries such as Turkey could be conducted. This may add a regional perspective to the global literature (Glänzel, 2001).

Our study examined the distribution of publications over time. Future bibliometric studies could analyze thematic shifts (e.g. the impact of technological developments) in specific periods in more detail. This could provide important clues in understanding the evolution of the field (Small, 1999).

In some countries, such as Türkiye, it is recommended to strengthen international collaborations and financial support mechanisms to increase local research capacity and visibility in global scientific networks.

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KATKI ORANI ***CONTRIBUTION RATE***	**AÇIKLAMA** ***EXPLANATION***	**KATKIDA BULUNANLAR** ***CONTRIBUTORS***
Fikir ve Kavramsal Örgü *Idea or Notion*	Araştırma hipotezini veya fikrini oluşturmak *Form the research hypothesis or idea*	Yaşar ÇORUH
Tasarım *Design*	Yöntem ve araştırma desenini tasarlamak *To design the method and research design.*	Yaşar ÇORUH
Literatür Tarama *Literature Review*	Çalışma için gerekli literatürü taramak *Review the literature required for the study*	Yaşar ÇORUH
Veri Toplama ve İşleme *Data Collecting and Processing*	Verileri toplamak, düzenlemek ve raporlaştırmak *Collecting, organizing and reporting data*	Yaşar ÇORUH
Tartışma ve Yorum *Discussion and Commentary*	Elde edilen bulguların değerlendirilmesi *Evaluation of the obtained finding*	Yaşar ÇORUH

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Researchers do not have any personal or financial conflicts of interest with other people and institutions related to the research.

Etik Kurul Beyanı/ *Statement of Ethics Committee*

Bu araştırma, nitel yöntemle (Sistematik derleme) yapıldığı için Etik Kurul gereksinimi bulunmamaktadır.

Since this research was conducted with a qualitative method (Systematic review), there is no need for an Ethics Committee.