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ARAŞTIRMA YAZISI / RESEARCH ARTICLE

2010 - 2024 YILLARI ARASINDA EPİLEPSİ VE BEYİN HACMİ ÜZERİNE YAPILAN ARAŞTIRMALARIN BİBLİYOMETRİK ANALİZİ

BIBLIOMETRIC ANALYSIS OF RESEARCH ON EPILEPSY AND BRAIN VOLUME FROM 2010 TO 2024

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ÖZET

AMAÇ: Epilepsi, beyindeki anormal elektriksel aktiviteye bağlı olarak tekrarlayan nöbetlerle kendini gösteren ve potansiyel olarak bilinci, hareketi ve davranışı etkileyen nörolojik bir hastalıktır. Sinir sisteminin merkezi organı olan beyin epilepsiden yapısal olarak etkilendiği için, çalışmalar epilepsi ve beyin hacmi arasında karşılıklı bir ilişki olduğunu vurgulamıştır. Artan ilgiye rağmen, özellikle epilepsi ve beyin hacmine odaklanan bibliyometrik bir analiz tespit edilmemiştir. Bu çalışma, bibliyometrik bir analiz yaparak ve bu alandaki eğilimleri görselleştirerek bu boşluğu doldurmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: 2010-2024 yılları arasında yayınlanan makaleler ve incelemeler Web of Science Core Collection (WOSCC) veri tabanından alınmıştır. Bibliyometrik analizler ve görsel eşleştirmeler VOSviewer yazılımı kullanılarak gerçekleştirilmiştir.

BULGULAR: 69 ülkedeki 1.147 kurumdan 2.923 araştırmacı tarafından yazılan toplam 430 yayın tespit edildi. Matsumoto, N. 10 yayınla en üretken yazar olmuştur. Epilepsia 22 makale ile dergi sıralamasında başı çekerken, onu 15 makale ile Epilepsy & Behavior takip etmiştir. Amerika Birleşik Devletleri ve Birleşik Krallık en yüksek işbirliği ve yayın çıktılarına sahipken, onları Çin ve Almanya takip etmiştir. Anahtar kelime analizi, en sık kullanılan terimin "Epilepsi" olduğunu, bunu "Beyin Atrofisi" ve "Manyetik Rezonans Görüntüleme "nin izlediğini ortaya koymuştur.

SONUÇ: Bu çalışma, epilepsi ve beyin hacmi arasındaki ilişkiyi inceleyen ilk bibliyometrik çalışmadır. Bulgular, araştırma kalıpları ve eğilimleri hakkında değerli bilgiler sağlamakta ve bu alanda gelecekteki araştırmalara rehberlik edebilmektedir.

ANAHTAR KELİMELER: Epilepsi, Beyin Hacmi, Beyin Atrofisi, Manyetik Rezonans Görüntüleme, Bibliyometri.

ABSTRACT

OBJECTIVE: Epilepsy is a neurological disorder marked by recurrent seizures due to abnormal electrical activity in the brain, potentially affecting consciousness, movement, and behavior. As the brain the central organ of the nervous system is structurally impacted by epilepsy, studies have highlighted a mutual relationship between epilepsy and brain volume. Despite growing interest, no bibliometric analysis focusing specifically on epilepsy and brain volume has been identified. This study aims to fill that gap by conducting a bibliometric analysis and visualizing trends in this field.

MATERIAL AND METHODS: Articles and reviews published between 2010 and 2024 were retrieved from the Web of Science Core Collection (WOSCC) database. Bibliometric analyses and visual mappings were carried out using the VOSviewer software.

RESULTS: A total of 430 publications authored by 2,923 researchers from 1,147 institutions across 69 countries were identified. Matsumoto, N. was the most prolific author with 10 publications. Epilepsia led the journal rankings with 22 articles, followed by Epilepsy & Behavior with 15. The United States and United Kingdom had the highest collaboration and publication outputs, followed by China and Germany. Keyword analysis revealed "Epilepsy" as the most frequently used term, followed by "Brain Atrophy" and "Magnetic Resonance Imaging."

CONCLUSIONS: This is the first bibliometric study examining the relationship between epilepsy and brain volume. The findings provide valuable insights into research patterns and trends and can guide future investigations in this area.

KEYWORDS: Epilepsy, Brain Volume, Brain Atrophy, Magnetic Resonance Imaging, Bibliometrics.

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INTRODUCTION

Epilepsy is a neurological disorder characterized by recurrent seizures due to an abnormal increase in electrical activity in the brain (1). Seizures occur as a result of abnormal electrical discharges and may lead to temporary changes in behavior, consciousness, movements, or other bodily functions (2). Epilepsy can occur at any age and may originate from different etiologies depending on the period in which it manifests. In children, genetic factors or cortical developmental disorders are common etiological causes, while in adults, meningitis, encephalitis, or traumatic brain injuries are frequently observed as underlying causes (3).

Epilepsy affects approximately 50 million people worldwide, and the lifetime risk of experiencing an epileptic seizure is estimated at 10% (4). According to the World Health Organization (WHO), approximately 5 million people are diagnosed with epilepsy each year. The prevalence of epilepsy varies according to the development level of countries, ranging from 49 to 139 per 100,000 individuals (4).

For the classification of epilepsy, international scientists convened for the first time in 1960. The International League Against Epilepsy (ILAE) established a commission that introduced the 1989 Classification of Epilepsies and Epileptic Syndromes, creating a standardized global terminology for epilepsy (5). According to ILAE's 2014 report, epilepsy is defined as a disorder in which a person has two or more unprovoked or reflex seizures occurring more than 24 hours apart, has a single unprovoked or reflex seizure with a 60% risk of recurrence within the next 10 years, or is diagnosed with an epilepsy syndrome (6). The most recent ILAE classification report published in 2017 identified four types of epilepsy: focal, generalized, a combination of focal and generalized, and unknown etiology. Epilepsy type should be determined based on seizure type (7).

In focal epilepsy, the patient may experience one or multiple focal seizures, which can arise from single or multiple foci. The symptoms observed during seizures vary depending on the affected brain region (8). Temporal lobe involvement may present with various symptoms, including aura. Frontal lobe involvement is characterized by motor symptoms, such as sudden muscle contractions, head turning, and arm elevation. Parietal lobe involvement manifests with intense pain and numbness. Occipital lobe involvement is associated with visual disturbances, including flashes of light and altered color perception (9).

In generalized epilepsy, the entire brain is affected. During a seizure, the patient becomes rigid, collapses, and experiences alternating muscle contractions and relaxations. Unlike focal epilepsy, generalized seizures are characterized by loss of consciousness. (10). In the combination of focal and generalized epilepsy, the patient experiences both seizure types. Electroencephalography (EEG) findings indicate characteristics of both focal and generalized epilepsy. Dravet Syndrome and Lennox-Gastaut Syndrome are examples of combined focal and generalized epilepsy (8, 11). Diagnostic tools such as EEG and magnetic resonance imaging (MRI) are used to assess epilepsy patients and identify affected brain regions.

Volumetric MRI studies conducted on epilepsy patients provide us with information about volumetric changes in the hippocampus, amygdala, thalamus, caudate nucleus, putamen, cerebrum, and cerebellum structures. Atrophy and hypertrophy that may occur in these structures reveal the changes that epilepsy causes in the human brain (12).

With the development of artificial intelligence and the information age, automatic parcellation and artificial intelligence-assisted volumetric measurement programmes have recently emerged. This has made analyses faster, more reliable, and more reproducible. FreeSurfer, FSL (FMRIB Software Library), SPM (Statistical Parametric Mapping), and volBrain programmes are widely used to calculate brain volumes in epilepsy and many neurological diseases (13). These programmes enable analysis of cortical thickness, surface area, and cortical and subcortical volume changes in the brains of patients with epilepsy.

The brain, the largest component of the central nervous system within the cavitas cranii, wei-

ghs approximately 1,400 grams, constituting about 2% of total body weight (14). Functions such as cognition, memory, and consciousness are among the brain's complex processes. Evaluating brain volume is crucial for objectively analyzing changes occurring in both normal individuals and pathological conditions (15). Particularly in children and adults, brain volume is a critical parameter in the diagnosis of conditions such as autism, attention deficit hyperactivity disorder, schizophrenia, Alzheimer's disease, epilepsy, and multiple sclerosis. Changes in brain surface area are also emphasized in epilepsy and other neurological disorders (16). Studies have shown that individuals with epilepsy exhibit volume reductions in specific brain regions. The increasing number of studies in this field highlights the significance of brain volume as a research area in epilepsy. For this reason, it is necessary to summarize the historical progress of studies on epilepsy and brain volume and examine them using bibliometric analysis.

Bibliometric analysis involves quantitatively evaluating research data to reveal and assess the chronological progression of a particular field. Through bibliometric analysis, information on authors, countries, institutions, the number of studies conducted, citation counts, and their interrelations can be obtained (17). Bibliometric studies provide researchers with insights into the development, content, and current state of a particular research field (18). Our literature review has revealed no existing bibliometric analysis focused on epilepsy and brain volume. To fill this gap in the literature, we aim to conduct a bibliometric study on epilepsy and brain volume.

MATERIALS AND METHODS

Data Collection and Research Strategy

Data for this study were obtained from the Web of Science Core Collection (WOSCC), one of the most commonly and widely used databases for bibliometric analyses. To avoid being affected by potential changes in the database, the data were collected from WOSCC on a single day, 02.12.2024. The search formula used in the database was TS=(((“Epilepsy” OR “Seizure” OR “Convulsion” OR “Epileptic”) AND (“Brain volume” OR “Brain atrophy” OR “Brain volume loss”))). Publications within the date range from 2010 to 02.12.2024 were included in the study. Specific inclusion and exclusion criteria were applied in the study. Inclusion criteria comprised research investigating epilepsy and brain volume, document types classified as original research articles and reviews, and publications in English. Exclusion criteria included early access articles, conference abstracts, editorial materials, proceedings papers, book chapters, and letters to the editor. A total of 382 original research articles and 48 review articles were included in the study. The data acquisition diagram is presented in **Figure 1**.

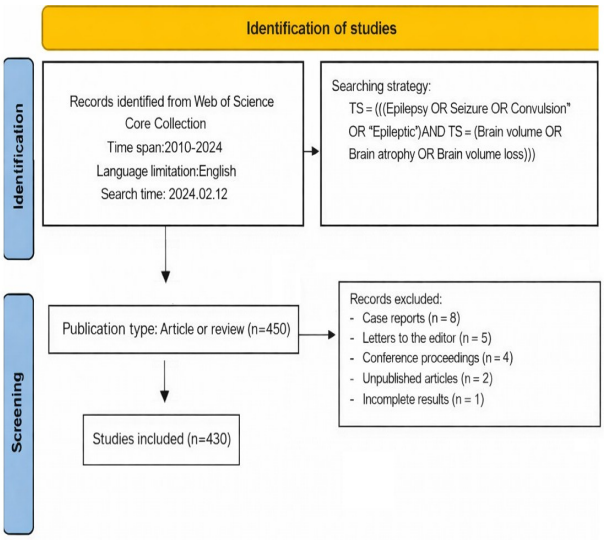


Figure 1: Flow diagram of Identification.

Ethical Committee

The study is a bibliometric analysis and was conducted without ethics committee.

Statistical Analysis

In this study, the VOSviewer software (version 1.6.20) was used to conduct bibliometric analyses and generate visualizations. VOSviewer is a powerful visualization tool widely employed for analyzing scientific publications and their associated networks. This software was specifically chosen for citation analyses, keyword relationships, and visualization of publication networks. The data collection process was performed using the export feature of the Web of Science Core Collection (WOS) database. Within this scope, all data from 430 articles selected based on the study's inclusion and exclusion criteria were downloaded. This dataset included details

such as article titles, abstracts, keywords, citation information, publication years, journals, and countries. The obtained dataset was analyzed in accordance with the study's primary objectives and categorized into the number of publications per year, countries of publication, received citations, published journals, and utilized keywords. All these analyses were visualized in detail using VOSviewer. Thanks to the program's robust graphical capabilities, the network relationships between articles and keyword connections were clearly illustrated. The findings provided a solid infrastructure for both qualitative and quantitative evaluations and presented visuals supporting the study's conclusions.

RESULTS

Annual Publications

In this study, a total of 430 articles written by 2,923 authors from 69 countries were analyzed. These articles were published in 205 different journals, with a general increasing trend in publication numbers over recent years. Despite fluctuations over the years, the number of studies has generally increased over time **(Figure 2)**. The highest number of studies was recorded in 2024, indicating an increased interest in the field during the final year.

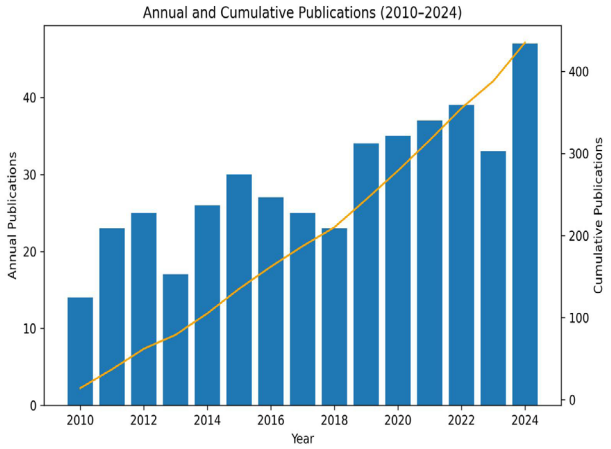


Figure 2: Annual and cumulative publications between 2010 and 2024.

Author Analysis

Identifying core authors within a specific field is a critical method for measuring scientific productivity and impact. In this context, Price's Law is a frequently used approach. This law provides a mathematical model for determining the minimum number of publications required for an author to attain core author status in a given field. According to Price's Law, the fundamental formula used to determine core authors is (0.749 x √nmax), where nmax represents the highest number of publications by an author in the relevant field. The result obtained from this formula indicates the minimum number of publications an author must have to be classified as a core author. Based on this calculation, the minimum number of publications required to be considered a core author was determined to be approximately 2.36. An analysis of scientific studies on epilepsy and brain volume conducted between 2010 and 2024 revealed that a total of 2,923 different authors contributed to research in this field. However, among these authors, only 77 exceeded the threshold value of two publications determined by Price's Law, qualifying them as core authors. This finding suggests that scientific production in the relevant field is primarily driven by a limited group of authors.

Examining the most productive authors, Matsumoto, N. emerged as the most prolific with 10 publications in this field. He was followed by Saitsu, H. with 8 publications and Luan, G. M. with 7 publications. This indicates that scientific knowledge production in the field is significantly shaped by these three authors. The number of publications, total citation counts of authors, and citation counts per article are presented in detail in **Table 1**. This table provides a quantitative assessment of the authors' productivity as well as the impact of their work on the scientific community.

Table 1: Authors within the top five publication ranks (including ties)

Rank	Author	Documents	Citations	Average citation/publication
1	Matsumoto N	10	224	22.4
2	Saitsu H	8	176	22
3	Luan GM	7	27	3.8
3	Pardoe HR	7	122	17.4
4	Guerrini R	5	168	33.6
4	Jackson GD	5	103	20.6
4	Kuzniecky R	5	42	8.4
4	O'brien TJ	5	169	33.8
4	Sisodiya SM	5	634	126.8
4	Striano P	5	202	40.4
5	Alfadhel M	4	125	31.2

Additionally, VOSviewer software was used to visualize and analyze collaboration networks among authors. The obtained network analysis results offer significant insights into the struc-

ture of collaborations, research groups, and the dynamics of the field. This visualization clearly highlights the intensity of connections between authors and key figures, as shown in **Figure 3**.

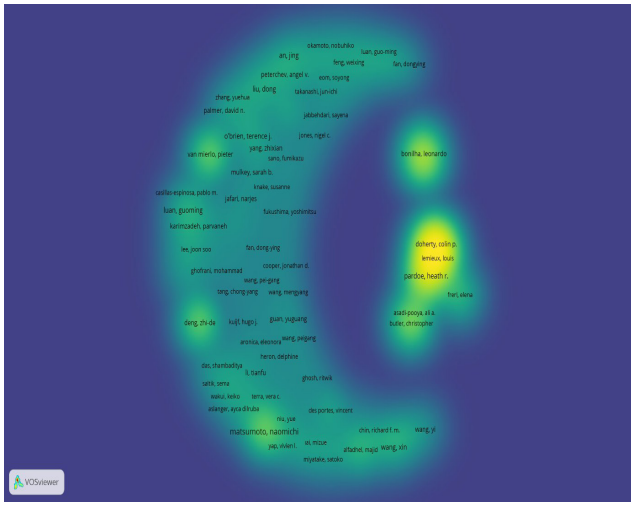


Figure 3: Network visualization of core authors.

Journal Analysis

Scientific studies on epilepsy and brain volume have been published in various journals contributing to the development of discipline. According to the analyses, a total of 205 different journals have published articles in this field between 2010 and 2024. This indicates that epilepsy and brain volume are topics of broad scientific interest and are addressed across multiple disciplines.

The relational analysis of journals was conducted using VOSviewer to explore author and article connections in greater depth. The resulting visualizations revealed the networks of scientific communication between journals and the intensity of these networks. This visualization, presented in **Figure 4**, provides detailed information on both the most prolific journals in this field and their interconnections. This analysis contributed to understanding the relational aspect of journal-based publications beyond mere publication counts (Figure 4).

Among the most frequently publishing journals, Epilepsia ranked first with 22 articles, establishing itself as a leading journal in this field. Another frequently preferred journal, Epilepsy & Behavior, ranked second with 15 publications. These two journals play a central role in terms of both publication volume and scientific contribution.

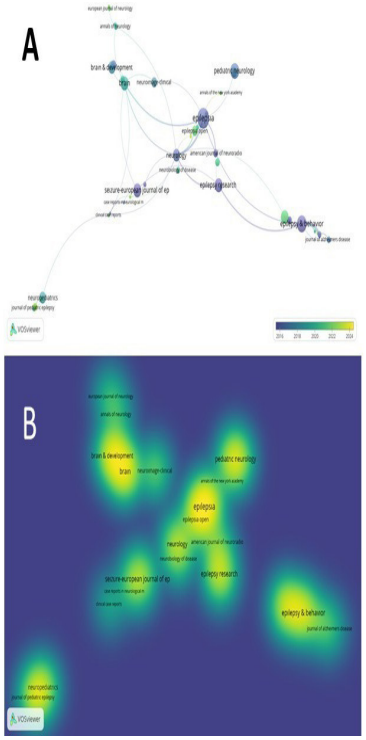


Figure 4: Visualization of the published journal network **A:** The greater the circle size, the greater the frequency of journal network. **B:** The greater the density, the greater the frequency of journal network.

The ranking of journals was evaluated not only based on publication count but also by considering citation counts and the average number of citations per article, providing a broader perspective. These data serve as key indicators for assessing the quality of scientific contributions made by journals in the field. Accordingly, the total citation counts for each journal and the average citation per article are presented in **Table 2**.

Table 2: The number of publications in the top 10 journals in the epilepsy and brain volume research field.

Rank	Source	Publication	Citations	Average citation/publication
1	Epilepsia	22	769	34.9
2	Epilepsy and Behavior	15	237	15.8
3	Pediatric Neurology	13	152	11.6
4	Brain	11	540	49
5	Epilepsy Research	11	194	17.6
6	Seizure-European Journal of Epilepsy	11	233	21.1
7	Frontiers in Neurology	10	68	6.8
8	Neurology	9	574	63.7
9	Brain and Development	9	113	12.5
10	Plos one	9	216	24

The relationships between journals are particularly significant for examining the dissemination and influence of research in the field. For instance, leading journals function as focal points for other journals, playing a critical role

in shaping the literature. This is associated with the high preference rates of these journals by both researchers and readers. Furthermore, this network structure also reflects the interdisciplinary approach to the literature in this field.

Analysis of Countries and Institutions

In this study, a total of 430 articles authored by 2,923 researchers from 1,147 institutions across 69 different countries were analyzed. The data obtained were analyzed using VOSviewer, a bibliometric analysis tool. For graphical representation, Figure 5 visualizes the distribution of countries based on the number of articles **(Figure 5)**. In this visualization, countries with a higher number of publications are represented by larger circles. Additionally, collaborative networks between countries are depicted with lines, where stronger collaborations are indicated with thicker lines.

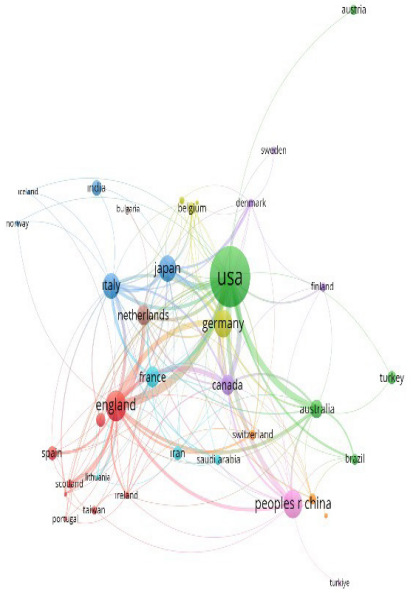


Figure 5: Cooperative relationships between countries; The thickness of the lines represents the strength of collaboration between countries.

Country-based evaluations reveal that the United States (USA) and the United Kingdom (UK) exhibit the highest collaboration rates and the highest number of publications in this field. These two countries are followed by China and Germany in terms of publication output and collaboration. Notably, the USA ranks first in both the number of articles and citations, distinguishing itself significantly from other countries. A detailed analysis of publication, citation, and collaboration counts is presented in **Table 3**. At the institutional level, the University of California System was identified as the leading institution in terms of both publication output and citation rates. Furthermore, the top five institutions with the highest number of publications were predominantly universities from the USA and the UK.

Tablo 3: The top 5 countries and Institutions for publications in the field of epilepsy and brain volume research.

Rank	Country	Publication	Citations	Institutions	Publication	Citations
1	USA	150	4595	University of California System	40	1761
2	England	54	2144	University of London	35	1657
3	Peoples R China	49	596	University College London	31	1497
4	Germany	46	1742	Harvard University	22	918
5	Japan	42	912	University of California San Francisco	18	902

Analysis of Keywords

A keyword analysis was conducted to understand the primary focal points of research on epilepsy and brain volume, as well as the distribution of these focal points within the field. Since keywords reflect the key areas of interest and trends within scientific literature, such analyses are crucial for understanding the scope of research domains. In this study, the frequency and interrelations of keywords were examined in detail using VOSviewer.

Figure 6 presents the visualization results of the keyword analysis. This figure visually represents the frequency of keyword usage and their connections with other terms **(Figure 6)**.

Figure 6A: Represents the frequency of keyword usage. The size of the circles in the visualization indicates how frequently a particular keyword appears in the research literature. Larger circles signify more commonly used keywords.

Figure 6B: Represents keyword frequency using color density and text size. The prominence of yellow coloring and the larger text sizes in the visualization highlight the intensity of specific keyword usage in more detail.

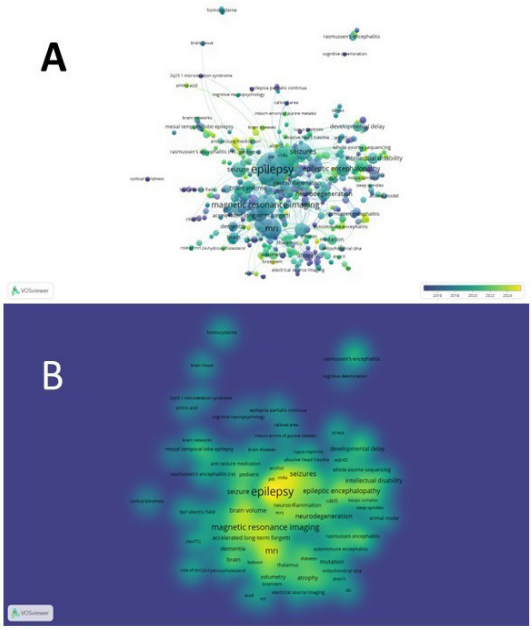


Figure 6: Analysis of Keywords **A:** The greater the circle size, the greater the frequency of keyword appearances. **B:** The greater the density, the greater the frequency of keyword appearances.

Based on these analysis results, the most frequently used keywords in studies on epilepsy and brain volume were identified. The top five keywords are listed in detail in **Table 4**. The most frequently used keyword was "Epilepsy", followed by "Brain Atrophy" and "Magnetic Resonance Imaging". These keywords represent the general trends and focal points of studies conducted in this field.

Table 4: The co-occurrence keywords of the top 5.

Rank	Keyword	Occurrences	Total link strength
1	Epilepsy	89	373
2	Brain Atrophy	31	129
3	Magnetic Resonance Imaging	30	131
4	MRI	28	127
5	Seizures	19	81

The findings indicate that keywords serve as descriptive and guiding tools for defining research focuses. Notably, the dominance of "Epilepsy" as the primary keyword suggests that research in this field is primarily concentrated on epilepsy itself. Keywords such as "Brain Atrophy" and "Magnetic Resonance Imaging" indicate that studies focus on neurological structures and imaging techniques, highlighting these methodologies as key approaches within the field. Such keyword analyses are critical for identifying research gaps and potential study topics in the field. For future research, these keywords serve as valuable references for guiding investigations. Additionally, the relational analysis of keywords facilitates a better understanding of interdisciplinary approaches and the overall structure of the literature.

DISCUSSION

Seizures occurring in epilepsy patients lead to structural changes in various brain regions (19). The earliest studies on this topic were conducted by Robert Bentley Todd in 1849 (20). According to Todd, seizures experienced by epilepsy patients can cause damage to brain structures. A global study conducted by Whelan et al. investigated structural brain abnormalities in patients with generalized epilepsy (21). This study demonstrated that losses occur in both cortical and subcortical structures. With the advancement of MRI imaging, the volumes of brain structures in epilepsy patients have been examined in greater detail (22,23). Recent years have witnessed an increasing number of studies exploring the relationship between epilepsy and brain volume. There are also studies that analyze epilepsy types and brain structures at a more detailed level. For this reason, bibliometric analysis was employed in this study to examine the association between epilepsy and brain volume. Our study is the first to use bibliometric techniques with visualized analyses to explore the field of epilepsy and brain volume, revealing the topics and boundaries of research using VOSviewer.

Our analysis found that Matsumoto N. ranked first in epilepsy and brain volume research with 10 publications. The researcher, affiliated with Yokohama City University in Japan, significantly contributed to positioning Japan among the top five countries in this field. Matsumoto has conducted extensive studies on epilepsy-related brain atrophy and focused on genetic mutations. This approach aligns with general trends in the literature suggesting that volume losses associated with epilepsy may not only be the result of seizures but may also be related to genetic and developmental predispositions. (24,25).

Meanwhile, Sisodiya SM. emerged as the most cited author in this field. Sisodiya's research explored the connections between hippocampal and intracranial volume changes and epilepsy. This approach is consistent with the extensive literature emphasizing the critical role of the hippocampus, particularly in temporal lobe epilepsy, and provides clinically significant complementarity to experimental and genetics-based findings. When these two lines of research are considered together, it is evident that the field possesses a holistic structure that bridges molecular mechanisms and clinical implications. (26).

Our bibliometric analysis summarized 205 journals in the epilepsy and brain volume field between 2010 and 2024. Epilepsia published the highest number of articles (5.0%) on epilepsy and brain volume, Epilepsy & Behavior followed with (3.4%), Pediatric Neurology ranked third (3.0%). The majority of research originated from: The United States (34.6%), The United Kingdom (12.4%), The People's Republic of China (11.5%). The United States dominated the research field on epilepsy and brain volume. However, the distribution of publishing nations and institutions was not equal. Thus, further international collaboration among more countries and institutions is necessary to advance this field.

Keywords serve as descriptors and summaries of an article's content. A detailed examination of keywords revealed that studies on epilepsy and brain volume investigate damage occurring in different brain regions. Research has focused on the effects of cortical and subcortical structural damage on epilepsy.

Studies have also analyzed epilepsy-related volumetric changes in different brain lobes. Rahatli et al. demonstrated that damage in the frontal lobe led to cortical thinning and volume loss in this region (27). Nakayama et al. found that individuals with temporal lobe epilepsy experienced neuronal and volume loss in the amygdala, leading to hippocampal sclerosis (28). Polli et al. investigated the relationship between hippocampal volume loss and seizure frequency (29).

In addition to these studies, Wu et al. observed thalamic atrophy in epilepsy patients. The anatomical connections and volume of the thalamus play a significant role in brain stimulation interventions for epilepsy (30). Similarly, Hogan et al. reported disruptions in hippocampal anatomy and decreases in parenchymal brain volume associated with temporal lobe epilepsy, emphasizing the importance of hippocampal mapping of these volumetric changes (23).

There is a bidirectional relationship between epilepsy and volumetric changes in brain structures, and they frequently co-occur.

From a literature perspective, this study represents the first bibliometric analysis conducted in the field of epilepsy and brain volume. It provides a bibliometric evaluation of studies conducted between 2010 and 2024. We identified key authors, journals, institutions, and countries in this field. Our study demonstrated an increasing trend in epilepsy and brain volume research and highlighted emerging topics and unexplored areas within the field.

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