

## Studies conducted on physical activity and brain: a bibliometric analysis

### *Fiziksel aktivite ve beyin arařtırmaları: bibliyometrik bir analiz*

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#### ABSTRACT

**Purpose:** The purpose of the study is to examine physical activity and brain-related studies published in international and peer-reviewed journals using the Bibliometric Analysis Method.

**Material and Methods:** By applying the visualized Bibliometric Analysis Method in the study, it was aimed to examine the general distribution characteristics, study progress, and highlights of existing studies on the effects of physical activity on the brain from 2001 to 2022. Studies that were published in journals containing SSCI, SCI-Expanded and AHCI indices of Web of Science (WoS) were examined within the scope of the study. After the elimination criteria were applied, a total of 6007 studies were included in the Bibliometric Analysis.

**Results:** When the year distributions of the publications were examined, it was found that they were few in number from 1990 to 2000, increased as of 2001, and a significant increase was detected especially in 2019. According to the articles reviewed based on WoS citations, it was found that the fields of neuroscience, clinical neurology and psychiatry came to the forefront. Considering the journal distribution of the examined articles, the PLoS One journal was in the first place. Four main clusters emerged in the common word analysis, which were green, red, blue and yellow. It was obtained that the green cluster occupying the center of the map was the field of sports sciences. The words found in the clusters that emerged from the analysis were physical activity, exercise, cognition, aging, Alzheimer's disease, depression, dementia, and hippocampus.

**Conclusion:** The study systematically summarizes and analyzes studies conducted on the promotion of physical activity by emphasizing the improvement of cognitive functions. It is expected that the study will provide guidance and reference for future research.

**Keywords:** *Bibliometric analysis, brain, physical activity, common word analysis, WoS*

#### ÖZ

**Amaç:** Bu çalışmanın amacı, uluslararası ve hakemli dergilerde yayımlanan fiziksel aktivite ve beyin içerikli arařtırmaların bibliyometrik analiz yöntemiyle incelemektir.

**Gereç ve Yöntem:** Görselleřtirilmiş bibliyometrik analiz yöntemiyle, 2001'den 2022'ye kadar fiziksel aktivitenin beyin üzerindeki etkisine iliřkin arařtırmaların genel dağılım özelliklerini, arařtırma gelişimlerini ve önemli noktalarını incelemek amaçlandı. Çalışma kapsamında Web of Science'ın (WoS) SSCI, SCI-Expanded ve AHCI indeksleri içeren dergilerde yayımlanan arařtırmalar incelendi. Eleme kriterleri uygulandıktan sonra toplam 6007 arařtırma bibliyometrik analize alındı.

**Bulgular:** Yayınların yıl dağılımları incelendiğinde 1990 yılından 2000 yılına kadar az sayıda oldukları, 2001 yılından itibaren arttığı, özellikle de 2019 yılında önemli düzeyde artış olduğu gözlemlendi. WoS atıflarına dayalı olarak incelenen makalelere göre, nörobilim, klinik nöroloji ve psikiyatri alanlarının öne çıktığı görülmektedir. Yayınların dergi dağılımlarına bakıldığında PLoS One dergisi ilk sırada yer almaktadır. Ortak sözcük analizinde dört ana küme ortaya çıktı. Bu ana kümeler; yeřil, kırmızı, mavi ve sarı kümelere ayrıldı. Haritanın merkezinde yer kaplayan yeřil kümenin spor bilimleri alanı olduğu anlaşıldı. Analiz sonucunda ortaya çıkan kümelere bulunan sözcükler fiziksel aktivite, egzersiz, biliř, yaşlanma, Alzheimer hastalığı, depresyon, demans ve hipokampus oldu.

**Sonuç:** Bu çalışma, biliřsel fonksiyonların gelişimine etkisini vurgulayarak, fiziksel aktivitenin desteklemesine iliřkin arařtırmaları sistematik olarak özetleyip analiz etmektedir. Gelecekteki arařtırmalara rehberlik ve referans sağlayacağı ön görülmektedir.

**Anahtar Sözcükler:** *Bibliyometrik analiz, beyin, fiziksel aktivite, ortak sözcük analizi, WoS*

## INTRODUCTION

It can be argued that human evolution is shaped by an active lifestyle, and contemporary sedentary behaviors have serious consequences for human health. For this reason, inactivity has become a major public healthcare concern (1). In this context, physical activity level was associated

with cardiovascular disease and Type 2 Diabetes (2). It has only recently been understood that physical activity can be a powerful medicine to counter the effects of inactivity. Furthermore, studies report that physical activity has also positive effects on brain structure and health (3-6).

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Evidence obtained in human and animal studies reveals that physical activity has direct roles in improving brain health by affecting both brain structure and brain function (7). It is already known that physical activity has important effects on brain health of people of all ages. Regular participation in physical activity during early childhood and adolescence optimize the neuronal environment for cerebral and cognitive development at different stages of life (8). Physical activity may be central to the maintenance of cognitive function by reducing vascular risk factors and preventing a series of neurobiological events that occur as cognitive decline later in life in middle-aged individuals (9,10).

There are also studies conducted on positive effects of physical activity on the preservation of, and even an increase in brain volume (11). Observational studies found that brain volume, particularly in the hippocampus, is preserved in more physically active people (12-14). Physical activity is also associated with the preservation of cortical thickness (15,16). MRImaging displays that white matter integrity is associated with better and higher physical activity levels in individuals, as measured by diffusion tensor imaging (17-19). Also, physical activity is considered to support neuroplasticity, the brain's ability to continually adapt throughout life, as well as neurogenesis, which is the production of new neurons (20,21).

Although there are numerous publications on physical activity and the brain, few attempts were made to collect bibliometric data systematically to identify research trends and highlight publications that influenced the development of the field. The bibliometric method generally aims to reveal citation paths in the scientific literature or academic publications (22). This method was used in different fields from past to present. However, its use in physical activity and brain studies is limited by a small number of studies conducted in recent years (23-25).

Previous studies focused on all articles on physical activity and the brain published in journals within the scope of Social Science Citation Index (SSCI), Science Citation Index (SCI)-Expanded, Arts & Humanities Citation Index (AHCI), by using the Web of Science (WoS) database. However, common word analysis, which is among the most popular bibliometric methods, was not included in the studies that were conducted based on a descriptive perspective, and limited to trend and co-authorship analyses. Also, most of the bibliometric studies that focused on physical activity and brain research did not use current science mapping methods.

In this context, the present study aimed to analyze the general status of physical activity and brain-related research published in SSCI, SCI-Expanded and AHCI indexed jour-

nals in the Web of Science (WoS) Core Collection, and included in international indices from 2001 to 2021 with the help of visual maps, and to contribute to the literature. The study questions that guided the study are as follows.

1. What is the annual distribution of publications on physical activity and the brain?
2. What is the journal distribution of publications on physical activity and the brain?
3. What are the Web of Science (WoS) categories of publications scanned with the keyword “physical activity and brain”?
4. What common word network model emerged from publications on physical activity and the brain?

## **MATERIAL and METHODS**

### **Study Model**

The model of the study is a case study design, which is one of the qualitative research methods. A case study provides an in-depth examination of a phenomenon or event (26). The case study design was chosen in the study to examine the articles published within the scope of physical activity and brain in terms of bibliometric parameters, and determine the current situation. This research did not require an ethics committee approval.

### **Search Strategy**

The data of this study were obtained from Social Science Citation Index (SSCI), Science Citation Index (SCI)-Expanded, and Arts & Humanities Citation Index (AHCI); and from the articles published between years 2001-2021. The search strategy was to review only articles of peer-reviewed journals in “Physical activity AND Brain” (All Fields), AND 2022 (Excluding Publication Year), AND articles (document type), AND Science Citation Index Expanded (SCI-Expanded), OR Social Sciences Citation Index (SSCI), OR Arts & Humanities Citation Index (A&HCI) (Web of Science Index).

### **Data Collection Process**

The bibliometric data in this study were taken from the Web of Science (WoS) database produced by Clarivate Analytics. The WoS Database is one of the world's most important scientific citation search and analytical information platforms, and includes many bibliometric indicators and a large database of different disciplines (27).

An online search was made in the WoS Database with bibliometric analysis. The scanning range covered the period between 2001 and 2021. The keywords “physical activity and brain” were scanned in this search both in the article

titles and in the article contents, and 6007 records related to the subject were accessed out of a total of 8623 records.

### Data Analysis

The Bibliometric Analysis Method was used in the study. Data obtained with the method were compared by two different researchers, the deviating data were reviewed again, and the final results were obtained. Data are presented here in the form of tables and figures. The VOSviewer (Version 1.6.9) package program, which can be used free of charge, was used in the study to make the bibliometric analysis,

create maps, and view the articles published on physical activity and brain (28).

## RESULTS

### Annual distribution of publications on physical activity and the brain

When the trend of the related publications was examined, it was found that they were few in number from 1990 to 2000, increased by gaining momentum as of 2001, and there was a significant increase especially in 2019 (Figure 1).



### Journal distribution of publications on physical activity and the brain

When the journal distribution of publications was assessed, it was observed that there were over 1000 journals covering the subject area of 'physical activity and the brain'. Only journals with more than both 50 citations and 50 publications are given (Table 1), led by PLoS One with 170 articles; followed by Behavioral Brain Research, Frontiers in Aging Neuroscience, and Brain Research, and with over 90 articles. Brain Behavior and Immunity, International Journal of Environmental Research, Neuroscience, Journal of Alzheimer's Disease, Physiology & Behavior, Scientific Reports, Medicine and Science in Sports and Exercise, Frontiers in Psychology, BMJ Open, Frontiers in Human Neuroscience, and Neurobiology of Aging journals listed more than 50 articles. Finally, the Neuroimage journal published 50 articles.

### Web of Science (WoS) categories of publications scanned with the keyword 'physical activity and brain'

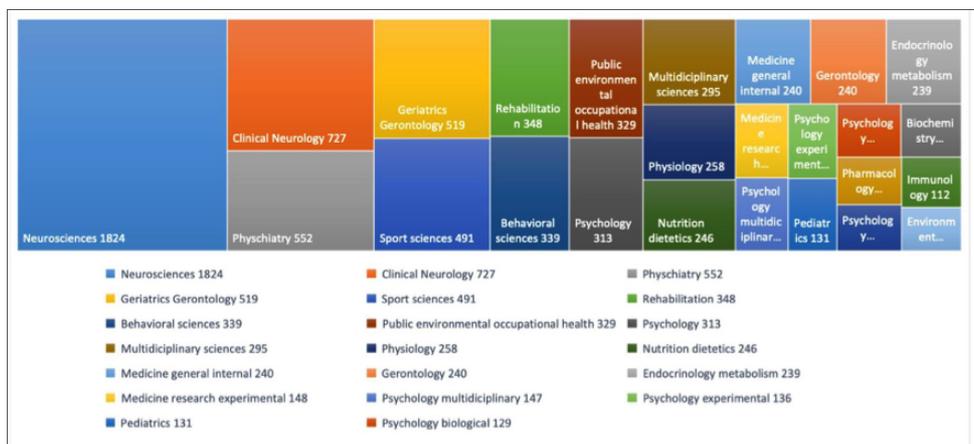
When the categories of related publications were reviewed, the first five fields that had the highest number of publications were 'Neuroscience' (1824), 'Clinical Neurology' (727), 'Psychiatry' (552), 'Geriatrics Gerontology' (519), and 'Sport Sciences' (491) (Figure 2).

### Common word network model emerged from publications on physical activity and the brain

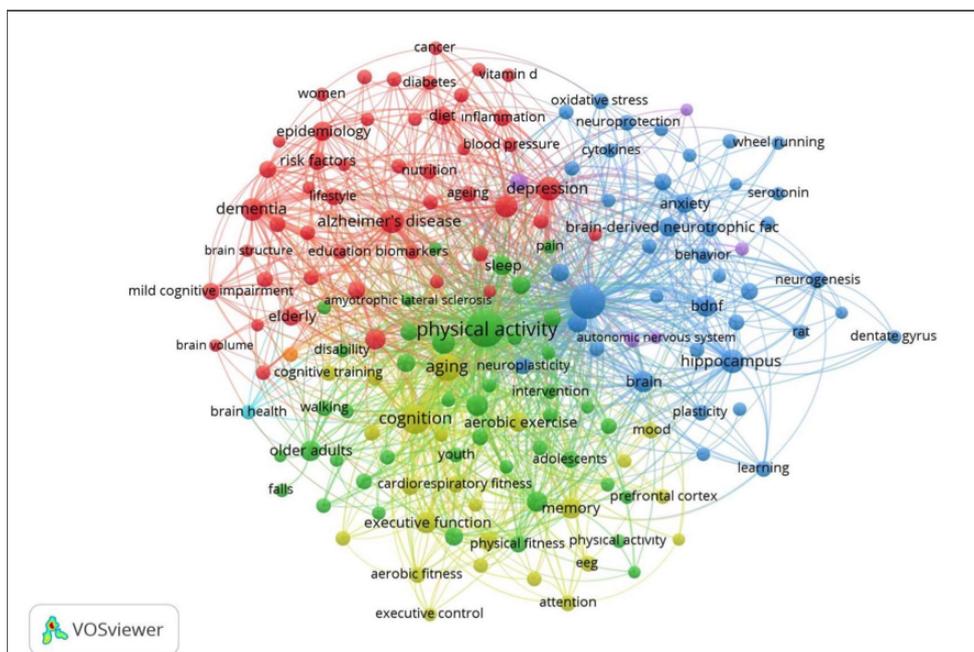
When the keywords that were repeated in the publications were examined, it turned out that 9239 different keywords were used. When the cut-off point was determined as 'to be used at least 20 times', 162 frequently used keywords were detected (29). When the map that consisted of these frequently used keywords was examined (Figure 3), it was found that there were four main clusters (green, red, blue and yellow) and relatively smaller clusters. It was also found that the words 'physical activity', 'exercise', 'cognition', 'aging', 'Alzheimer's disease', 'depression', 'dementia', and 'hippocampus' were used frequently by different disciplines. Thus, it can be argued that these words are the common keywords used by different fields.

**Table 1.** The distribution of journal publications and number of citations

Journal name	Articles (n)	Citations (n)	Link strength
PLoS One	170	4277	177
Behavioural Brain Research	108	3706	310
Frontiers in Aging Neuroscience	93	2238	150
Brain Research	91	4895	353
Brain Behavior and Immunity	89	4215	78
International Journal of Environmental Research Neuroscience	75	605	28
Neuroscience	74	5732	356
Journal of Alzheimers Disease	72	2685	108
Physiology & Behavior	71	2000	155
Scientific Reports	61	821	52
Medicine and Science in Sports and Exercise	60	3123	150
Frontiers in Psychology	59	619	59
BMJ Open	58	443	14
Frontiers in Human Neuroscience	56	1301	66
Neurobiology of Aging	51	2896	215
Neuroimage	50	2116	169



**Figure 2.** The distribution of related publications according to Web of Science categories



**Figure 3.** The analysis of keywords

When the clusters are examined, it is understood that the green cluster (the large cluster) focuses on sport sciences. In this cluster, concepts such as physical activity, aerobic exercise, walking and physical fitness reveal that this cluster mostly represents studies related to sport sciences and health. When the frequently used concepts are evaluated, it is seen that these studies mainly focus on pain, lateral sclerosis, sleep, falls, disability, adolescence, aging, fitness and exercise. There are studies related to brain health, physical activity, exercise, cognition, aging, Alzheimer's disease, dementia, and nutrition in the turquoise cluster, which occupies very little space between the green and red clusters.

The red cluster contains the words Alzheimer's disease, aging, vitamin D, cancer, mild cognitive impairment, brain volume, blood pressure, amyotrophic, and brain structure. It is considered that this cluster focuses on clinical neurology, geriatrics and gerontology in general, and might refer to areas related to brain health (e.g., epidemiology, dementia, women, lifestyle, diabetes, inflammation, nutrition, depression, biomarkers, and risk factors). There are studies on cerebral blood flow related to more general topics such as physical activity, Alzheimer's disease, obesity, exercise, hippocampus, and cognition in the orange cluster just above this one.

The blue cluster contains the words oxidative stress, nerve protection, cytokines, anxiety, serotonin, brain-derived neurotrophic factor (BDNF), behavior, neurogenesis, neuroplasticity, autonomic nervous system, mouse, hippocampus, brain, plasticity, and learning. It can be argued that this cluster mostly represents the field of neuroscience. The words related to Covid-19, mental health, heart rate variability, pregnancy, and autonomic nervous system are given in the purple cluster just above this cluster.

Finally, the yellow cluster includes words such as aging, cognitive training, cognition, mood, cardiovascular fitness, prefrontal cortex, memory, executive function, aerobic fitness, executive control, EEG, and attention. This cluster generally seems to represent the multidisciplinary field and displays that these concepts are frequently used in other fields as well.

## DISCUSSION

The field of physical activity, which recently received increasing attention, can be considered an area that must be studied together with other disciplines. The bibliometric analysis in this article aimed to add value to the existing literature as it provided an overview of the general publication landscape, and informed the scientific community about the publications that had the greatest effect on physical

activity and brain research. In this context, the research problems were discussed respectively.

### Annual distribution of publications on physical activity and the brain

It was revealed that the number of publications followed a steep upward trend as of 2001 and increased steadily over time, peaking in 2019 when more than 700 scientific studies were published. Most of the studies were conducted in the United States. The rapid growth in the number of publications might also have played an active role in the physical activity and health promotion programs in the United States. As an example, it is possible to mention the 'Exercise is Medicine' health promotion program, which was launched jointly in 2007 by the American College of Sports Medicine and the American Medical Association (30). This program aimed to promote health with physical activity and exercise based on the basic idea of spreading the belief that "exercise is beneficial to the human body and proper exercise prescription is necessary" (24).

Müller et al. used bibliometric data to provide an overview of the eHealth and mHealth research area on physical activity, sedentary behavior and diet, and concluded that the number of articles on mHealth increased rapidly over a 17-year period (31). The findings of our study are similar to those of the studies that were conducted by Müller et al. (23) and Wang et al. (24). Unlike our study, Li et al. (25) conducted bibliometric analyzes of research trends on traditional Chinese health exercises to improve cognitive function, and reported a slight decrease in the publication output between 2001-2002, 2009-2010, and 2014-2016.

### Journal distribution of publications on physical activity and the brain

Journals that had more than 50 citations and more than 50 publications in a total of 6007 publications in physical activity and brain research were used as the bibliometric data. All highly cited publications had quantitative design, and most were cross-sectional, experimental and meta-analysis studies. PLoS One is the most popular journal for researchers in this field. The leading journals by citation count represented open access and non-open access journals, and the journals following PLoS One were Behavioral Brain Research, Frontiers in Aging Neuroscience, and Brain Research. Also, Medicine and Science in Sports and Exercise, and BMJ Open journals, which accept many publications in the field of sport sciences, were also included in this ranking. Other journals in the ranking were Frontiers in Aging Neuroscience and Frontiers in Human Neuroscience that included bibliometric analysis findings of trend studies related to exercise to improve cognitive functions by Li et al.

(25). Journals that publish open access articles take advantage of citations in terms of citation speed and overall citation count (32). However, the extent of this effect appears to be site-specific, which might explain why many non-open access journals that publish articles on physical activity and the brain receive high citations (33).

### **Web of Science (WoS) categories of publications scanned with the keyword ‘physical activity and brain’**

When the most productive and effective articles on physical activity and the brain were examined, it was observed that authors working in the field of neuroscience came to the forefront in terms of productivity. Also, the fact that the most cited articles were in the field of neuroscience coincided with the number of citations and author productivity. The prominence of neuroscience in terms of the number of publications and citations indicates that there is a need for effective cooperation and publication activities in other fields of physical activity. In this context, increasing projects and funding in the fields other than the abovementioned disciplines will help create research collaborations and quality publications in these fields.

### **Common word network model emerged from physical activity and brain-related publications**

When the keyword analysis was examined, it was determined that 9239 different keywords had been used in the studies. When ‘used at least 20 times’ was determined as the cut-off point, 162 frequently used keywords were reached (29). It was observed that the concepts that became evident in the clusters emerging in the analysis were ‘physical activity’, ‘exercise’, ‘cognition’, ‘aging’, ‘Alzheimer’s disease’, ‘depression’, ‘dementia’, and ‘hippocampus’. Dong et al. (34) stated that the most used keywords were ‘paralysis’, ‘rehabilitation’, and ‘recovery’ in their study that was designed to perform a bibliometric analysis of global trends in studies conducted on exercise interventions for stroke. These keywords highlight research over the past 20 years and can help define the limits of research.

### **Limitations and Recommendations**

The study is the first bibliometric analysis to summarize the progress and trends of scientific studies conducted on physical activity and the brain over the past 20 years based on WoS data, and was derived from 6007 articles and enriched with results. As well as analyzing the number of publications, citations and journals, the study also analyzed subject categories, publication years, authors and keywords.

The study covered physical activity and brain research published in SSCI, SCI-Expanded and AHCI indexed journals in WoS. In this context, not including publications from databases such as ERIC and SCOPUS can be considered the limitation of the study.

However, the indices used in the study were chosen because of their high international validity. Only the types of articles that were published in English were selected for the study; book chapters, reviews, and studies written in different languages were excluded. It can be suggested for future studies that different systematic review methods can be used together because methods such as content analysis and thematic analysis were not used in this study.

### **CONCLUSION**

The study represents the first attempt to conduct a bibliometric study in the field of physical activity and brain research. The study accessed 6007 records on the topic from 2001 to 2021, and revealed that the number of articles published each year is increasing. Most journals were in the fields of medicine and sports. It was determined that the PLoS One journal had the most publications and citations. It was also revealed that the publications scanned with the keyword ‘physical activity and brain’ were mostly in the field of neuroscience. Physical activity, exercise, cognition, aging, Alzheimer’s disease, depression, dementia, and hippocampus were the most important keywords. Although the study had certain limitations, it serves as a reference for future research and highlights the undeniable importance of physical activity for brain health.

#### **Ethics Committee Approval / Etik Komite Onayı**

This research did not require an ethics committee approval

#### **Conflict of Interest / Çıkar Çatışması**

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

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#### **Author Contributions / Yazar Katkıları**

Concept:SB,IK,GD; Design: SB,IK; Supervision: GD; Materials: SB,IK; Data Collection and/or Processing: SB,IK; Analysis and Interpretation: SB,IK; Literature Review: SB; Writing Manuscript: SB; Critical Reviews: GD,IK

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