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REVIEW

# Research Trends and Progress in Exercise Interventions for Depression: A Bibliometric Visualization Analysis

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**Objective:** Depression is a chronic disorder that affects a considerable population worldwide. Exercise has been proposed as an effective adjunct for depression. Although there has been a significant amount of research on exercise for depression, there is a lack of reviews analyzing current state and frontier of the research. This study aims to identify current hot topics and tendencies in the field of exercise for depression.

**Methods:** Articles and reviews on the topic of exercise for depression published in English between January 2010 and December 2023 were screened from the Web of Science Core Collection. The qualified records were evaluated quantitatively and visualized using CiteSpace software. The analysis contains information on authors, institutions, journals, publications, and countries/regions, as well as subject categories and keywords.

**Results:** A total of 2405 records were analyzed. The number of related publications has been growing rapidly from 2010 to 2023. The Journal of Affective Disorders published the most articles (n = 137). The USA leads in terms of the number of publications (n = 684) and citations (n =19688). The most productive institution and author were King's College London (n = 69) and Stubbs B (n = 31), respectively. Psychiatry (n = 783) was definitely the first research hotspot category. The keywords analysis revealed that the group of interest was older adults, and the form of exercise of interest was Hatha yoga in the area.

**Conclusion:** The topic of exercise for depression is an expanding field of research, with the expectation that it will remain a focus of investigation. The findings of our study indicate the key areas and potential avenues for further investigation in this field. More research is required to investigate potential mechanisms of exercise and to develop more personalized exercise prescriptions in order to effectively improve depression in specific populations.

**Keywords:** exercise, depression, global trend, CiteSpace, bibliometrics

## Introduction

Depression is a highly common and persistent psychiatric disorder that impacts over 300 million individuals around the world.[1] The World Health Organization (WHO) has recognized it as a leading cause of mental and physical disability,[2] expected to result in about 47 million disability-adjusted life years.[3] Depression is also linked to premature mortality and multiple clinical comorbidities, such as anxiety,[4] cardiovascular disease,[5] diabetes,[6] and cancer,[7] observably adding to the global public health burden.

At present, first-line methods for treating depression generally involve pharmacological therapy, psychotherapeutic interventions, or a combination of both.[8] However, research has shown that depression is highly prone to relapse even with treatment. Around 74% of patients experience a relapse, and nearly 20% report at least 10 episodes in their lifetime.[9] Moreover, the challenge of treatment resistance and limited access to antidepressants or psychotherapy affects many patients with depression. A significant proportion (about 30% to 50%) of patients diagnosed with depression do not

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respond positively to the first-line therapeutic interventions.[10] Meanwhile, it is noteworthy that in high-income regions, only half of patients with depression receive adequate treatment.[11] In lower-middle and low-income regions, this number drops to one in five.[11] Therefore, there is a need to develop additional evidence-based and accessible treatments for people with depression.

Exercise is a non-drug therapy that has been proposed as a promising supplement or alternative to antidepressants and psychotherapy for depression.[12–14] A growing body of evidence suggests that adequate exercise is significantly associated with an improvement in depressive symptoms in people of varying age groups who suffer from depression.[15–17] A network meta-analysis of 218 randomized controlled studies (RCT) conducted in 2024 has suggested that exercise is an effective therapy for depression with moderate effect sizes, showing dose-dependent effects proportional to the prescribed intensity.[18] Pearce et al[19] performed a meta-analysis of 15 prospective studies to examine correlation between physical activity and depression. The results found that engaging in physical activity in an active way have positive effects on depressive symptoms, even with activity levels lower than the recommended guidelines. In addition, a meta-analysis of 41 RCT involving over 2200 adults with depression indicated that supervised, group-based aerobic exercise at moderate intensity significantly improves depressive symptoms, representing an effective intervention for depression.[20] Currently, exercise has been suggested as an essential complementary treatment for depression by clinical guidelines in WHO, USA, England, and Australia.[21–24] The quantity of research exploring the potential benefits and optimal prescriptions of exercise for depression has rapidly increased globally over the past decade. Although previous bibliometric studies have mapped the research landscape on exercise for depression symptoms in university students,[25] and conducted concurrent bibliometric analyses of physical activity for both anxiety and depression,[26] rigorous bibliometric analyses specifically examining the field of exercise for depression in general populations remain absent. Consequently, a comprehensive bibliometric study is warranted to gain deeper insights into research trends, status, and future development directions of this field. This will guide researchers in identifying current branches and limitations of the field, as well as providing directions for future advancements.

Bibliometrics is a valuable approach that uses quantitative and visual methods to map the development trends and collaborative networks within a particular research field. In this study, we employed CiteSpace, a validated bibliometric tool, to conduct a comprehensive quantitative and visual examination of research on exercise for depression. The analysis systematically mapped and evaluated various dimensions, including publications, citations, journals, authors, institutions, regions/countries, subject category, and keyword occurrence.[27] Therefore, the objective of this study is to undertake a comprehensively bibliometric analysis of the current development trends, research landscape and emerging frontiers in the field of exercise for depression. The findings will provide a meaningful overview and reference point for researchers, and will foster the progress of this field.

# Methods

## Data Collection

The bibliometric analysis examined records identified from the Web of Science Core Collection, which comprises four indexes: SCI-EXPANDED, SSCI, CCR-EXPANDED, and IC. The search queries used to retrieve records were "Title = (exercise OR 'exercise therapy' OR 'physical education and training' OR 'physical fitness' OR 'physical exertion' OR 'physical activity' OR sport OR training OR aerobic OR endurance OR fitness OR walking OR running OR jogging OR dance OR swimming OR cycling OR strength OR resistance OR stretch OR yoga OR 'mind-body exercise' OR 'traditional exercise' OR Qigong OR 'tai chi' OR 'tai ji' OR baduanjin) AND Title =. (depression OR 'depressive disorder')". The search was conducted for studies published between January 2010 and December 2023, limited to articles and reviews in English language. The complete bibliographic records, including titles, author information, keywords, abstracts, and cited references, were extracted from WOSCC and saved in plain text format. The subsequent data cleaning process was conducted manually in Microsoft Excel 2019, involving the standardization of institutions, authors, and countries/regions. A total of 2405 records were finally identified, comprising 2112 articles and 293 reviews. The full records and cited references were exported to CiteSpace as plain text for further analysis. Figure 1 shows the process of retrieving and filtering the records.

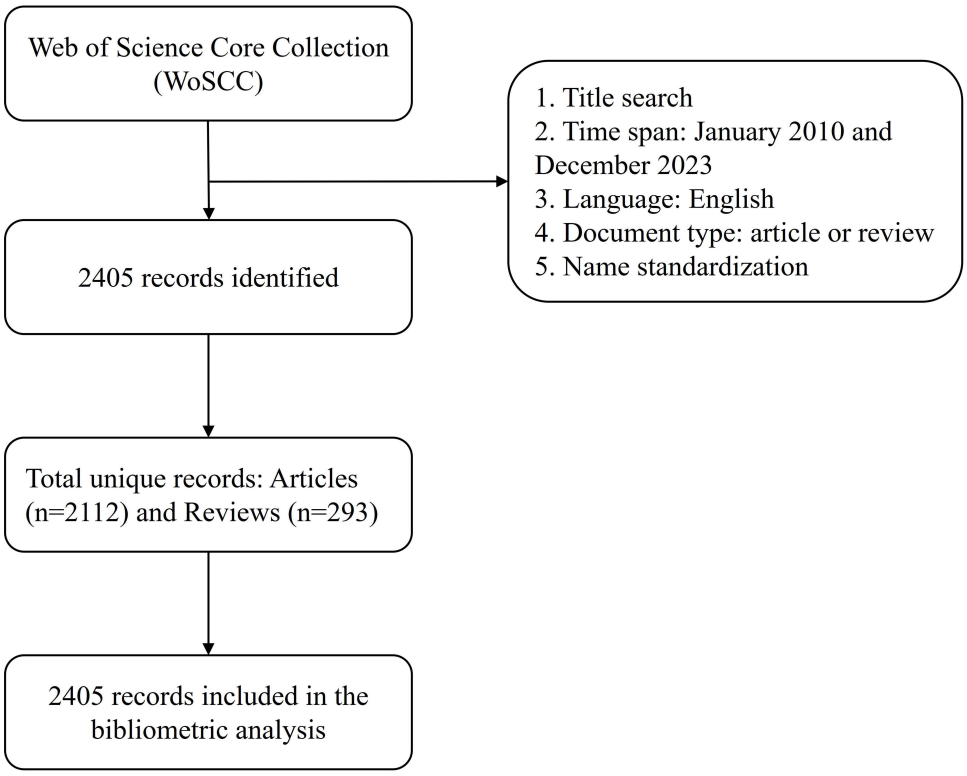


**Figure 1** Flow chart of the study.

## Analytical Tools

This study employed CiteSpace and Microsoft Office Excel 2019 as analytic tools for bibliometric analysis. CiteSpace is interactive visual analytical software developed by Professor Chen Chaomei of the School of Information Science and Technology at Drexel University in the United States.[28] The software is widely employed to visualize documents and analyze bibliometric data, with the objective of identifying the most significant developments and research hotspots within a given field. Therefore, it can reveal the research direction, collaboration, and frontier characteristics of countries/regions, institutions, and authors within the field.[29] The nodes and links in the network map were determined based on the item count and level of collaboration, respectively. In addition, centrality measures the importance of nodes in the network maps. The main parameters for data processing are described below. The time-slicing was divided into yearly slices, ranging from January 2010 to December 2023. All items in the term source were selected. Depending on the specific analytical objectives, we selected appropriate node types such as author, country, institution, or keyword for examination. The selection threshold was set to retain the top 50 most frequent items per time slice, with a g-index of 25 applied to normalize citation impact. Network connections were subsequently optimized using the Pathfinder algorithm to eliminate redundant links while preserving the most significant relationships in the co-occurrence network. Other parameters were maintained at their default settings. Additionally, we also analyzed yearly publications and citations, with findings graphically represented using Microsoft Excel 2019.

# Results

## Annual Publications and Citation Trend

Figure 2 displays the distribution of annual publications and citation trends in the field of exercise for depression, based on a review of 2405 records. The orange bars indicate annual publications, while the black line chart represents the citation trend. Overall, the number of annual publications has exhibited a consistent increase over time, with the exception of 2014 and 2020, which showed a decline relative to the adjacent years from 2010 to 2023. The publication years with the greatest number of publications were 2022, with 309 publications. The number of citations has been on the rise, reaching a peak of 10,882 in 2022 and subsequently declining slightly to 10,564 in 2023.

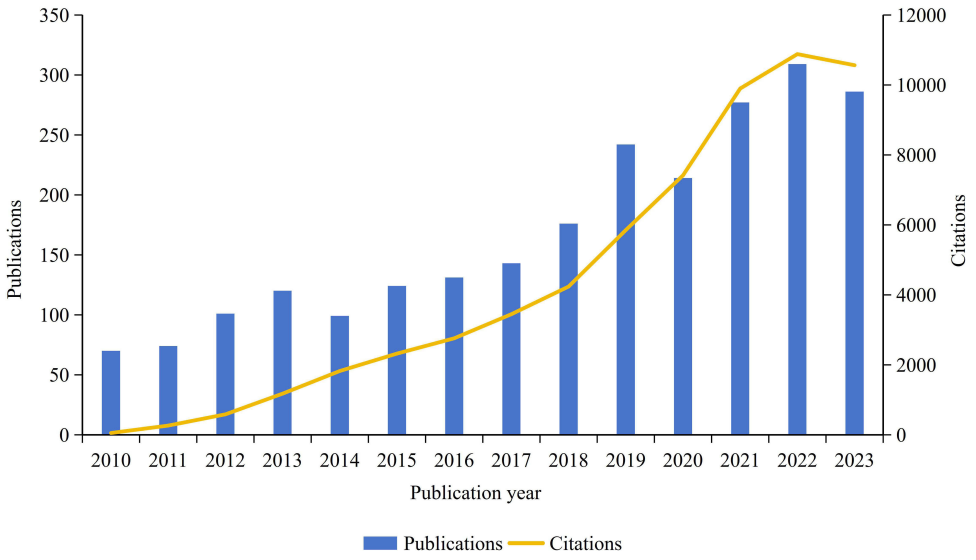


**Figure 2** The annual count of publications and citations in the field of exercise for depression.

## Analysis of Journals

A total of 2405 articles have been published in 881 professional journals. Table 1 presents key information on the top 10 journals. The Journal of Affective Disorders published the highest number of articles (n = 137) and received the most citations (n = 4557). The International Journal of Environmental Research and Public Health was ranked second (n = 72), with Frontiers in Psychiatry (n = 69) following in third place. The aforementioned journals were all cited on at least 1000 times. Moreover, the Journal of Psychiatric Research has the highest average number of citations per item (n = 65.77), followed by PLOS ONE (n = 43.72) and the Journal of Affective Disorders (n = 33.26). In terms of impact factor (IF), Psychiatry Research is the highest-ranking journal with an IF of 11.30, followed by Journal of Affective Disorders with an IF of 6.60, and Journal of Psychiatric Research with an IF of 4.80. It is noteworthy that despite having the least number of publications, the Journal of Psychiatric Research has the highest average per-item citation. In the field of academic publishing, Elsevier has emerged as the most prominent and influential publisher, with the highest publication counts, citations, and IF.

## Analysis of Countries/Regions

A total of 95 countries/regions have published research on the topic. Table 2 displays the top 10 countries/regions with the highest number of publications from 2010 to 2023. The USA was the country with the highest quantity of publications (n = 684), followed by China (n = 408) and England (n = 242). In terms of citations, the USA had the highest number (n = 19,688), followed

**Table 1** Top 10 Journals with the Most Publications in the Field of Exercise for Depression

| Rank | Journals | Counts | Citations | Average per Item | IF | Publishers |
|---|---|---|---|---|---|---|
| 1 | Journal of Affective Disorders | 137 | 4557 | 33.26 | 6.60 | Elsevier |
| 2 | International Journal of Environmental Research and Public Health | 72 | 1642 | 22.81 | 4.61 | MDPI |
| 3 | Frontiers in Psychiatry | 69 | 1241 | 17.99 | 4.70 | Frontiers Media |
| 4 | Mental Health and Physical Activity | 45 | 744 | 16.53 | 4.70 | Elsevier |
| 5 | Frontiers in Psychology | 38 | 478 | 12.58 | 3.80 | Frontiers Media |
| 6 | Psychiatry Research | 33 | 578 | 17.52 | 11.30 | Elsevier |
| 7 | PLOS ONE | 29 | 1268 | 43.72 | 3.70 | Public Library of Science |
| 8 | BMC Public Health | 27 | 610 | 22.59 | 4.50 | BMC |
| 9 | BMC Psychiatry | 24 | 448 | 18.67 | 4.40 | BMC |
| 10 | Journal of Psychiatric Research | 22 | 1447 | 65.77 | 4.80 | Elsevier |

**Abbreviation**: IF, Impact Factor.

**Table 2** Top 10 Countries/Regions with the Most Publications in the Field of Exercise for Depression

| Rank | Countries | Counts | Citations | Average per Item | H-Index | Centrality |
|---|---|---|---|---|---|---|
| 1 | USA | 684 | 19,688 | 28.78 | 67 | 0.24 |
| 2 | China | 408 | 5646 | 13.84 | 37 | 0.11 |
| 3 | England | 242 | 12,370 | 51.12 | 53 | 0.28 |
| 4 | Australia | 221 | 11,831 | 53.53 | 50 | 0.08 |
| 5 | Germany | 190 | 5449 | 28.68 | 35 | 0.10 |
| 6 | Canada | 134 | 6205 | 46.31 | 37 | 0.08 |
| 7 | Brazil | 129 | 6104 | 47.32 | 37 | 0.09 |
| 8 | Spain | 127 | 3117 | 24.54 | 30 | 0.18 |
| 9 | South Korea | 104 | 1269 | 12.20 | 20 | 0.02 |
| 10 | Netherlands | 92 | 3586 | 38.98 | 26 | 0.06 |

by England (n = 12370) and Australia (n = 11,831). In terms of the average number of citations per item, Australia had the highest value (n = 53.53), followed by England (n = 51.12) and Brazil (n = 47.32). Despite a relatively low average per-item citation (n = 28.78), the USA exerted the greatest influence on the area of exercise for depression due to its largest H-index of 67. Regarding the H-index, the countries of England (H-index = 53) and Australia (H-index = 50) exhibited superior performance in comparison to the other countries/regions included in the list. In terms of centrality, England achieved the highest score, with a value of 0.28. This was followed by the USA (0.24) and Spain (0.18). China, Switzerland, and Germany exhibited similar centrality scores, with values ranging from 0.10 to 0.11 (Figure 3).

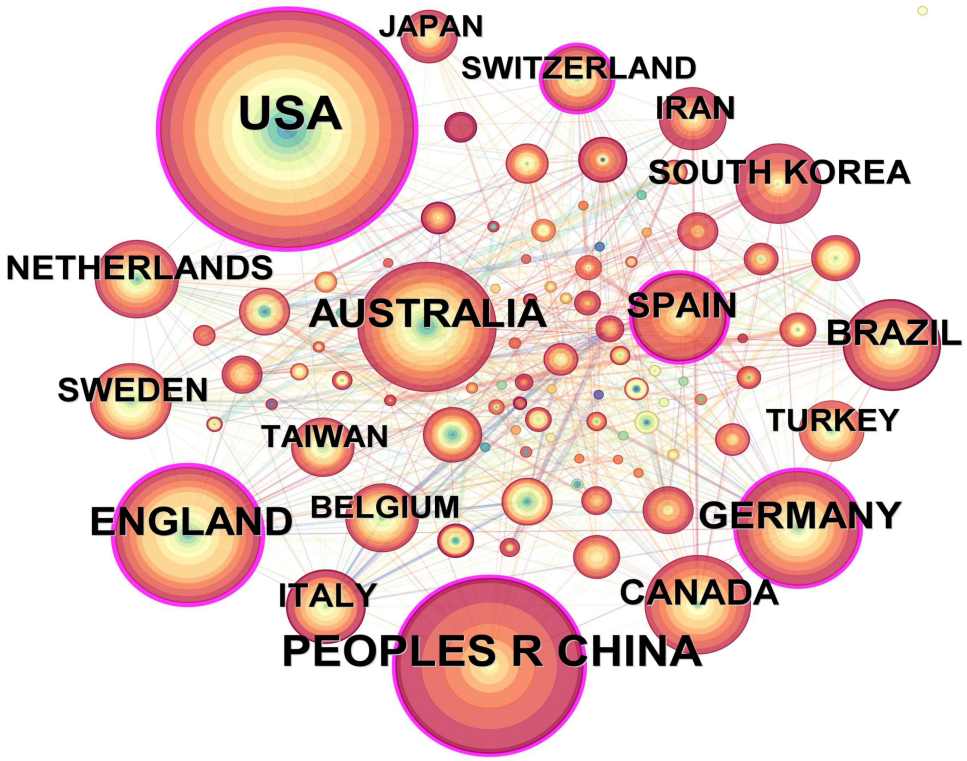


**Figure 3** National cooperation network map in the field of exercise for depression.
**Notes**: Nodes show regions or countries, with size indicating publication count. Lines between nodes represent citations, their thickness showing citation frequency.


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**Table 3** Top 10 Institutions with the Most Publications in the Field of Exercise for Depression

| Rank | Institutions | Counts | Citations | Average per Item | Countries | Centrality |
|---|---|---|---|---|---|---|
| 1 | King's College London | 69 | 6473 | 93.81 | England | 0.16 |
| 2 | Karolinska Institute | 49 | 3313 | 67.61 | Sweden | 0.14 |
| 3 | Harvard Medical School | 44 | 1589 | 36.11 | USA | 0.09 |
| 4 | University of Toronto | 43 | 3402 | 79.12 | Canada | 0.07 |
| 5 | KU Leuven | 39 | 3909 | 100.23 | Belgium | 0.02 |
| 6 | University of Basel | 38 | 1552 | 40.84 | Sweden | 0.08 |
| 7 | Deakin University | 37 | 1043 | 28.19 | Australia | 0.05 |
| 8 | University of Melbourne | 36 | 1355 | 37.64 | Australia | 0.07 |
| 9 | Massachusetts General Hospital | 34 | 1176 | 34.59 | USA | 0.02 |
| 10 | Brown University | 31 | 644 | 20.77 | USA | 0.01 |

## Analysis of Institutions

The study analyzed literature from 3310 institutions. Table 3 lists the top 10 institutions with the most publications. The three institutions with the highest number of publications were King's College London (n = 69), Karolinska Institute (n = 67), and Harvard Medical School (n = 44). In terms of citations, King's College London (n = 6473) was the most prolific institution, followed by KU Leuven (n = 3909) from Belgium. In terms of the average number of citations per item, KU Leuven (n = 100.23), King's College London (n = 93.81) and the University of Toronto were the top three institutions that received the greatest number of citations, respectively. The top three institutions with the highest centrality scores were King's College London (0.16), Karolinska Institute (0.14), and Harvard University (0.09) (Figure 4). It is of significant importance to note that developed countries have demonstrated a considerable advantage in this field.

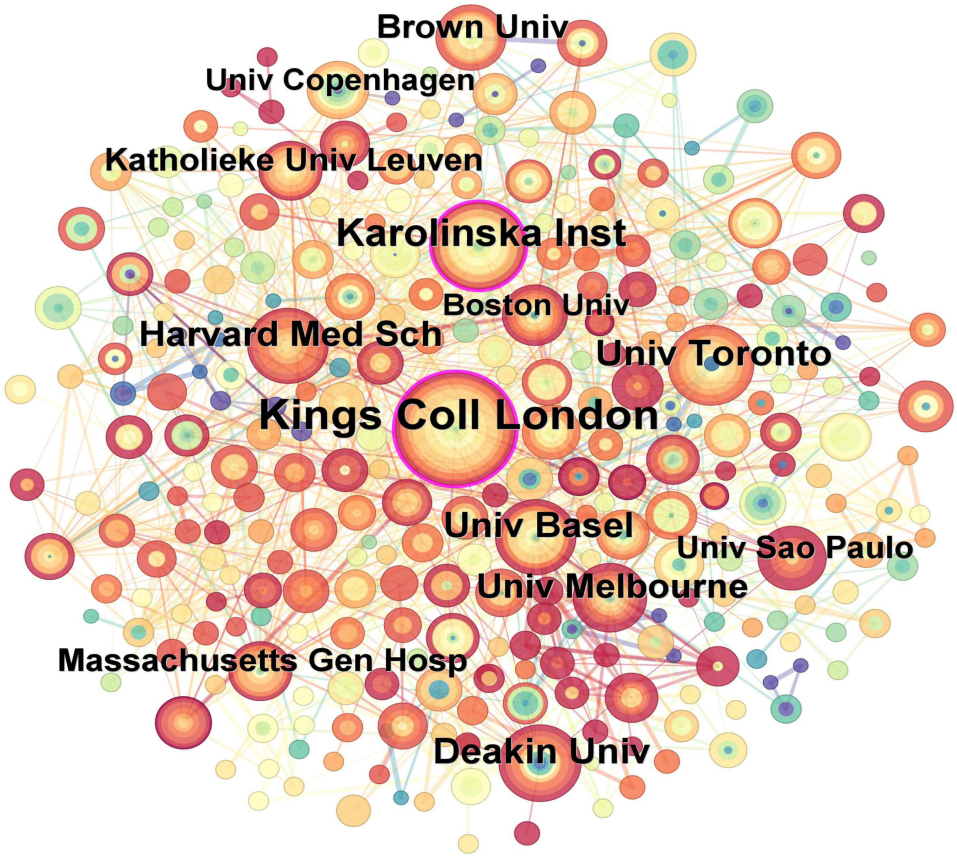


**Figure 4** Institutional cooperation network map in the field of exercise for depression.
**Notes**: Nodes show institutions, with size indicating publication count. Lines between nodes represent citations, their thickness showing citation frequency.

## Analysis of Authors

A total of 11,743 authors have published studies in this field. Table 4 summarizes the top 10 most productive authors in the field. Among the authors, the three most prolific authors with the highest number of publications are Stubbs B (n = 31), Schuch FB (n = 27) and Gerber M (n = 25). With regard to citations, four authors have had their publications cited in excess of 3000 times. These are Stubbs B (n = 4233), Vancampfort D (n = 3653), Schuch FB (n = 3651), and Rosenbaum S (n = 3341). The top three authors with the highest average number of citations per item are Rosenbaum S (n = 196.53), Vancampfort D (n = 152.21), and Stubbs B (n = 136.55). The top three authors with the highest H-index are Stubbs B (H-index= 20) from Kings College London, Schuch FB (H-index = 19) from Federal University of Rio Grande do Sul, and Vancampfort D (H-index = 18) from Catholic University of Leuven. None of the authors showed a centrality value greater than 0.1 in the network map (Figure 5).

## Analysis of Subject Categories

The studies were carried out across 137 different subject categories. Table S1 presents the top 10 subject categories of Web of Science in the field. Psychiatry (n = 783) ranked the first with the absolutely leading position, followed by Public Environmental Occupational Health (n = 255) and Neurosciences (n = 255). In addition to publication numbers, the Psychiatry category also had the highest number of citations (n = 24982) and H-index (n = 74). In terms of citations per publication, Medicine General Internal had the highest number (n = 36.81), followed by Psychology (n = 36.64) and Neurosciences (n = 34.89).

## Analysis of Keywords

As illustrated in Table 5, the three most frequently occurring keywords were "physical activity" (n = 675), "symptom" (n = 545) and "exercise" (n = 435). Figure 6 shows the network of co-occurring keywords within the field. Nevertheless, none of the keywords showed a centrality value exceeding 0.1. Figure 7 presents a timeline view of keyword clustering, encompassing seven keyword clusters: #0 hippocampus, #1 physical activity, #2 insulin resistance, #3 major depressive disorder, #4 postpartum depression, #5 autobiographical memory, and #6 post-stroke depression. The clusters exhibited a weighted mean silhouette (S = 0.68) and modularity (Q = 0.31), which collectively indicated a convincing clustering quality. Table S2 presents a summary of the keyword clusters and their respective Silhouette values (S-values). All clusters showed an S-value greater than 0.5, indicating a satisfactory result. Table 6 presents the top 25 keywords with the strongest citation bursts. Among the 25 keywords, the term with the highest burst was "management" (n = 7.36), while the keyword "coronary heart disease" was consistently from 2012 to 2018. It noteworthy that the keywords "systematic review", "working memory", "sleep", and "Parkinson's disease" have been popular research topics in recent years.

**Table 4** Top 10 Authors with the Most Publications in the Field of Exercise for Depression

| Rank | Authors | Counts | Citations | Average per Item | H-Index | Institutions |
|---|---|---|---|---|---|---|
| 1 | Stubbs B | 31 | 4233 | 136.55 | 20 | Kings College London |
| 2 | Schuch FB | 27 | 3651 | 135.22 | 19 | Federal University of Rio Grande do Sul |
| 3 | Gerber M | 25 | 534 | 21.36 | 12 | University of Basel |
| 4 | Vancampfort D | 24 | 3653 | 152.21 | 18 | Catholic University of Leuven |
| 5 | Trivedi MH | 20 | 804 | 40.20 | 14 | University of Texas Southwestern Medical Center |
| 6 | Hallgren M | 17 | 1817 | 106.88 | 14 | Karolinska Institute |
| 7 | Rosenbaum S | 17 | 3341 | 196.53 | 13 | University of New South Wales Sydney |
| 8 | Brand S | 16 | 306 | 19.13 | 10 | University of Basel |
| 9 | Uebelacker LA | 16 | 382 | 23.88 | 8 | Brown University |
| 10 | Holsboer-trachsler E | 14 | 298 | 21.29 | 10 | University of Basel |

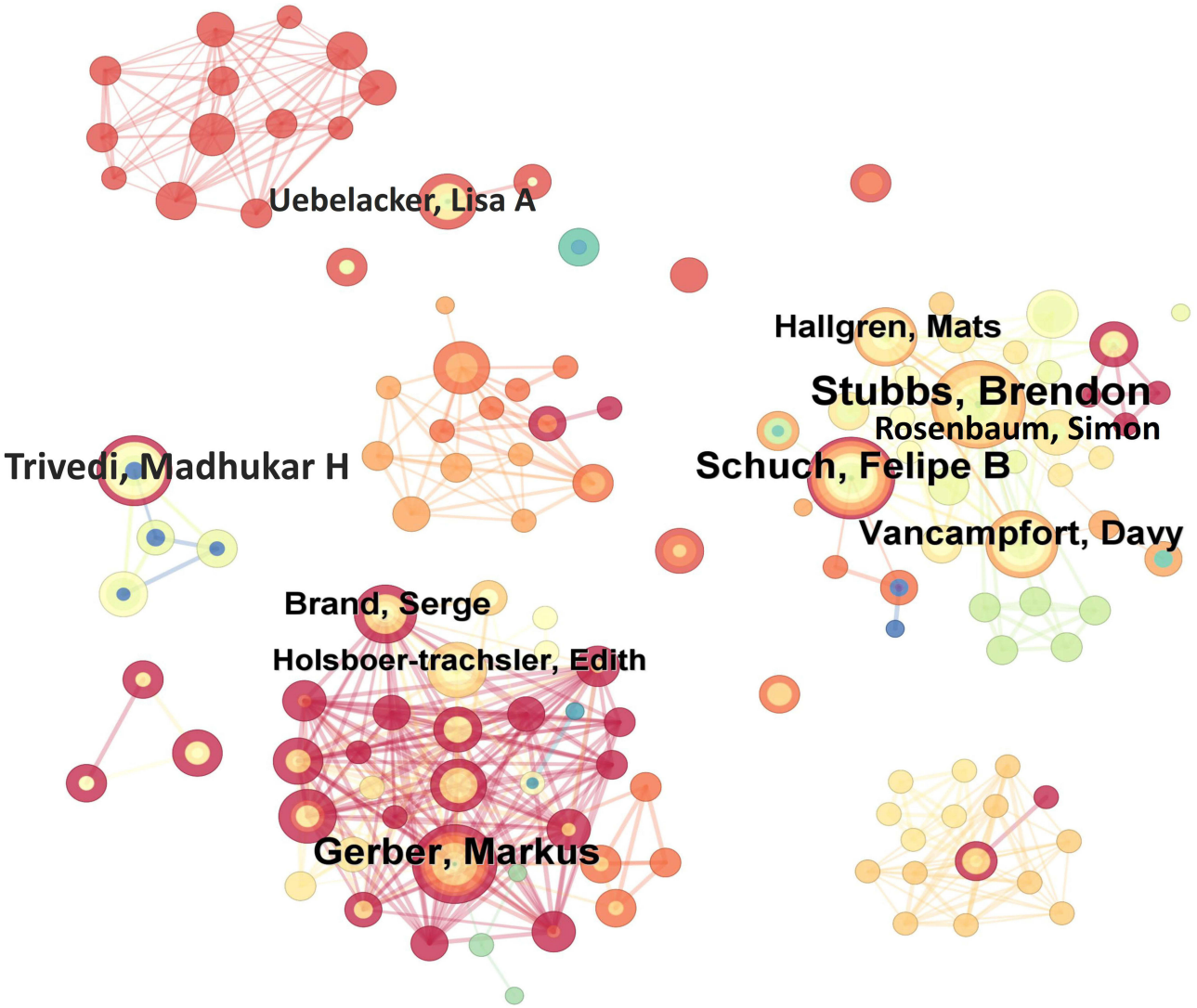


**Figure 5** Network map of co-authors in the field of exercise for depression.
**Notes**: Nodes show authors, with size indicating publication count. Lines between nodes represent citations, their thickness showing citation frequency.

## Analysis of the Top 10 Most Cited Publications

Table S3 shows the top 10 most cited papers in the field. The citations of these articles ranged from 512 to 819. The article entitled "Depression, Anxiety and Stress during COVID-19: Associations with Changes in Physical Activity, Sleep, Tobacco

**Table 5** Top 10 Keywords in the Field of Exercise for Depression

| Rank | Keyword | Year | Count | Centrality |
|---|---|---|---|---|
| 1 | Physical activity | 2010 | 675 | 0.01 |
| 2 | Symptom | 2010 | 545 | 0.01 |
| 3 | Exercise | 2010 | 435 | 0.03 |
| 4 | Disorder | 2010 | 358 | 0.02 |
| 5 | Meta-analysis | 2011 | 319 | 0.01 |
| 6 | Health | 2010 | 318 | 0.01 |
| 7 | Mental health | 2010 | 315 | 0.03 |
| 8 | Anxiety | 2010 | 291 | 0.02 |
| 9 | Quality of life | 2010 | 279 | 0.03 |
| 10 | Prevalence | 2010 | 253 | 0.02 |

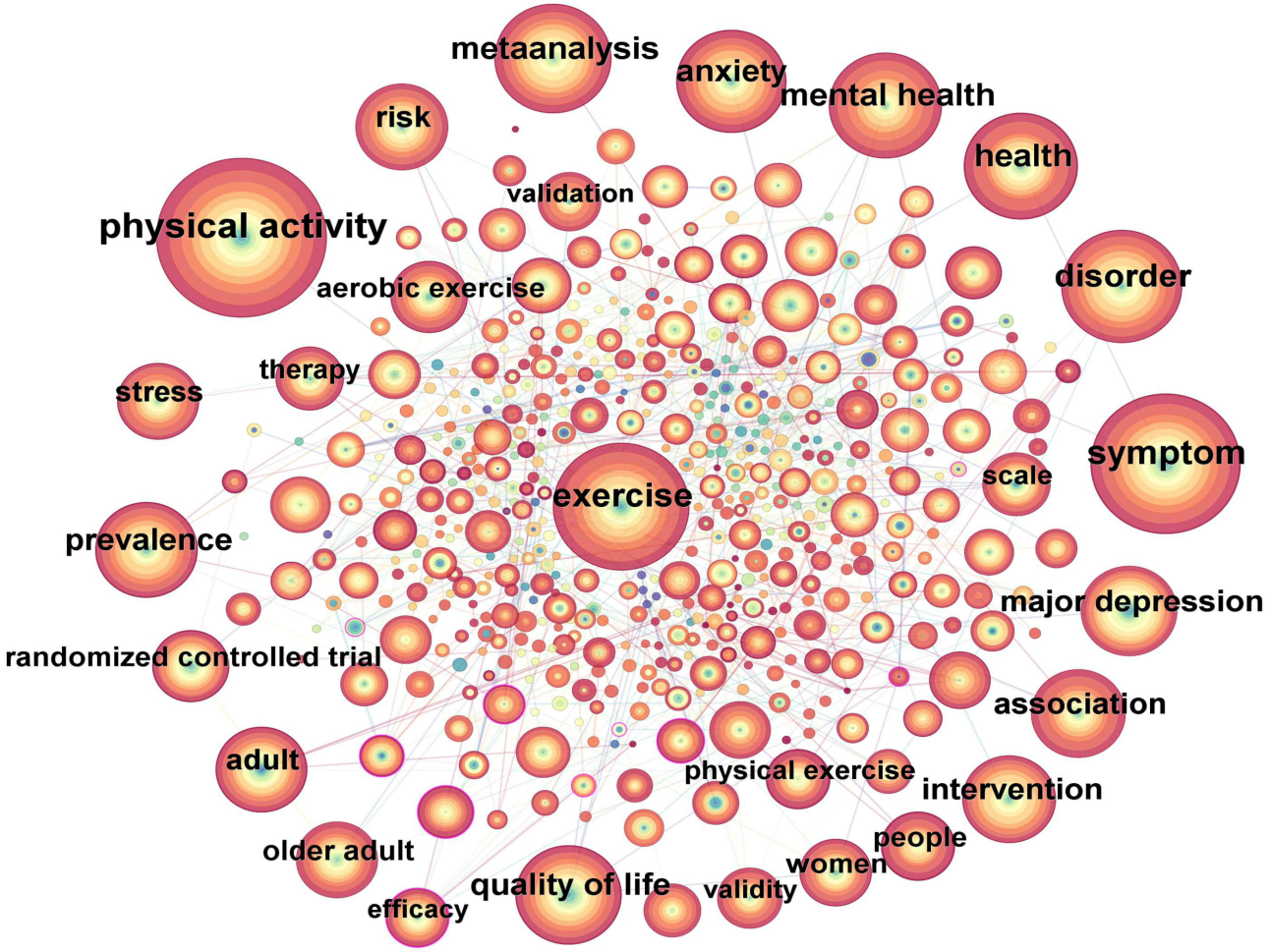


**Figure 6** Network map of co-occurring keywords in the field of exercise for depression.
**Notes**: Nodes represent keywords, sized by its frequency. Connecting lines show co-occurrence relationships, with thickness indicating co-occurrence frequency.

and Alcohol Use in Australian Adults"[30] by Stanton R, published in the International Journal of Environmental Research and Public Health in 2020, had the greatest number of citations. The article by Vancampfort D, published in World Psychiatry, had the highest IF of 73.30. The title of the article is "Sedentary Behavior and Physical Activity Levels in People with Schizophrenia, Bipolar Disorder and Major Depressive disorder: A Global Systematic Review and Meta-analysis".[31] The majority of the most highly cited articles in the area are reviews that examine the relationship between exercise or physical activity and depression.

## Discussion

Our results indicated a general increase in the number of publications, with minor fluctuations and a peak in recent years. Meanwhile, the citation trend exhibited a marked acceleration, reaching its peak in 2022. In the terms of journal analysis, the Journal of Affective Disorder (n = 137), the International Journal of Environmental Research and Public Health (n = 72) and the Frontiers in Psychiatry (n = 69) were identified as the top three. A total of five journals accumulated over 1000 citations, with the Journal of Affective Disorder (n = 4557) receiving the most. However, when considering the IF, the Psychiatry Research emerged as the leading journal (IF = 11.30), indicating a robust and high-quality platform for psychiatry research. The publishers of Elsevier were the most favored among researchers in this field. There was a notable absence of journals on the list dedicated to the field of sport or physical education, despite the existence of numerous journals in the field of medicine and psychology. Additionally, Psychiatry (n = 783) was the subject category with the highest number of citations. The journal analysis reveals a strong dominance of medical and psychiatric journals


**Figure 7** Timeline view of keywords clustering in the field of exercise for depression.

over sports science publications, suggesting potential interdisciplinary gaps. This observed imbalance underscores the necessity for enhanced interdisciplinary integration within the field.

In the analysis of countries, the USA (n = 684), China (n = 408) and England (n = 242) were the first three countries on the list by virtue of the number of publications. Moreover, the USA demonstrated a clear dominance in terms of

**Table 6** Top 25 Keywords with the Strongest Citation Bursts in the Field of Exercise for Depression

| Keywords | Year | Strength | Begin | End | 2010–2024 |
|---|---|---|---|---|---|
| Management | 2010 | 7.36 | 2010 | 2013 | |
| Diagnosis | 2010 | 5.05 | 2010 | 2011 | |
| Major depression | 2010 | 4.69 | 2010 | 2012 | |
| Forced swimming test | 2010 | 3.93 | 2010 | 2014 | |
| Chronic mild stress | 2011 | 4.53 | 2011 | 2015 | |
| Coronary heart disease | 2012 | 5.54 | 2012 | 2018 | |
| Depressive disorder | 2013 | 4.91 | 2013 | 2017 | |
| Clinical depression | 2010 | 3.89 | 2013 | 2014 | |
| Heart failure | 2014 | 4.4 | 2014 | 2016 | |
| Randomized trial | 2014 | 3.99 | 2014 | 2016 | |
| Trial | 2011 | 4.3 | 2015 | 2017 | |
| Geriatric depression | 2015 | 4.03 | 2015 | 2018 | |
| Hatha yoga | 2012 | 4.13 | 2016 | 2018 | |
| Comorbidity | 2016 | 4.04 | 2016 | 2017 | |
| Dentate gyrus | 2013 | 4.2 | 2017 | 2019 | |
| Metabolic syndrome | 2011 | 4.2 | 2017 | 2019 | |
| Grip strength | 2020 | 4.46 | 2020 | 2022 | |
| Handgrip strength | 2018 | 4.44 | 2020 | 2022 | |

(*Continued*)

**Table 6** (Continued).

| Keywords | Year | Strength | Begin | End | 2010–2024 |
|---|---|---|---|---|---|
| Phq-9 | 2021 | 6.23 | 2021 | 2022 | |
| Version | 2013 | 5.02 | 2021 | 2022 | |
| Systematic review | 2018 | 4.78 | 2021 | 2023 | |
| Older adults | 2010 | 4.31 | 2022 | 2023 | |
| Working memory | 2022 | 4.22 | 2022 | 2023 | |
| Sleep | 2022 | 4.22 | 2022 | 2023 | |
| Parkinson's disease | 2018 | 4.04 | 2022 | 2023 | |

citations (n = 19,688), thereby exhibiting an absolute authority. In this context, it is recommended that Chinese researchers devote greater resources to the investigation of novel exercise therapies for depression and their underlying mechanisms. In terms of institutional analysis, King's College London appears to be the most prominent and authoritative institution, with the highest number of publications (n = 69), citations (n = 6473), and the highest centrality (0.16). In terms of author analysis, Stubbs B, a researcher from Kings College London demonstrated the greatest number of publications (n = 31), citations (n = 4233) and H-index (20). The geographic imbalance in research productivity carries profound implications for global mental health equity.[32] While current evidence primarily originates from high resource settings, the transferability of these findings to low resource contexts remains questionable given documented variations in healthcare infrastructure, cultural perceptions of mental health, and physical activity norms. Multilateral collaboration between funding agencies, local communities, and international organizations will be essential to develop contextually appropriate exercise prescriptions that truly serve the global mental health agenda.

The keyword frequency analysis revealed that the term "physical activity" was the most frequently occurring keyword, occurring 675 times. Physical activity is generally defined as the expenditure of energy resulting from the contraction of skeletal muscles.[33] It is evident that sufficient physical activity confers multiple benefits to health, whereas insufficient activity can have a detrimental impact on individuals' physical and mental well-being.[34] Moreover, the term "meta-analysis" (319 times) was the type of study of interest in this field. Meta-analysis offers clinicians and researchers a more robust evidence base by quantitatively analyzing the results of studies on a given topic. This approach enables the drawing of more comprehensive conclusions, which could potentially advance the development of clinical practice. A growing body of evidence from meta-analysis suggests a significant correlation between physical activity and depression. Those who are physically inactive tend to have a higher risk of developing depression.[19,35–37] A meta-analysis of 49 prospective studies revealed a significant 17% increased risk of depression in individuals with low levels of physical activity compared with those with higher levels of physical activity.[35] For specific populations, a meta-analysis involving 5084 pregnant women demonstrated that adequate levels of physical activity (≥450 METs-min/week) significantly reduced the risk and severity of post-delivery depressive symptoms in pregnant women.[37] Pearce et al[19] conducted a meta-analysis involving 191,130 subjects, which further explored the dose-response relationship between physical activity levels and the risk of depression. The analysis demonstrated an inverse curvilinear association, namely an inverse U-shaped relationship, between physical activity levels and the risk of depression. Specifically, adults who achieved the recommended level of physical activity (about equivalent to 2.5 hours of brisk walking per week) exhibited a lower risk of depression compared with physically inactive adults. Furthermore, even smaller doses of physical activity levels were also associated with a lower risk of depression. The convergence of high frequency keywords "physical activity" and "meta-analysis" signifies two established priorities in the field, including the validation of physical activity as a modifiable protective factor against depression across populations, and the maturation of evidence synthesis methodologies enabling robust quantification of dose-response relationships. These trends collectively affirm exercise as a core component of depression prevention strategies, while underscoring the need for standardized protocols tailored to individual characteristics, a gap requiring further translational research.

The keyword cluster analysis reveals that postpartum depression (clusters #4) and post-stroke depression (cluster #6) represent two significant strands in the field. This suggests that the field of exercise for depression places a strong focus

on the depression status of pregnant women and stroke patients. Postpartum depression is a common postpartum complication, defined as a typical depressive episode or significant depressive symptoms occurring between 1 and 12 months postpartum.[38] Approximately 75% of pregnant women experience mild depressive symptoms during pregnancy, while around 15% experience varying degrees of depression in the short-term postpartum period.[39] Despite the high prevalence of postpartum depression, up to 90% of patients cannot be effectively treated, which places a heavy burden on families.[40] It has been demonstrated that exercise, as a non-pharmacological treatment, is an effective preventative and therapeutic intervention for postpartum depression. A network meta-analysis[41] that included 26 studies showed that aerobic exercise can significantly reduce the risk of postpartum depression and can effectively improve the severity of postpartum depressive symptoms. The study recommended that the optimal frequency of exercise is 35–45 minutes of moderate-intensity aerobic exercise 3–4 times per week. Similarly, randomized controlled studies from multiple centers have demonstrated that moderate-intensity water aerobics during pregnancy can be employed as a means of preventing postnatal depression in women, and that it is highly safe for both mother and baby. Yoga appears to be a more acceptable form of exercise for pregnant women and has been shown to be more effective in preventing postpartum depression than other forms of exercise.[42] Additionally, post-stroke depression is a prevalent chronic mental disorder affecting approximately 33% of stroke patients, significantly impairing prognosis and quality of life.[43] A network meta-analysis by Chen et al[44] indicates that home-based exercise, particularly Tai Chi, has been demonstrated to effectively alleviate the symptoms of patients with post-stroke depression. For middle-aged and elderly patients with mild stroke, exercise has been demonstrated to be an effective treatment for improving depressive symptoms.[45] Notably, while both conditions have attracted substantial attention, the volume of study investigating the antidepressant effects of exercise on post-stroke depressive symptoms remains limited. This disparity highlights an direction to strengthen the evidence base for exercise interventions in stroke survivors through more systematic investigations.

The hippocampus (Cluster #1) offers a valuable insight into the potential mechanisms by which exercise alleviates depression. The hippocampus plays a pivotal role in regulating mood and stress, and is extensively involved in cognitive and emotional processing in humans.[46] Exercise could induce structural and functional changes in various brain regions, including the hippocampus, prefrontal cortex, striatum, anterior cingulate gyrus, and amygdala.[47] Of these, the hippocampus is the most extensively studied region, in accordance with the results of the keyword cluster analysis in this study. It has been demonstrated that regular exercise increases the volume of the hippocampus in the human brain and modulates the strength of functional brain network connections associated with the hippocampus.[48] In a male mouse model of depression, exercise has been shown to facilitate the differentiation and myelination of oligodendrocytes in the hippocampus to a greater extent than fluoxetine.[49] Erickson et al[50] demonstrated that engaging in moderate-intensity aerobic exercise three times per week for 12 months led to an approximately 2% increase in hippocampal volume. In conclusion, a growing body of research suggests that exercise is an effective treatment to increase hippocampal volume.

The results of keyword bursts demonstrate that systematic review, older adults, sleep, and Parkinson's disease are the keywords that have received the greatest attention in the field over the past three years. This reflects the current research focus. A systematic review is a comprehensive examination of the existing literature on a specific topic, employing a systematic approach to identify, evaluate, and synthesize relevant studies.[51] This process allows researchers to gain insights from high-quality systematic reviews, which can serve as valuable theoretical references to inform the use of exercise in the treatment of depression and contribute to the advancement of the field. It is anticipated that by 2030, the global population of older adults aged 60 years and above will exceed 1.4 billion.[52] Geriatric depression (also known as late-life depression) is a significant health concern among the elderly population, with approximately 28.4% of older adults worldwide suffering from depression.[52] Older adults experience greater functional impairment and higher rates of disease recurrence due to depressive symptoms than younger adults.[53] Consequently, they require adequate attention. Non-pharmacological treatments, such as exercise, play an important role in the prevention and treatment of depression in the elderly. A growing body of evidence, including meta-analysis and prospective cohort studies, has demonstrated that regular physical activity can prevent the onset of depression in old age.[54,55] Laird et al[19] demonstrated that even low doses (400–600 MET-min/week) of exercise were effective in ameliorating depressive symptoms in older adults, and higher doses of exercise were associated with a lower risk of depression. A network meta-analysis revealed that exercise, particularly mind-body exercise and high-intensity strength training, is an effective intervention for improving sleep

quality in individuals with depression.[56] Imboden et al[57] found that aerobic exercise was effective in improving working memory in patients with depression, whereas strength training did not result in cognitive enhancement. Therefore, the development of individualized exercise prescriptions may be particularly important. Recent studies have indicated a significant correlation between depression and Parkinson's disease.[58] A meta-analysis conducted by Wang et al[58] revealed that individuals diagnosed with depression are at an increased risk of developing Parkinson's disease compared to those without depression. However, the underlying mechanisms remain unclear. Depression is also a prevalent non-motor symptom in patients with Parkinson's disease, affecting approximately 20% of patients.[59] There is evidence that yoga can significantly improve depressive symptoms and quality of life in patients with Parkinson's disease.[60] A growing number of studies are examining potential benefits of exercise for improving mental health of patients with Parkinson's disease. The above study findings suggests that recent studies increasingly examine systematic reviews, aging populations, sleep-mood links, and Parkinson's related depression, showing a shift from general exercise effects to specific applications. This reflects stronger evidence synthesis for clinical use, more tailored approaches for at risk groups, deeper study of sleep and cognition mechanisms, and broader acceptance of exercise as supplemental treatment. These developments support more personalized mental health care.

## Limitations

The study has several limitations that need to be noted. Firstly, while the WOSCC is a reliable and the most widely adopted database for bibliometric analyses, it is important to note that its coverage may not encompass all pertinent literature in this field. This limitation may constrain the scope of the analysis and lead to the omission of relevant studies, potentially introducing publication bias. Meanwhile, the English-language restriction may result in linguistic bias, potentially overlooking scholarly contributions published in other languages. Secondly, to ensure the literature included is highly relevant and to reduce the impact of confounders in the abstract, the search terms were restricted to the title. However, this approach may result in omission of some literature in the field, potentially biasing the search results. Finally, while our analysis applied basic filters by publication type and language, the absence of additional inclusion criteria might have allowed some marginally relevant publications to be included. We recognize this methodological consideration and will implement more rigorous screening protocols in future studies to enhance literature relevance.

## Conclusions

The study's findings highlight the development trends and hot topics in exercise for depression research from 2010 to 2023. The number of studies has been steadily growing, with a significant rise in citations since 2018. The vast majority of studies are related to psychiatry, but they also involve public environmental occupational, and neuroscience. The current research hot topics focuses on physical activity, systematic review, older adults, working memory, sleep, and Parkinson's disease. Research in this field is predominantly performed by professionals from developed countries, such as the USA and the England. Developing countries should proactively explore global cooperation to improve their influence in this field. There is insufficient evidence to guide clinicians in developing personalized exercise prescriptions for patients with depression, who exhibit diverse characteristics. In the future, more high-quality RCTs are required to target underrepresented populations, depression subtypes, and exercise mechanisms. International research consortia are required to be established to overcome geographic and cultural barriers, as well as developing evidence-based clinical guidelines for personalized exercise prescriptions. This requires coordinated engagement from public funding bodies, research institutions, competitive grant programs, and academic journals publishing dedicated special issues. Overall, the field of exercise for depression is expected to continue attracting more researchers and attention, resulting in more meaningful and valuable findings for the well-being of patients.

## Data Sharing Statement

The data associated with this study are available from the corresponding author on reasonable request.

## Ethics Statement

Informed consent was not necessary for this study as all data utilized were obtained from the WoSCC database and did not involve any animal or human subjects.

## Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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