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Global Shifts and Emerging Themes in Parkinson's Disease Rehabilitation: A Comprehensive 30-Year Bibliometric Analysis

Parkinson Hastalığı Rehabilitasyonunda Küresel Değişimler ve Ortaya Çıkan Temalar: 30 Yıllık Kapsamlı Bir Bibliyometrik Analiz

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Abstract: The aim of this bibliometric study was to analyze the global research landscape in Parkinson's disease (PD) rehabilitation from 1995 to 2024. The present study employed a bibliometric analysis, leveraging the Web of Science (WoS) database, to identify publications on "Parkinson's Disease rehabilitation" from January 1995 to January 2024. The top 100 (T100) highest-cited articles were identified through a meticulous examination of citation frequency. Extracted data included publication year, journal name, citation count, authorship, study type, and regional contributions. Trends in publication frequency were analyzed using linear and quadratic regression models, while Spearman's rank correlation assessed relationships between total and annual citations. The Archives of Physical Medicine and Rehabilitation contributed the most articles (n=13). Highly cited studies focused on exercise interventions, virtual reality, and community-based rehabilitation, with the top article receiving 244 citations. The United States was the leading contributor, while Nieuwboer A. and Rochester L. were the most prolific authors. Publication frequency showed non-linear growth, peaking around 2015 and slightly declining thereafter. A moderate positive correlation ($r = 0.59$) between total citations and annual citations reflected the sustained impact of influential works. This analysis highlights key contributors, research trends, and global collaboration in PD rehabilitation. Future studies should focus on cost-effective, scalable interventions and longitudinal evaluations of emerging therapies to improve patient outcomes.

Keywords: Bibliometric analysis, parkinson disease, rehabilitation, web of science

Özet: Bu bibliyometrik çalışmanın amacı, 1995'ten 2024'e kadar Parkinson hastalığı (PH) rehabilitasyonundaki küresel araştırma ortamını analiz etmektir. Bu çalışmada, Ocak 1995'ten Ocak 2024'e kadar "Parkinson Hastalığı rehabilitasyonu" ile ilgili yayınları belirlemek için Web of Science (WoS) veri tabanından yararlanılarak bibliyometrik bir analiz yapılmıştır. En çok atıf alan ilk 100 (İ100) makale, titiz bir atıf sıklığı incelemesiyle belirlenmiştir. Elde edilen veriler arasında yayın yılı, dergi adı, atıf sayısı, yazarlık, çalışma türü ve bölgesel katkılar yer almıştır. Yayın sıklığındaki eğilimler doğrusal ve ikinci dereceden regresyon modelleri kullanılarak analiz edilirken, Spearman'ın sıra korelasyonu toplam ve yıllık atıflar arasındaki ilişkileri değerlendirdi. The Archives of Physical Medicine and Rehabilitation en fazla makaleye katkıda bulunmuştur (n=13). En çok atıf alan çalışmalar egzersiz müdahaleleri, sanal gerçeklik ve toplum temelli rehabilitasyon konularına odaklanırken, en çok atıf alan makale 244 atıf almıştır. Amerika Birleşik Devletleri en çok katkıda bulunan ülke olurken, Nieuwboer A. ve Rochester L. en üretken yazarlar olmuştur. Yayın sıklığı doğrusal olmayan bir büyüme göstermiş, 2015 yılı civarında zirve yapmış ve sonrasında hafifçe düşmüştür. Toplam atıflar ile yıllık atıflar arasındaki ılımlı pozitif korelasyon ($r = 0,59$), etkili çalışmaların sürdürülebilir etkisini yansıtmaktadır. Bu analiz, PH rehabilitasyonuna katkıda bulunan önemli kişileri, araştırma eğilimlerini ve küresel iş birliğini vurgulamaktadır. Gelecekteki çalışmalar, hasta sonuçlarını iyileştirmek için maliyet etkin, ölçeklenebilir müdahalelere ve yeni ortaya çıkan tedavilerin uzunlamasına değerlendirmelerine odaklanmalıdır.

Anahtar Kelimeler: Bibliyometrik analiz, parkinson hastalığı, rehabilitasyon, web of science

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1. Introduction

Aging is considered a significant risk factor for neurodegenerative diseases, with an increasing prevalence of these conditions observed in ageing populations (1). Parkinson's Disease (PD) is the second most prevalent neurodegenerative disorder worldwide, affecting approximately 1% of individuals over the age of 60 (2). PD is typified by a range of motor symptoms, including bradykinesia, tremor, rigidity, and postural instability, as well as non-motor symptoms such as cognitive impairment, mood disturbances, and autonomic dysfunction (3). These symptoms have a markedly deleterious impact on patients' functional independence and quality of life, underscoring the imperative for comprehensive rehabilitative interventions (4).

The role of rehabilitation in PD has expanded considerably in recent years, as traditional pharmacological treatments, while efficacious in symptom management, are unable to impede disease progression (5). The value of multimodal rehabilitation approaches has grown, encompassing physical therapy, occupational therapy, speech and language therapy, and neuropsychological support. These approaches target specific PD symptoms and improve overall patient outcomes (6, 7).

Over the past two decades, there has been a notable shift towards the utilisation of advanced technology in rehabilitation. This has encompassed the integration of robotics, virtual reality (VR), wearable devices and non-invasive brain stimulation as adjunctive therapies to conventional rehabilitation practices (8). The use of robotic-assisted rehabilitation has gained significant attention as a potential means of enhancing motor recovery through the administration of repetitive, task-specific exercises that promote neuroplasticity and functional improvements (9). A number of studies have demonstrated that robotic-assisted gait training, upper limb robotics, and exoskeletons can facilitate improvements in motor function and mobility in patients with PD (10, 11). Furthermore, VR-based rehabilitation has demonstrated efficacy in addressing both motor and cognitive impairments by engaging patients in immersive environments that encourage movement and improve balance, cognitive function, and coordination (12).

These developments reflect a broader trend in PD rehabilitation research, characterised by an increasing interdisciplinary collaboration among neuroscientists, engineers, and rehabilitation professionals. Notwithstanding the expanding corpus

of research, considerable obstacles persist in facilitating the accessibility and cost-effectiveness of these sophisticated interventions, particularly in lower-income settings (13). Furthermore, the absence of long-term data assessing the sustained effects of technology-based rehabilitation represents a significant gap in the current research landscape (14).

Over the past decades, numerous studies have laid the foundations for understanding and treating PD through rehabilitation (15-17). However, a comprehensive evaluation of the specific contributions from different countries, institutions and authors, as well as an analysis of current research hotspots and trends, remains a challenge.

Bibliometrics, first introduced in 1969, addresses this need by applying statistical and mathematical techniques to quantitatively evaluate the literature, helping to identify influential contributors, emerging trends and critical issues in research fields (18, 19).

This study applies bibliometric analysis to explore the landscape of PD rehabilitation research over the past 30 years. By systematically examining contributions from key countries, institutions and authors, this analysis provides valuable insights into current research directions, highlights gaps requiring further investigation and anticipates future trends. The findings are intended to support the evidence-based advancement of PD rehabilitation research and inform the development of clinical guidelines.

2. Materials and Method

A detailed bibliometric study was conducted to systematically examine trends and contributions in PD rehabilitation research. The study analyzed the literature from January 1995 to January 2024. The Web of Science (WoS) database was selected as the primary source for data collection. A title-specific search was conducted in December 2024 using the key term "Parkinson's Disease rehabilitation". This phrase was chosen based on preliminary searches which showed that broader terms such as 'physical therapy', 'motor recovery', or 'exercise' led to the retrieval of many irrelevant results. Therefore, a more specific phrase was selected to ensure the inclusion of directly relevant studies. The WoS database was selected to enable a comprehensive search of the publications that make up the field, thus providing the basis for quantitative bibliometric evaluation and trend analysis.

Three independent reviewers performed the search, evaluation and data extraction to ensure the reliability of the methodology. Articles were carefully reviewed to confirm relevance to PD rehabilitation, specifically focusing on studies addressing physical, cognitive, and technological interventions. Articles were then curated in descending order of citation frequency, highlighting the most frequently cited and thus potentially most influential publications within the PD rehabilitation literature. It should be noted that this particular analysis was not subject to any ethical approval or informed consent requirements, as it exclusively relied on published research data and did not involve human or animal subjects.

The data extraction process entailed the retrieval of pertinent information from the selected literature, comprising publication information (such as the title, authors, year of publication journal), study design (such as randomized controlled trial, research article or systematic review), and bibliometric indicators (such as impact factor, H-index, quartile classification). The annual citation rate (Citations per Year, CI) was calculated by dividing the total citations (TC) through the number of years since publication. The journals that contributed to the top-cited articles were classified according to their quartile rankings (Q1-Q3) based on their impact factor and H-index, with a particular emphasis on those with a high impact factor. Additionally, the geographic distribution of article contributions and individual author productivity were analyzed to identify the leading countries and researchers in the field.

The application of descriptive statistics was instrumental in the summary of the characteristics of the included articles, journals, authors, and countries. Continuous variables, such as TC and CI, were expressed as median and range (min-max) due to the non-normal distribution of citation data. Categorical variables, such as study type, journal quartile rankings, and country of contribution, were expressed as frequency and percentage (n, %). The Shapiro-Wilk test was employed for the purpose of evaluating the normality of continuous variables. In instances where the variables were non-normal, Spearman's rank correlation analysis was implemented for the purpose of assessing the relationships between total citations, average citations per year, and year of publication. Regression analyses (linear and quadratic) were employed to identify trends in publication frequency over time, as well as relationships between total citations and average annual citations. The selection of these models was based on preliminary scatterplot inspections suggesting a curvilinear pattern. Model

fit was assessed using the R^2 coefficient of determination. The p value was considered to be statistically significant if it was less than 0.05. All statistical analyses were performed employing IBM SPSS Statistics, version 22.0.

3. Results

Figure 1 displays the trajectory of Parkinson's rehabilitation-related publications over time, with analysis conducted using linear and quadratic regression models. The data indicate a gradual increase in the frequency of publications from 1995 to approximately 2015, followed by a slight decline in recent years. The higher R^2 value for the quadratic model suggests that research activity in Parkinson's rehabilitation grew in a nonlinear manner, with rapid increases during the early 2000s, potentially reflecting the emergence of interest in innovative rehabilitation approaches, such as exercise-based interventions and virtual reality. The decline observed after 2015 may be attributable to a shift in research priorities or a degree of saturation in specific research domains.

Figure 2 shows the annual citation frequency for articles on Parkinson's rehabilitation covering the period from 1995 to 2024. The data reveals a significant increase in citations over the period examined, highlighting the expanding impact and importance of research in this field. The first growth period is defined as the period between 1995 and 2010. The gradual increase in citations during this period indicates a consistent increase in basic research in the field of Parkinson's rehabilitation. The next period, 2010-2020, is characterized by an accelerated growth phase. A significant increase in citations occurred after 2010, peaking around 2020. This period likely reflects the proliferation of highly impactful studies, including randomized controlled trials and systematic reviews, as well as advances in therapeutic modalities such as exercise interventions and virtual reality applications. The recent decline in citations (post-2020) might be ascribed to a variety of reasons, comprising the publication of fewer high-impact studies, shifts in research focus, or the effects of the global pandemic, which may have temporarily impacted research dissemination.

Figure 3 presents a scatter plot that examines the relationship between the total number of citations and the average number of citations per year for articles on Parkinson's rehabilitation. The data indicate a positive correlation, suggesting that articles with a higher total citation count tend to maintain a higher annual citation rate. The red line represents the best-fit linear regression model. The R-squared value is 0.59, indicating that 59% of the

variation in average annual citations can be explained by the total number of citations. The moderate to strong correlation serves to underscore the persistent and long-term impact of highly cited articles. The majority of articles exhibit a low citation range, with a total number of citations below 100 and an annual average of less than 10. This observation reflects the prevalence of low-impact studies in the field. However, a few outliers with high total and annual citation rates (e.g., total citations >200, annual average >15) indicate extraordinary impact in the field. The shaded region around the regression line represents the confidence interval, indicating variability in the observed data. It should be noted that papers with similar TC may differ in annual rates due to factors such as year of publication or relevance.

Figure 4 (a) illustrates the distribution of contributions to T100 articles by country. In alignment with global research endeavors in the domain of Parkinson's rehabilitation, the United States emerges as the foremost contributor, trailed by Italy and the United Kingdom. Figure 4 (b) illuminates the individual authors who have made the most significant contributions to T100 articles. Author Nieuwboer A. leads the list with seven papers, followed by Author Rochester L., who has contributed six papers, underscoring their substantial influence and expertise in this field.

Table 1 presents the distribution of T100 articles by journal. The Archives of Physical Medicine and Rehabilitation leads with 13 articles, followed by

Neurorehabilitation and Neural Repair and Movement Disorders, each contributing 6 articles. The highest impact factor (IF) is 8.8 for the Cochrane Database of Systematic Reviews and 7.7 for Neurology. The H-index, which indicates the quality of a journal's research and its impact on citations, is highest for Neurology (411) and Movement Disorders (229). While most of the journals are classified as Q1, which reflects their top-tier status, contributions also come from Q2 and Q3 journals.

The top 20 articles included randomized controlled trials (RCTs), systematic reviews, and research articles. The studies most frequently cited were those conducted by Duncan et al. (2012) and Troche et al. (2010), which focused on community-based dance and swallowing rehabilitation. These studies were cited a total of 244 times. The article by Dockx et al. (2016) exhibited the highest annual citation rate (26.12), wherein the authors examined the potential of VR for rehabilitation purposes. Additionally, exercise interventions were a prominent feature of the literature, as evidenced by studies conducted by Tajiri et al. (2010) (TC: 220) and Schenkman et al. (2012) (TC: 154). Other studies explored novel treatments, such as VR and rhythmic sensory stimulation, and emphasized innovation in treatment approaches (Table 2). Descriptive statistics for the top 20 most cited papers reveal a median total citation count of 160.0 (range: 120-244) and a median annual citation rate of 11.05 (range: 5.21-26.12).

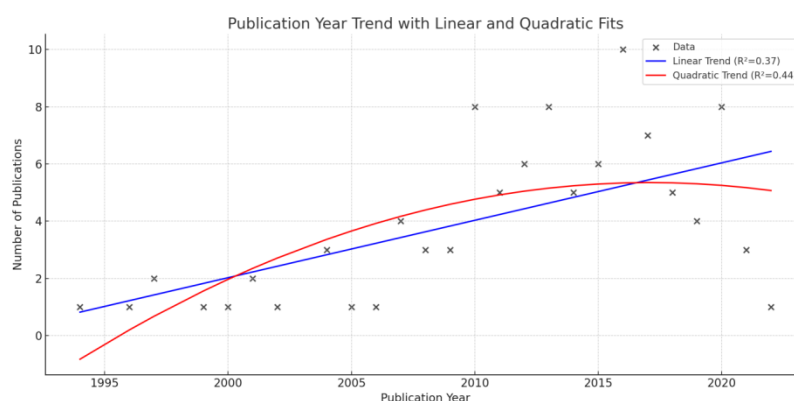


Figure 1. Trend in publication years with linear and quadratic fits (The quadratic model demonstrated a better fit (higher R^2) compared to the linear model, suggesting that the trend in publication frequency was not purely linear but exhibited a growth-peak-decline pattern)

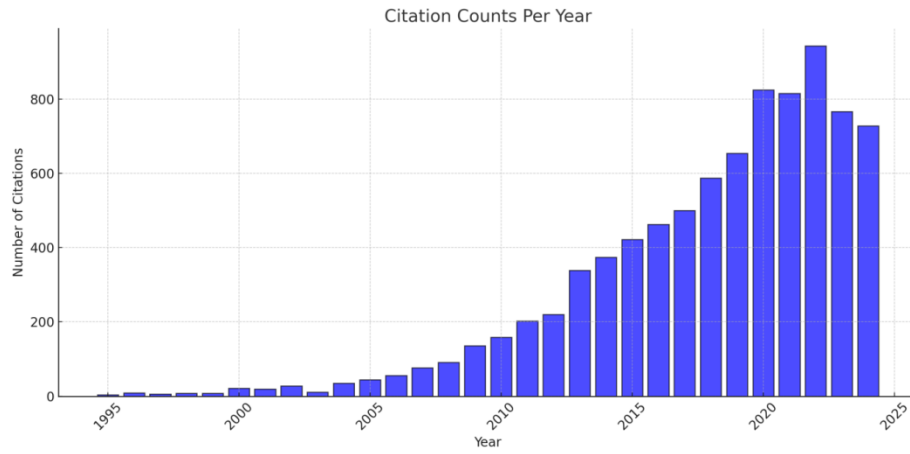


Figure 2. Citation Counts Per Year

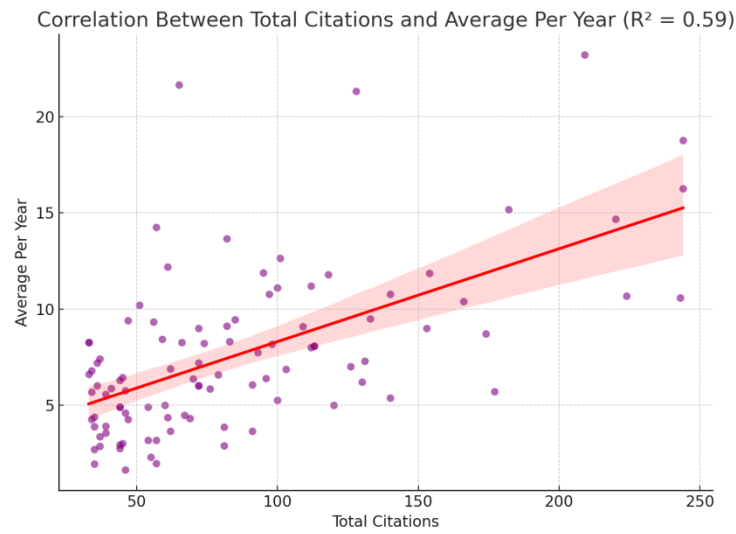
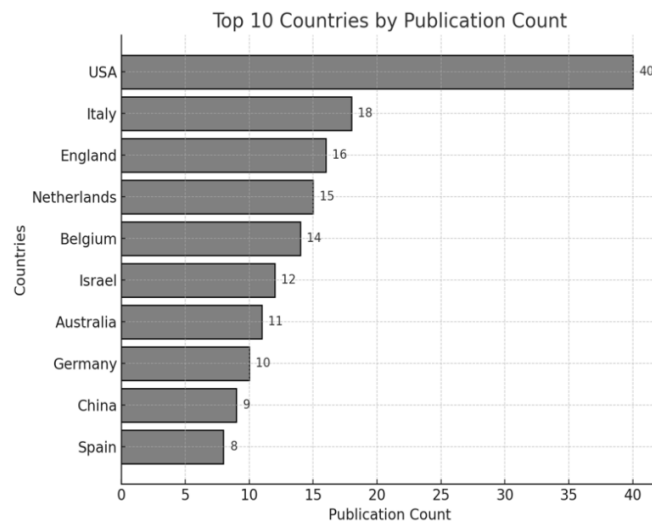


Figure 3. Correlation Between Total Citations and Average Per Year (The coefficient of determination ($R^2 = 0.59$) indicates that 59% of the variability in average annual citations can be explained by total citations. This suggests a moderately strong relationship between citation volume and long-term impact)



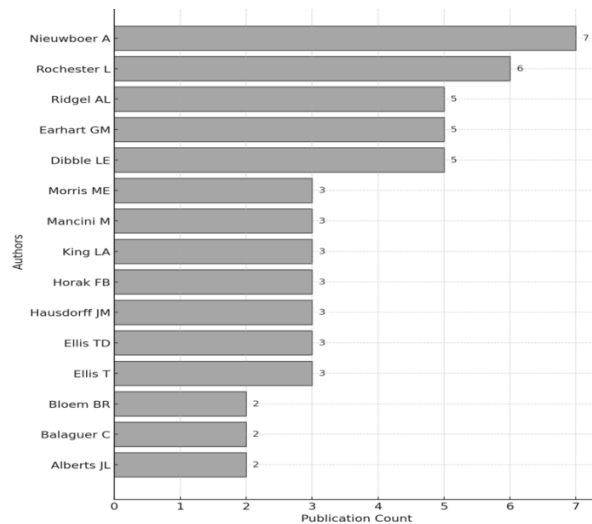


Figure 4. Number of contributions to T100 articles according to: a) countries and b) authors.

Table 1. Journals with T100 articles, ranked according to >2 times cited

Journal name	Number of articles	IF	H - Index	Q Classification
ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION	13	3.6	216	Q1
NEUROREHABILITATION AND NEURAL REPAIR	6	3.7	128	Q1
MOVEMENT DISORDERS	6	7.4	229	Q1
PHYSICAL THERAPY	5	3.5	176	Q1
FRONTIERS IN NEUROLOGY	5	2.7	105	Q3
PARKINSONISM & RELATED DISORDERS	5	3.1	122	Q2
JOURNAL OF NEUROENGINEERING AND REHABILITATION	4	5.2	120	Q1
AMERICAN JOURNAL OF PHYSICAL MEDICINE & REHABILITATION	3	2.2	117	Q2
NEUROREHABILITATION	3	1.7	78	Q2
JOURNAL OF REHABILITATION RESEARCH AND DEVELOPMENT	3	1.04	121	Q1
NEUROLOGY	2	7.7	411	Q1
COCHRANE DATABASE OF SYSTEMATIC REVIEWS	2	8.8	327	Q1
JOURNAL OF NEUROLOGIC PHYSICAL THERAPY	2	2.6	64	Q1
NEUROSCIENCE AND BIOBEHAVIORAL REVIEWS	2	7.5	288	Q1
NEUROLOGICAL SCIENCES	2	2.7	87	Q1
FUNCTIONAL NEUROLOGY	2	1.27	49	Q3
JOURNAL OF AGING AND PHYSICAL ACTIVITY	2	1.4	69	Q3
CLINICAL REHABILITATION	2	2.6	125	Q1
JOURNAL OF PARKINSONS DISEASE	2	4	68	Q2

Table 2. General information related to the top 20 articles on parkinson rehabilitation

Title	Authors	Source Title	PY	TC	CI	AT
1-Randomized Controlled Trial of Community-Based Dancing to Modify Disease Progression in Parkinson Disease	Duncan et al.	NEUROREHABILITATION AND NEURAL REPAIR	2012	244	20.33	Randomized Controlled Trial
2-Aspiration and swallowing in Parkinson disease and rehabilitation with EMST A randomized trial	Troche et al.	NEUROLOGY	2010	244	17.42	Randomized Controlled Trial
3-The power of cueing to circumvent dopamine deficits: A review of physical therapy treatment of gait disturbances in Parkinson's disease	Rubinstein et al.	MOVEMENT DISORDERS	2002	243	11.04	Review
4-Attending to the task: Interference effects of functional tasks on walking in Parkinson's disease and the roles of cognition, depression, fatigue, and balance	Rochester et al.	ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION	2004	224	11.20	Controlled Clinical Trial
5-Exercise exerts neuroprotective effects on Parkinson's disease model of rats	Tajiri et al.	BRAIN RESEARCH	2010	220	15.71	Research Article
6-Virtual reality for rehabilitation in Parkinson's disease	Dockx et al.	COCHRANE DATABASE OF SYSTEMATIC REVIEWS	2016	209	26.12	Systematic Review
7-Treadmill exercise elevates striatal dopamine D2 receptor binding potential in patients with early Parkinson's disease	Fisher et al.	NEUROREPORT	2013	182	16.54	Randomized Controlled Trial
8-PHYSICAL THERAPY AND PARKINSONS-DISEASE - A CONTROLLED CLINICAL-TRIAL	COMELLA et al.	NEUROLOGY	1994	177	5.9	Controlled Clinical Trial
9-The effect of external rhythmic cues (auditory and visual) on walking during a functional task in homes of people with Parkinson's disease	Rochester et al.	ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION	2005	174	9.15	Research Article
10-The Effects of Exercise on Balance in Persons with Parkinson's Disease: A Systematic Review Across the Disability Spectrum	Dibble et al.	JOURNAL OF NEUROLOGIC PHYSICAL THERAPY	2009	166	11.06	Systematic Review
11-Exercise for People in Early- or Mid-Stage Parkinson Disease: A 16-Month Randomized Controlled Trial	Schenkman et al.	PHYSICAL THERAPY	2012	154	12.83	Randomized Controlled Trial
12-Effects of rhythmic sensory stimulation (auditory, visual) on gait in Parkinson's disease patients	Arias et al.	EXPERIMENTAL BRAIN RESEARCH	2008	153	9.56	Research Article
13-Motor learning, retention and transfer after virtual-reality-based training in Parkinson's disease - effect of motor and cognitive demands of games: a longitudinal, controlled clinical study	dos Santos Mendes et al.	PHYSIOTHERAPY	2012	140	11.66	Controlled Clinical Trial
14-Identification of axial rigidity during locomotion in Parkinson disease	Van Emmerik et al.	ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION	1999	140	5.6	Research Article
15-It Is Not About the Bike, It Is About the Pedaling: Forced Exercise and Parkinson's Disease	Alberts et al.	EXERCISE AND SPORT SCIENCES REVIEWS	2011	133	10.23	Review
16-Integration of motor imagery and physical practice in group treatment applied to subjects with Parkinson's disease	Tamir et al.	NEUROREHABILITATION AND NEURAL REPAIR	2007	131	7.70	Controlled Clinical Trial
17-Role of sensory input and muscle strength in maintenance of balance gait and posture in Parkinson's disease - A pilot study	Nallegowda et al.	AMERICAN JOURNAL OF PHYSICAL MEDICINE & REHABILITATION	2004	130	6.5	Research Article
18-Effects of virtual reality rehabilitation training on gait and balance in patients with Parkinson's disease: A systematic review	Lei et al.	PLOS ONE	2019	128	25.6	Systematic Review
19-The immediate effect of attentional, auditory, and a combined cue strategy on gait during single and dual tasks in Parkinson's disease	Baker et al.	ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION	2007	126	7.41	Controlled Clinical Trial
20-Resistance training and gait function in patients with Parkinson's disease	Scandalis et al.	AMERICAN JOURNAL OF PHYSICAL MEDICINE & REHABILITATION	2001	120	5.21	Research Article

IF:
Impact
factor,

H-Index: Hirsch Index, Q Classification: Quarter classification of Journal

PY: Publication year, TC: Total citations, CI: Citation index, AT: Article type

4. Discussion

Bibliometric analysis is a foundational methodology for deciphering the intricacies of scientific research environments. Through the quantitative assessment of patterns in publication output, citation impact, and thematic evolution, bibliometrics serves as a potent instrument for accentuating influential contributors, emerging trends, and under-explored areas of research (18).

In the domain of PD rehabilitation, marked by rapid technological advancements and multidisciplinary innovations, bibliometric insights are indispensable. These insights provide a retrospective assessment of progress and identify pathways for future discoveries and global collaboration. Spanning nearly three decades of research, this bibliometric study provides a powerful analysis of the evolution of PD rehabilitation. The findings reveal a dynamic interplay of innovation, collaboration and ongoing challenges and provide a comprehensive framework for understanding the trajectory of this critical field.

The observed correlation between total and annual citation rates implies that highly cited articles maintain consistent scholarly influence over time. This may reflect the foundational nature or widespread applicability of these studies, which continue to be referenced regardless of publication year.

The United States has emerged as the top contributor to PH rehabilitation research, supported by strong funding sources, advanced academic infrastructure, and an understanding of interdisciplinary collaboration (2, 4), while Italy and the United Kingdom have also made significant contributions, reflecting the global nature of efforts to advance rehabilitation. Researchers such as Nieuwboer and Rochester have made significant contributions to the field of motor rehabilitation and provided foundational knowledge that continues to inform evidence-based clinical practice (20, 21). The role of leading academic journals such as *Archives of Physical Medicine and Rehabilitation*, *Neurorehabilitation* and *Neural Repair and Movement Disorders* has been instrumental in the dissemination of high quality research findings. These journals not only increase the visibility of influential studies, but also serve as conduits for integrating the latest findings into clinical practice (22).

The preponderance of Q1-ranked journals among the most cited articles serves to emphasize the rigorous academic standards and relevance of PD rehabilitation research to evidence-based medicine. The integration of advanced technologies into PD rehabilitation represents a paradigm shift that is redefining the scope and impact of therapeutic interventions. VR exemplifies this transformation by offering immersive environments that promote motor and cognitive recovery through neuroplasticity and patient engagement (9). Robotics-assisted therapies have become an integral part of advancing motor recovery by providing measurable and reproducible outcomes due to their precision, consistency and task specificity (10). Wearables and tele-rehabilitation platforms represent another frontier in technological advancement by increasing accessibility and enabling real-time monitoring of patient progress. These technologies are particularly valuable for extending care to remote and underserved populations, filling gaps in healthcare access and equity (23). Collectively, these innovations mark a shift towards personalized, data-driven care, aligning rehabilitation strategies with the principles of precision medicine. Exercise-based interventions remain fundamental, with new approaches such as community-based dance therapy and rhythmic sensory stimulation addressing not only motor impairments but also emotional well-being and social connectedness (24, 25). These holistic strategies emphasize the multidimensional nature of rehabilitation, going beyond physical restoration to include psychological and social health. Despite the notable advancements in the field, significant barriers persist. Accessibility remains a critical issue; the high costs of technologies such as VR and robotics limit their widespread adoption, particularly in low- and middle-income countries (26). Addressing these inequalities necessitates scalable, cost-effective solutions that provide equal access to high-quality rehabilitation. Another notable shortcoming is the limited availability of longitudinal data assessing the sustainable impact of new interventions.

While short-term benefits are well-documented, the long-term efficacy of technologies such as VR and robotics on motor recovery, quality of life, and neurodegenerative progression has not been adequately investigated (12). Addressing this gap with robust longitudinal research will provide the necessary evidence to inform comprehensive

clinical guidelines.

The observed peak in publication activity around 2015, followed by a mild decline, may reflect thematic saturation in traditional rehabilitation approaches. During the 2005–2015 period, intensive research on physiotherapy, gait training, and exercise-based interventions reached maturity. Subsequently, the focus of scientific interest may have shifted toward emerging areas such as telerehabilitation, wearable technologies, and artificial intelligence (AI) supported therapy, which may not always be indexed under traditional 'Parkinson's Disease rehabilitation' keywords (23, 27). One such area that has seen significant growth in recent years is the integration of AI and machine learning in rehabilitation (3). The application of AI in rehabilitation has the potential to transform the field environment by personalizing interventions, predicting patient outcomes and improving the efficiency of rehabilitation delivery.

The decline in citation counts after 2020 may also be partially attributed to the COVID-19 pandemic, which disrupted non-urgent clinical research worldwide and affected dissemination and publication cycles (28).

While this bibliometric study offers valuable insights into global research trends in PD rehabilitation, it is important to note that it is not without its limitations. First, the study's exclusive reliance on the WoS database may have resulted in the omission of relevant publications indexed in other databases, such as PubMed or Scopus. This limitation reduces the study's overall comprehensiveness. Second, the study's emphasis on citation criteria introduces a form of citation bias, as highly cited studies may not always represent the most clinically relevant or methodologically rigorous research. Ultimately, the

emphasis on the top 100 most cited articles may result in the exclusion of significant yet less frequently cited studies, particularly those that pertain to novel or specialized research domains that have not yet garnered substantial citations. These limitations underscore the necessity for a more extensive and inclusive approach in subsequent bibliometric analyses.

Future bibliometric studies should consider integrating multiple databases (such as Scopus, PubMed) to improve comprehensiveness. Moreover, the use of natural language processing and AI assisted classification methods may enhance the sensitivity and specificity of search strategies. In addition to citation counts, future analyses should incorporate quality-based metrics such as levels of evidence, clinical applicability, and innovation potential to provide a more holistic assessment of scientific impact.

5. Conclusion

This study constitutes a landmark effort to conduct a bibliometric analysis of the research landscape in PD rehabilitation. The results indicate that as academics focus on PD rehabilitation, insights into disease mechanisms and therapeutic innovations will deepen significantly. Future research is expected to increasingly utilize advanced technologies to improve treatment classifications and methodologies. This analysis serves as a critical resource for researchers seeking strategic partnerships by facilitating collaborative initiatives that will shape the future of evidence-based PH rehabilitation practice and improve patient care outcomes.

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