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REVIEW ARTICLE

Geriatrics, Gerontology and Aging

Physical exercise interventions for people with Parkinson's disease: a bibliometric review of systematic reviews

Intervenções de exercícios físicos para pessoas com doença de Parkinson: uma revisão bibliométrica de revisões sistemáticas

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Abstract

This bibliometric study aimed to characterize published systematic reviews assessing the effects of physical exercise on people with Parkinson's disease. Eligible studies were searched in Web of Science, Scopus, Cochrane Library, and MEDLINE via PubMed databases. No date or language restrictions were applied. Studies were selected based on the inclusion criteria, and the results were uploaded to Bibliometrix 4.0 for R for bibliometric analysis. A total of 146 studies were included in the analysis, with the first one having been published in 2005. The annual growth rate was 14.72%, with an average publication time of 3.72 years. Themes based on indexed keywords represented elements of the PICO question, namely Parkinson's disease, exercise, therapy, rehabilitation, and outcomes such as gait, balance, and quality of life. A considerable number of systematic reviews addressing the effects of physical exercise interventions on people with Parkinson's disease have been published since the mid-2000s. Systematic reviews were first published by countries with long-established older populations. Exercise-based interventions and their effects on gait, balance, and quality of life in people with Parkinson's disease have been the focus of the most recent reviews.
Keywords: Parkinson disease; exercise; physical activity; review; bibliometrics.

Resumo

Este estudo bibliométrico teve como objetivo caracterizar as revisões sistemáticas que avaliaram os efeitos do exercício físico em pessoas com doença de Parkinson. Estudos elegíveis foram pesquisados nas bases de dados Web of Science, Scopus, Biblioteca Cochrane e United States National Library of Medicine — MEDLINE via PubMed. Nenhuma restrição de data ou idioma foi adotada. Os estudos foram selecionados com base nos critérios de inclusão, e os resultados foram carregados no Bibliometrix 4.0 para R para análise bibliométrica. No total, foram incluídos 146 estudos na análise, o primeiro dos quais foi publicado em 2005. Verificou-se taxa de crescimento anual de 14,72%, com tempo médio de publicação de 3,72 anos. Temas baseados em palavras-chave indexadas representam elementos da questão problema, intervenção, controle e *outcome* — PICO, ou seja, doença de Parkinson, exercício, terapia, reabilitação e resultados, como marcha, equilíbrio e qualidade de vida. Um número considerável de revisões sistemáticas que abordam o efeito de intervenções de exercícios físicos em pessoas com doença de Parkinson foi publicado desde meados dos anos 2000. Revisões sistemáticas foram publicadas pela primeira vez por países com uma população idosa estabelecida há muito tempo. Intervenções baseadas em exercícios e seus efeitos na marcha, no equilíbrio e na qualidade de vida de pessoas com doença de Parkinson têm sido o foco das revisões mais recentes.
Palavras-chave: doença de Parkinson; exercício; atividade física; revisão; bibliometria.

INTRODUCTION

Parkinson's disease (PD) is a complex, chronic, progressive, and debilitating neurodegenerative disease that develops slowly and irreversibly.[1,2] It is characterized as a movement disorder with 3 main signs: tremor, rigidity, and bradykinesia. Some patients may develop postural instability as the disease progresses.[3] Its etiology is not fully known. Even so, loss of dopamine in the brain is recognized as the cause of motor impairment in people with PD.[4] Unhealthy eating, lack of physical activity, and alcohol consumption, which may lead to overweight or obesity and increase blood pressure and cholesterol levels, have been recognized as risk factors common to PD and other chronic noncommunicable diseases.[5]

PD is the second most prevalent neurodegenerative disease, affecting 1 to 2% of the world population at any age,[6] and has the fastest growing rates of prevalence, disability, and death.[7] Its incidence and prevalence increase with age, affecting up to 3% of the population over 55 years of age.[8] In 2016, PD caused more than 211,000 deaths in addition to 3.2 million cases of functional disability (1.4 million females and 1.8 million males).[7] Also, people with PD commonly require assistance due to functional impairment, movement difficulties, gait disturbances, and lack of balance. This comprehensive care involves both caregivers and family members and may generate high levels of stress.[9]

Physical exercise, due to its safety and efficacy, has been proposed as an effective non-pharmacological intervention to minimize harm in patients with PD.[10] The positive effects of properly prescribed physical exercise include lowering of blood pressure,[11] prevention and management of diabetes,[12] control of body weight by improving the lipoprotein profile and increasing insulin sensitivity,[13] prevention and improvement of mild symptoms of depression, anxiety, and dyspnea with a positive impact on quality of life,[14] improvement of cognitive function and mind-body connection,[15] and increase in the concentration of biomarkers related to neurogenesis and neuroprotection.[16] For people with PD, physical exercise is believed to improve motor symptoms, namely bradykinesia, gait, and turning performance, and also to affect positively non-motor aspects, such as mood disturbance, cognitive deficits, and sleep disorder.[17,18]

Although physical exercise is considered a safe and effective intervention in PD, the appropriate dose to potentiate its effects, considering exercise type, frequency, volume, and intensity, has not yet been established. Health care must be provided considering the patient's context and preferences, professional experience, and the best available evidence.[19] In this respect, a considerable number of systematic reviews addressing different types of physical exercise protocols and evaluating different outcomes in patients with PD have been published. Therefore, an umbrella review, which is a scoping review of systematic reviews,[20] was first proposed to characterize the level of evidence available to support the prescription of physical exercise for people with PD, considering the gaps related to exercise dose and type of outcome analyzed. This study is a subanalysis of the umbrella review and focuses on the bibliometric characterization of the scientific production on the issue.

METHODS

Search strategy

For this bibliometric review, systematic reviews reporting the effects of physical exercise on people with PD were searched in Web of Science (Clarivate Analytics), Scopus (Elsevier), Cochrane Library, and MEDLINE (via PubMed) databases. The search strategy was developed by a librarian experienced in health information recovery and run on May 22, 2022, to allow the bibliometric analysis of the retrieved studies. No date or language filter was used.

The terms 'Systematic reviews,' 'Exercise,' and 'Parkinson's Disease' were used as indexed terms (MeSH terms) and synonymous (free terms) to build the query using Boolean operators. The search strategy applied to each database is depicted in Table S1.

Study selection

The information retrieved from each database was uploaded to the open-source science mapping package Bibliometrix 4.0 for R,[21] which removed duplicate references and generated an Excel spreadsheet (Microsoft Office version 365, Microsoft Corp.) containing 544 references. These references were cross-checked with those previously included in the umbrella review by 2 authors and updated to produce the final dataset for bibliometric analysis.

Data extraction and analysis

The following bibliometric indicators were extracted: number of articles and sources, time span, average publication time (years), annual scientific production, annual growth rate, number of citations, average citations per document, average citations per year per document, top 20 most productive and most cited journals, institutions, and countries, study publications and citations per country per year, total number of authors, authors of single-authored documents, authors of multi-authored documents, articles per author, authors per article, co-authors per article, collaboration index, collaboration

between authors and between countries, indexed keywords (keywords plus), topic trends, and thematic evolution based on authors' keywords.

Data were analyzed in R package Bibliometrix 4.0 and Excel™. Scientific collaboration based on co-authorship was analyzed based on a collaboration network where the nodes represent the authors, and the links represent the co-authorships.[20] Louvain clustering algorithm with normalization by association was used. Other network parameters were the number of nodes (n=50) and a minimum number of one link. Thematic maps and evolution analysis were based on 250 authors' keywords, with a minimum cluster frequency per thousand documents of 5, inclusion index weighted by word occurrences with a minimum weight index of 0.1, and 3 cutting points (2010, 2015, and 2020). A keyword co-occurrence matrix was expressed graphically as undirected weighted networks, based on the simple center algorithm, allowing the identification of subgroups of strongly linked terms. Thematic diagrams were plotted based on 2 parameters, the Callon centrality and Callon density. The former expresses the importance of the topic within the study collection, and the latter expresses a measure of the topic development. The diagram is divided into 4 quadrants: the upper-right quadrant characterizes the motor themes, with high centrality (important) and high density (well developed) in the field; the lower-right quadrant represents basic and transversal themes, with high centrality and low density; the lower-left quadrant represents emerging or declining themes, which translate into weakly developed or marginal themes (low centrality and low density); and the upper-left quadrant characterizes highly developed and isolated themes, with limited importance to the field.[22]

RESULTS

Figure S1 shows the study flow diagram. A total of 905 records were identified by searching the 4 electronic databases, from which 361 records were identified as duplicates and removed with Bibliometrix. The remaining 544 records were screened, and other 398 records were removed mainly for not being related to the topic. Therefore, 146 records were analyzed as to bibliometric indicators and properties. Twenty-one other studies from the umbrella review were not identified for the bibliometric analysis.

The first systematic review assessing the effects of physical exercise on PD was published in 2005. After that, more than 100 reviews were published addressing the issue with a 14.72% annual growth rate (Table S2 and Figure S2). The average publication time was 3.72 years, showing that reviews have been published recently. Most published studies had more than 1 author, with an average of 5 authors per article (Table S2).

Table 1 presents the most relevant journals. The highest number of articles published in one journal was 8, in Clinical Rehabilitation and PLoS One. The most cited journal was Movement Disorders.

Table 2 shows the most productive and cited institutions. Queensland University of Technology was the most productive institution, being involved in the production of 12 studies. The most cited institution was the University of Exeter, accounting for 14.36% of the citations.

Table 3 shows the most productive and cited countries based on corresponding author affiliation. Figure S3 depicts the production of the 10 most productive countries and the citations of the 10 most cited countries per year.

Collaboration networks (Figure S4) depicted individual collaborations and collaborations between institutions and countries, while Figure S5 maps scientific collaborations between countries. Small clusters of authors mainly from the same country represent the individual collaborations (Figure S4.A). Institutional collaboration was observed mostly between universities from the same country, such as the Spanish universities of León and Vigo and the Australian universities James Cook University and Queensland University of Technology. Also, Australian universities such as La Trobe University and Deakin University were linked to Limerck University from Ireland. Other links between universities from different countries are depicted in Figure S4.B. Figure S4.C shows 5 clusters representing collaboration between countries. The most central clusters reveal USA and Australia as the most collaborative countries. The main between-country collaborations, depicted by the thickness of the links between nodes, involved mainly USA/China, USA/South Korea, and Australia/Spain (Figures S4.C and S5).

Themes explored in the systematic reviews were analyzed based on indexed keywords. The analysis revealed that, other than *Parkinson's disease*, *exercise*, *people,* and *humans*, *gait*, *balance,* and *quality of life* were also indexed as keywords in the studies. These words express some of the outcomes assessed in the systematic reviews (Figure S6). Most of these words represent the themes of systematic reviews conducted mostly from 2016 to 2020, while *physical therapy*, for instance, has been proposed and assessed as an intervention for people with PD since 2012 (Figure S7).

The bibliometric analysis revealed 269 authors' keywords. Thematic evolution analysis (Figure 1) highlighted the co-occurrence of authors' keywords that expressed various types of exercise interventions and outcomes assessed, since the population and the type of study were the same.

In the first subperiod, 1 main theme emerged (Figure 1A, 1B), being expressed by the *Parkinson's disease* cluster (centrality: 1.4; density: 247.9) and composed of the words *Parkinson's disease*, *exercise*, and *systematic review*. In the second subperiod, the 5 main themes were *Parkinson's disease*, *exercise therapy*, *rehabilitation*, *humans,* and *parkinsonism*

TABLE 1. Top 20 most relevant and cited journals.

Ranking by number of articles	Journal	Number of articles	%	Ranking by number of citations	Journal	Total citations	Impact factor (2022)
1st	Clinical Rehabilitation	8	5.48	1st	Movement Disorders	461	9.628
1st	PLoS One	8	5.48	2nd	Archives of Physical Medicine and Rehabilitation	215	4.06
2nd	Journal of Parkinsons Disease	6	4.11	3rd	Parkinsonism and Related Disorders	214	4.402
3rd	Journal of Physiotherapy	5	3.43	4th	Neurorehabilitation and Neural Repair	150	4.895
4th	Complementary Therapies in Medicine	4	2.74	5th	Clinical Rehabilitation	147	2.884
4th	Movement Disorders	4	2.74	6th	Neurology	121	6.682
5th	Aging Clinical and Experimental Research	3	2.06	7th	Physical Therapy	116	3.679
5th	Archives of Physical Medicine and Rehabilitation	3	2.06	8th	Journal of Neurology, Neurosurgery and Psychiatry	106	13.654
5th	BMC Neurology	3	2.06	9th	Cochrane Database of Systematic Reviews	85	11.874
5th	Frontiers in Neurology	3	2.06	10th	Neurorehabilitation	81	1.986
5th	Parkinsonism and Related Disorders	3	2.06	11th	PLoS One	76	3.752
6th	Acta Neurologica Scandinavica	2	1.37	12th	Journal of Neurologic Physical Therapy	73	4.655
6th	American Journal of Occupational Therapy	2	1.37	13th	British Medical Journal	66	96.216
6th	Cochrane Database of Systematic Reviews	2	1.37	13th	Gait Posture	66	2.746
6th	Critical Reviews in Physical and Rehabilitation Medicine	2	1.37	14th	Complementary Therapies in Medicine	65	3.335
6th	European Review of Aging and Physical Activity	2	1.37	15th	Lancet Neurology	62	59.935
6th	Evidence-Based Complementary and Alternative Medicine	2	1.37	16th	Medicine & Science in Sports & Exercise	59	6.289
6th	Frontiers in Aging Neuroscience	2	1.37	17th	Parkinson's Disease	50	5.520
6th	International Journal of Environmental Research and Public Health	2	1.37	18th	Journal of Neurology	48	6.682
6th	Journal of Bodywork and Movement Therapies	2	1.37	19th	Disability and Rehabilitation	47	2.439

(Figure 1C). PD was the most central, transversal theme (centrality: 5.1; density: 325.2), consisting mainly of the words *Parkinson's disease*, *exercise*, *balance*, *gait*, and *systematic review*, while *exercise therapy* was the motor theme (centrality: 4.6; density: 379.5), highlighting *Parkinson's disease* and *exercise therapy*. During this subperiod, the term *quality of life* showed up in the *rehabilitation* cluster, appearing in the lower-left quadrant.

TABLE 2. Top 20 most productive and cited institutions.

Ranking by number of articles	Institution	Number of articles	%	Ranking by number of citations	Institution	Total citations	%	Average citations per document
1st	Queensland University Technol	12	8.22	1st	University of Exeter	577	14.36	192.3
2nd	Henan University of Chinese Medicine	9	6.16	2nd	Vrije University	421	10.48	273.5
2nd	IRCCS San Raffaele Scientific Institute	9	6.16	3rd	University of Sydney	206	5.13	103
2nd	La Trobe University	9	6.16	4th	Vu University	162	4.03	162
3rd	University Vigo	7	4.79	5th	University of Utah	145	3.61	145
4th	Aarhus University	6	4.11	6th	Lakehead University	138	3.44	138
4th	Harvard Medical School	6	4.11	7th	Aarhus University	104	2.59	52
4th	Saint Louis University	6	4.11	8th	Cardiff University	100	2.49	100
4th	The first affiliated Hospital of Henan University of Chinese Medicine	6	4.11	9th	University of British Columbia	92	2.29	92
4th	University Almeria	6	4.11	10th	Boston University	84	2.09	84
4th	University León	6	4.11	11th	Chang Gung University	77	1.92	77
4th	Universidade Federal do Espírito Santo	6	4.11	12th	Universidade Federal Minas Gerais	71	1.77	71
4th	University of Calgary	6	4.11	12th	Harvard Medical School	71	1.77	71
5th	Chengdu Medical College	5	3.42	13th	Griffith University	70	1.74	70
5th	Kyung Hee University	5	3.42	14th	University of Western Australia	67	1.67	67
5th	McGill University	5	3.42	15th	Witten/Herdecke University	66	1.64	66
5th	Shanghai University Sport	5	3.42	15th	Jining Medical University	66	1.64	33
5th	University of Illinois	5	3.42	16th	General Hospital Peoples Liberation Army Chengdu Military Region	65	1.62	65
5th	Washington University	5	3.42	17th	Universidade do Estado Santa Catarina	63	1.57	63
6th	Anhui University Chinese Medicine	4	2.74	18th	Washington University	62	1.54	31

TABLE 3. Top 20 most productive and cited countries.

Ranking by number of articles	Country	Number of articles	%	Ranking by number of citations	Country	Total citations	%	Average citations per document
1st	Brazil	19	13.01	1st	United Kingdom	682	16.97	136.4
2nd	China	17	11.64	2nd	Australia	633	15.75	39.56
3rd	Australia	16	10.96	3rd	Netherlands	628	15.62	104.67
4th	Spain	13	8.90	4th	USA	479	11.92	39.92
5th	USA	12	8.22	5th	China	327	8.14	19.24
6th	Italy	10	6.85	6th	Canada	243	6.05	40.5
7th	Germany	8	5.48	7th	Brazil	189	4.70	9.95
8th	Canada	6	4.11	8th	Germany	172	4.28	21.5
8th	Netherlands	6	4.11	9th	Italy	140	3.48	14.0
9th	United Kingdom	5	3.43	10th	Denmark	104	2.59	52.0
10th	India	3	2.06	11th	Taiwan	99	2.46	49.5
10th	Ireland	3	2.06	12th	France	76	1.89	38
10th	South Korea	3	2.06	13th	Spain	47	1.17	3.62
11th	Belgium	2	1.37	14th	Belgium	31	0.77	15.5
11th	Denmark	2	1.37	15th	Hong Kong	28	0.70	28
11th	France	2	1.37	16th	North Ireland	26	0.65	26
11th	Poland	2	1.37	17th	Ethiopia	25	0.62	25
11th	Sweden	2	1.37	18th	Finland	23	0.57	23
11th	Taiwan	2	1.37	19th	Sweden	18	0.45	9.0
12th	Czech Republic	1	0.69	20th	South Korea	13	0.32	4.3

The third subperiod was the most productive of systematic reviews addressing physical exercise interventions for people with PD (Figure 1D). The most central theme in this subperiod was *Parkinson's disease* (centrality: 8.2; density: 259.5), highlighting *exercise*, *rehabilitation*, *physical therapy*, and *physical activity* as interventions, and *freezing of gait*, *mobility*, and *quality of life* as outcomes. The motor theme was *systematic review* (centrality: 4.8; density: 447.3), which was linked to the central theme and addressed *dance* as an intervention and *mood*, *cognition*, and *sleep* as outcomes. Another *Parkinson's disease* cluster resulting from the *exercise therapy* cluster of the second subperiod presented *Tai Chi*, *Yoga*, *Qigong*, and *virtual reality* as interventions.

The most central theme in the fourth subperiod was *rehabilitation* (centrality: 7.0; density: 251.9) (Figure 1E), which consisted mainly of the words *rehabilitation*, *systematic review*, *meta-analysis*, *exercise*, *Parkinson's disease*, and *pain* that came from the *Parkinson's disease* and *systematic review* clusters of the third subperiod. It was closely linked to the *Parkinson's disease* clusters, one of which was also rather central and more densely developed (centrality: 5.2; density: 294.0). This cluster involved the co-occurrence of *Parkinson's disease*, *gait*, *aerobic exercise*, *physical activity*, *quality of life*, *multiple sclerosis*, *postural balance*, and *resistance training*. The higher density may be interpreted as a potential theme for further exploration. Two other themes were in the upper-left quadrant, with a Callon density of 350 and low centrality, meaning that they had been sufficiently explored and have unimportant external links. The *stroke* theme consisted of *virtual reality exposure therapy* and *telerehabilitation*, which were linked to other clusters by the term *stroke*. The *physical* cluster involved *insomnia*, *fall prevention*, and *therapy* and was linked to the main themes by the term *physical*.

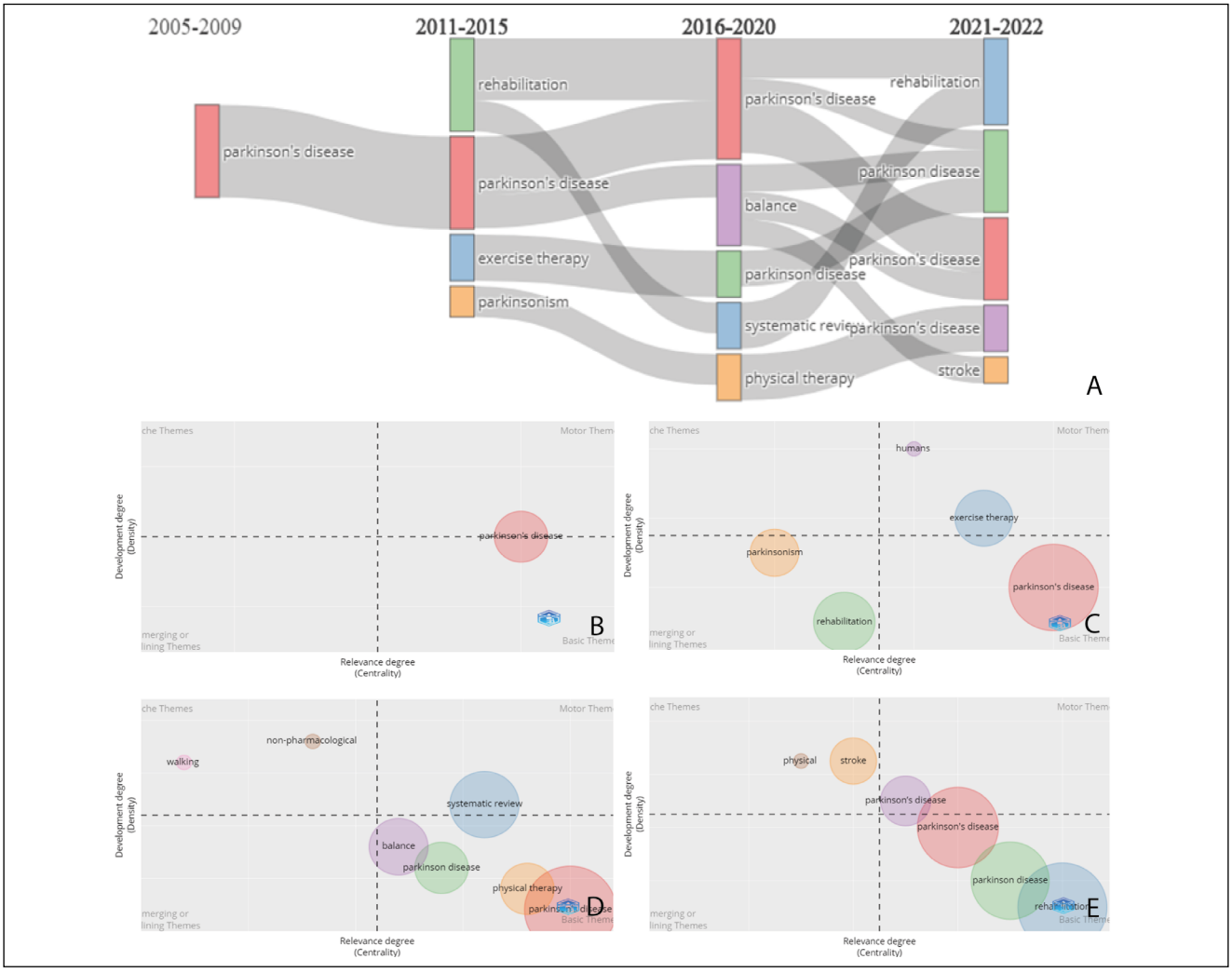

FIGURE 1. (A) Thematic evolution of authors' keywords from systematic reviews of physical exercise interventions for people with Parkinson's disease at the A – 2005–2022 time span; (B) Time span 1: 2005-2009; (C) Time span 2: 2011–2015; (D) Time span 3: 2016–2020; and (E) Time span 4: 2021–2022.

DISCUSSION

The increasing number of older people around the world has raised the global burden of PD by 20%, with a more than doubling of the number of cases in 2016 compared to 1990.[7] Also, disability-adjusted life years (DALYs), which are a sum of the years lived with disability and years of life lost, were 2.5 times higher in 2016 than in 1990.[7] Additionally, high direct and indirect costs and resource use have been associated with assistance to people with PD, mainly in advanced and late stages.[23] This review identified and characterized the effort to synthesize evidence by means of systematic reviews of the effects of physical exercise on people with PD. Its results reflect the impact imposed by PD on the society globally, since more than 100 studies have attempted to synthesize evidence related to the effects of physical exercise on people with PD since 2005 (Table S2). Also, the average publication time and annual growth rate reveal that these attempts are recent and growing in number (Table S2).

The first systematic review identified here analyzing the effects of physical exercise on PD was published in 2005. The movement towards evidence-based practice in health care began in the medical field in the 1980s, a period that also marked the beginning of the synthesis of evidence from systematic reviews.[19] Yet, other health fields joined this movement later, in the early 2000s. Therefore, the time of the first publication in the field agrees with the moment that evidence-based health care became more widespread.

More than 650 authors were associated with the published studies. The average number of authors was 4.5, and only 1 study was single authored. This study may be

considered an anomaly, since a minimum of 2 authors are expected in the development of a systematic review.[24] The main guidelines for conducting systematic reviews indicate that these are team-performed studies,[24,25] requiring at least 2 authors for the phases of study selection and data extraction. In addition, a systematic review team requires experts in epidemiology and statistics, in the subject being investigated, and in literature search. Consequently, the average number of authors found may be explained by team demands to produce the type of study under analysis.

Clinical Rehabilitation and PLoS One were the most relevant journals, with 8 systematic reviews of the effects of physical exercise interventions on people with PD. Clinical Rehabilitation is a peer-reviewed, multiprofessional journal that publishes highly ranked articles on research and scientific discussions about disability and rehabilitation. It combines the theoretical aspects and practical application of results mainly from studies on the effectiveness of therapeutic interventions and evaluation of new methodologies.[26] PLoS One publishes multidisciplinary research, including systematic reviews in the biomedical sciences. It provides open access to its articles, which may contribute to the dissemination and reading of the information.

The most cited journal was Movement Disorders, which is managed by the International Parkinson and Movement Disorder Society (MDS), the largest society of physicians, researchers, and human movement professionals. The journal's scope involves movement in PD, movement disorders, neurodegeneration, genetic alterations, hyperkinetic movement, and motor control abnormalities.[27] Both journal scope and prestige have been shown to be positively correlated with citations.[28]

The most productive institution was the Queensland University of Technology with 12 published studies, followed by the Henan University of Chinese Medicine, IRCCS San Raffaele Science Institute, and La Trobe University with the production of 9 studies each. The most cited institutions were the University of Exeter, with 3 studies, and Vrije University, with 2 studies. These institutions happened to produce some of the first studies on the issue and to be cited by the following studies.

When analyzing the most productive countries, those with long-established older populations stand out. Also, the countries responsible for the main methodological recommendations in systematic reviews (United Kingdom, Canada, and Australia) are among the 10 most productive countries (Table 3). The exception is Brazil, which was the most productive country despite the comparatively smaller older population. Brazil was the seventh most cited country, which may be explained by the recent publication of a large number of studies (Figure S3). The United Kingdom, Australia, and Netherlands, with older studies, had the highest number of citations (Figure S3).

Scientific collaboration may be analyzed at individual, cross-national, and multinational levels.[29] The individual level refers to collaboration between individual scientists, while the cross-national level characterizes the collaboration between affiliated scientists in different countries and the multinational level characterizes the collaboration between more than 2 countries.[29] Most of the research collaboration at the individual level was observed between authors from the same research group or country (Figure S4A). Most of the between-country collaboration involved a single article. Greater collaboration involved mainly USA/China, USA/South Korea, and Australia/Spain (Figure S5). Noteworthy, training and a learning curve are required to develop a qualified review team, which would benefit from the collaboration between groups. Besides, given that PD is a global reality that poses health-care, emotional, and economic challenges,[7] the effort to synthesize evidence and to develop and apply guidelines could be potentiated by the collaboration between countries. This collaboration behavior has been previously identified in other fields of study and is characterized as an obstacle to the progress of the understanding of the issue under study.[30]

Systematic reviews of the effects of physical exercise on people with PD were mostly published in European countries, with increased life expectancy.[9] USA and China also have a considerable older adult population, and in both, life expectancy and aging have been positively correlated with PD.[7] Even Brazil, which produced 19 reviews and whose population's life expectancy is not as high as that of the abovementioned countries, has estimated that approximately 200,000 people will develop PD,[31] reinforcing the impact of this increasingly occurring and highly demanding disease.

Co-word analysis was performed to determine the thematic evolution of the studies during the 2005–2022 time span. In such analysis, clusters of co-words and their interconnections are considered themes and labelled after the most significant keyword, usually the most central one in the thematic network.[32] Also, the importance of the theme in the field is put into perspective based on its evolutionary life cycle, which involves birth, growth, maturity, and decay.[33] The themes expressed in the thematic evolution analysis were limited by the structured nature of the question and the PCC framework (Population, Concept, and Context) of the scoping review that refers to the study design, type of interventions being assessed, and the population involved.

Noteworthy, the first subperiod depicted one main theme (Figure 1A and 1B), labelled *Parkinson's disease* and consisting of the words *Parkinson's disease*, *exercise*, and *systematic review*, which precisely represented the population under study, the type of intervention, and the study design.

In the second subperiod (Figure 1C), the number of themes increased and the most densely studied theme was the association between *Parkinson's disease* and *exercise therapy*. However, the second most studied theme during the 2011–2015 period involved *rehabilitation*, which was closer to the main theme than the one involving *exercise therapy*. It may be interpreted as a growing theme that happens to comprise the main topic in the third subperiod and involves interventions such as *dance, music, rhythm,* and *water-based exercise*, along with *quality of life* as an outcome measure. Therefore, there has been a shift of attention from managing basic signs of PD to providing a more active life through physical activities that do not necessarily characterize dose-prescribed exercise.

Parkinson's disease was the transversal theme of the third subperiod (Figure 1D), composed mainly of *Parkinson's disease, exercise,* and *rehabilitation*. The 2016-2020 period revealed further attempts to synthesize evidence on the effect of exercise on PD, as expressed by the *systematic review* topic, consisting mainly of *systematic review* and *meta-analysis*. It also showed two closely related topics that involved *Tai Chi, Yoga, virtual reality, Nintendo Wii, physical therapy*, and *treadmill. Aerobic exercise, aquatic therapy, Qigong*, and *walking endurance* made up the topic *balance*, with lower centrality during this period. The analysis of the most recent period, from 2020 to 2022, revealed *rehabilitation* as the central theme. It also showed an increasing centrality of the words *aerobic exercise, physical activity*, and *resistance training* as interventions and *gait, postural balance*, and *quality of life* as outcome measures.

Study limitations

Limitations of the study were those inherent to a bibliometric analysis, which, in this case, involved a small number of databases searched for bibliometric purposes and was restricted to bibliometric outcomes. This means that the exhaustive search and study selection based on full-text reading used in the umbrella review was not reproduced in the bibliometric review. The databases searched are common in the biomedical field[33] and allowed the identification of 87.4% of the systematic reviews on the theme. This study, though, avoided a common drawback of bibliometric studies, which is false-positive results generated by broad research queries.[34] The focus of the review, which was limited to clinical trials involving physical exercise interventions for people with PD, and the individual selection of studies resulted in the inclusion of only studies that met the inclusion criteria.

This review does not address the potential impact of the included systematic reviews, since their content or methodological quality is better assessed in an umbrella review or overview. Although it suggests that Global North countries have dealt with PD longer than other countries, differences or similarities between countries in the effects of exercise on people with PD would be better represented by the primary studies included in the systematic reviews. Still, this review highlights the need for a global effort to identify gaps in the knowledge of exercise effects on people with PD and to propose a global guideline to enhance exercise prescription based on solid evidence.

CONCLUSION

A considerable number of systematic reviews addressing the effects of physical exercise interventions on people with PD have been published since the mid-2000s. Additionally, an increasing trend of evidence synthesis production is observed in recent years. Countries with long-established older populations were responsible for earlier publications, while countries with shorter life expectancy have increased the number of publications recently. Enhanced collaboration between countries could be established focusing on standardized guidelines and exercise prescription, since PD represents a major problem for the world's aging population.

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Conflict of interest

the authors declare no conflicts of interest.

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Authors' contributions

sARJ: conceptualization, data curation, methodology, resources, software, supervision, writing – original draft. CP: conceptualization, data curation, funding acquisition, investigation, validation, visualization, writing – review & editing. RS: data curation, investigation, validation, visualization, writing – review & editing. CAS: supervision, validation, visualization, writing – review & editing.

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Appendices

Harvard Dataverse:
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Online Appendix Table S1. Electronic search strategies.
Online Appendix Table S2. Main data.
Online Appendix Figure S1. Flow diagram of the study.
Online Appendix Figure S2. Annual production from 2005 to 2022.
Online Appendix Figure S3. A – Study publication per country per year; B – Citations per country per year.
Online Appendix Figure S4. Collaboration networks considering a minimum of one collaboration link. A – Collaboration between review authors; B – Collaboration between institutions; C – Collaboration between countries.
Online Appendix Figure S5. Country collaboration map highlighting a minimum of one collaboration.
Online Appendix Figure S6. Word cloud – Frequency of indexed keywords.
Online Appendix Figure S7. Topic trends based on indexed keywords.