PHYSICAL
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SYSTEMATIC REVIEWS

Bibliometric analysis of core journals which publish articles of physical therapy on aging

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ABSTRACT. Objective. Increase in population's longevity has led to considerable efforts worldwide on physical therapy aging research. The aim of this study is to identify which are the main scientific journals, as well as the most productive authors, institutions and keywords related to the journals, that have published about physical therapy and aging. Methods. Original articles published from 1990 to 2014 were retrieved from the bibliographic database Science Citation Index Expanded of Web of Science Core Collection. After standardization of the bibliographic information, a series of bibliometric indicators was obtained regarding authors, institutions, citation and keywords of the core journals using bibliometric software. The PAJEK network analysis program was used for graphic representation. Results. A total of 2,237 original articles are included in this analysis. The number of identified journals is 573, with an average growth of publishing journals throughout the studied period of 9.41%. Bradford's distribution shows 12 core journals, out of which 41.67% have published constantly all throughout the 25-year period, being the most productive one Physical Therapy. Fritz, Julie M is the most productive author, and University of Sydney the most productive institution. The keyword exercise is used in an outstanding way. Conclusions. The productivity trends provided an indication of the greater scientific interest of physical therapy in aging as a line of research. Collectively, the data indicated that physical therapy-specific journals are being consolidated but non-specific are still a significant research source, and that a fundamental element of their research includes exercise and movement.

Key words: Bibliometrics, Physical therapy, Aging

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Globally, the number of older adults is growing faster than all younger age groups. It's expected to more than double by 2050 and more than triple by 2100, rising from 962 million in 2017 to 2.1 billion in 2050 and 3.1 billion in 2100[1)]. Aging has taken a prominent role in research strategies and it constituted 2.4% of all scientific publications in 2015 worldwide[2)].

Although physical therapy (PT) publications are a relatively new phenomenon[3,4)], considerable efforts have been made on aging research[5)]. The World Health Organization indicates that aging constitutes complex changes[6-8)], which are not linear or uniform[9,10)] plus there is also "successful aging" to be considered[11-15)]. Therefore, PT plays a fundamental part in maintenance or improvement of functionality throughout the cycle of life[16-18)].

When dealing with such complex phenomenon, bibliometric measures allow to identify emerging and innovative topics, anticipate advances and determine which paradigms will dominate research in the future[19,20)]. It has already been implemented in, mostly, all scientific fields[21,22)], and it can allow PT researchers and professionals to analyze publications and identify future research opportunities[23)].

The goal of a scientific work is its dissemination and consumption, for which publication in any of the established channels becomes necessary[24,25)]. Journals have a

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great importance on the scientific activity, in a qualitative and a quantitative focus[26-28].

The aim of this study is to identify the main scientific journals, the most productive authors, institutions and main thematic of the journals that have published about PT and aging.

Methods

A bibliometric study was conducted through the SCI-Expanded (SCI-E) of Web of Science (WoS) Core Collection as in previous bibliometric studies[29,30], in order to retrieve all the original articles related to PT in aging. WoS allows to know the impact of publications from their citations[31] and a detailed citation analysis[32].

The search strategy was carried out with terms related to: PT, physical therapist, aging and PT techniques in aging. They were selected due to their existence in the Medical Subject Headings (MeSH) thesaurus[33], in previous bibliometric studies[34-39], or were professional terms of PT[16,40,41]. The final search strategy had 115 combined terms.

As for the limits, all categories of SCI-E were selected in order to obtain a multidisciplinary view. The search time limit finally was from 1990, year of the first result, to 2014. The type of document *Articles* was selected, since original articles of scientific journals with peer review are the most appropriate for bibliometric studies[21]. The literature search was applied on July 2015 and a total of 2,417 documents were retrieved.

A specific bibliometric relational database (*Bibliométricos.mdb*) in a Microsoft Access file was generated with the 2,237 documents after remove manually the 180 non-pertinent references.

The authors' signatures were standardized, because an author may use only one surname, or two. (e.g. standardized author *Hill, Keith D* had the variants *Hill, K.*, *Hill, Keith* and *Hill, Keith D.*) In relation with institutions, the different variants of universities or hospitals were unified.

Keywords were standardized considering the definitions of the World Confederation for Physical Therapy (WCPT) Glossary[41], Medline Plus Dictionary of United States National Library of Medicine and the MeSH thesaurus[42].

Global bibliometric indicators were obtained: number of journals, Bradford's distribution for journals, productivity of Bradford's core journals (BCJ) and identification of the journal's publishing countries. For the calculation of Bradford's distribution, scientific journals were sorted in descending order of productivity identifying a core of specialized publications (Bradford's nucleus) and several zones that had approximately the same number of articles than the nucleus, where the number of journals increases in n progression in the first zone around the nucleus, n^2 in the second zone and so on. In multidisciplinary areas it's considered the indicator that best fits the distribution[43].

Journals with 500 or more citations were identified, as well as citation indicators of highly productive journals, correlation between citation and productivity (Pearson correlation coefficient and coefficient of determination-CD), Impact Factor (IF) measurements and h-Index for BCJ[44]. The h-Index is the result of the combination of productivity and citation given in an index: a journal has an h-index, if all of its h works receive at least h citations each, and the rest have at most h citations[45].

The links between highly productive journals and keywords (used in at least 15 of its publications) were also identified. All BCJ met this criterion. For the graphic representation of links, PAJEK network analysis program was used.

Regarding authors, bibliometric indicators were calculated: number of authors, Lotka's Productivity Index (PI)[46] and productivity measurements of highly productive authors in relation with the journals. PI allows to identify highly productive authors (more than 10 published papers: $PI \geq 1$), medium producers (2-9 published papers: $0 < PI < 1$) and small producers, (1 article: $PI = 0$).

The same methodology was applied to analyse the institutional signatures, identifying the PI for the institutions. Quartiles were also calculated for institutions with $PI \geq 1$.

Results

The number of articles that were analysed was 2,237 (89.48 articles per year, SD=77.64), and the number of journals was 573 (177 articles per quinquennium, SD=130). The journals that published throughout the 25 years had grown an average of 9.41% (SD = 5.3), being the largest percentage increase between 2005-2009 and 2010-2014 (15.71% more publishing journals, n=139).

Regarding the journal's country publication, 33.68% of them were published in US (n = 193), 21.29% in UK (n = 122), 8.55% in Germany (n = 49), 3.32% in France (n = 19) and 2.97% in Australia (n = 17).

Bradford's distribution showed that there were 12 BCJ (Zone 1 or nucleus) with 724 articles; Zone 2 had 81 (756 articles); and Zone 3 had 480 (757 articles). BCJ corresponded to high productivity specialized journals sought by authors to publish their work, and had published between 25 and 149 articles each.

The most productive journals (Table 1) experienced a steady growth in the number of publications over the period 1990-2014 and had a 29% percentage variation between first and last quinquennium.

Five (41.67%) of BCJ had published constantly all throughout the 25-year period: *Phys Ther*, *Arch Phys Med Rehabil, JOSPT, Spine and J Am Geriatr Soc.*

In relation to the 12 BCJ, most of them were published in the US (58.33%, n = 7), followed by the UK (33.33%, n

Table 1. Productivity of Bradford's nucleus journals.

Journal*	Country	1990-1994	1995-1999	2000-2004	2005-2009	2010-2014	TOTAL
Phys Ther	US	13	16	14	47	59	149
Arch Phys Med Rehabil	US	5	10	33	34	42	124
JOSPT	US	3	8	10	22	30	73
BMC Musculoskelet Disord	UK	0	0	2	14	49	65
Physiotherapy	UK	0	0	0	27	37	64
Rev Bras Fisioter	Brazil	0	0	0	11	39	50
Clin Rehabil	UK	0	2	11	20	16	49
Spine	US	4	5	13	9	5	36
Disabil Rehabil	UK	0	0	9	6	18	33
J Am Geriatr Soc	US	5	2	8	9	4	28
J Geriatr Phys Ther	US	0	0	0	2	26	28
JMPT	US	0	3	6	8	8	25

* *Ordered by productivity.*

= 4) and Brazil (8.33%, n=1).

A total of 8,486 authors were identified and accumulated 10,582 signatures. Authors' productivity distribution showed: 14 highly productive (PI $\geq$1, 0.16% of authors, 1.8% of papers), 1,157 medium producers (0 < PI < 1, 13.63% of authors, 29.07% of articles), and 7,315 small producers (PI = 0, 86.20% of authors, 69.13% of papers).

Highly productive authors published in 46 journals, with an average of 7.79 (SD = 2.22) journals per author. The journal with highest number of published papers was *Phys Ther* (n=31, 16.23%), followed by *BMC Musculoskelet Disord* (n=23, 12.04%) and *JOSPT* (n=20, 10.47%).

The author with more publications in the same journal was Cleland, Joshua A., (9 articles in *JOSPT)*, followed by Fritz, Julie M, (7 publications in *Phys Ther*) and Hay, Elaine M. (7 in *BMC Musculoskelet Disord)* (Table 2).

A total of 2,164 institutions from 63 different countries were identified, and accumulated 5,156 signatures. When Lotka's distribution was applied, only 3.65% (n = 79) obtained a PI$\geq$1, 30.08% (n=651) were medium producers (0 < PI < 1) and 66.27% (n = 1,434) had a PI=0. The five most productive institutions were: University of Sydney (n = 52), University of Queensland (n = 47), University of Melbourne (n = 46), University of Washington (n = 41) and University of Toronto (n = 39).

The 79 highly productive institutions corresponded to 18 countries, with US leading with 24 institutions (30.38%) which published 416 documents (18.60%), followed by Australia with 10 institutions (12.65%) and 292 articles (13.10%).

The calculation of quartiles for the 79 institutions with a PI $\geq$ 1, allowed to identify 4 zones. In the first quartile the most highly productive institutions were found and had published in 433 journals being the main two: *BMC Musculoskelet Disord* (8 institutions, 38.10%), followed by *Phys Ther* (5 institutions, 23.81%) with an average of 20.62 (SD = 7.05) journals per institution.

The institution with more publications in the same journal was University of Washington with 12 articles in *Phys Ther*, followed by University of São Paulo with 9 publications in *Rev Bras Fisioter*.

Journals with at least one citation were 489 (85.34%), with a total of 42,764 citations. There were 84 (14.66%) with no citations, 40 (6.98%) cited once and 449 (78.36%) cited two or more times.

Seventeen journals had more than 500 citations. Six of these are in BCJ (*Phys Ther*, *Arch Phys Med Rehabil*, *Spine*, *JOSPT*, *J Am Geriatr Soc* and *Clin Rehabil*). The journal with more citations was *Phys Ther* (n = 4,007), followed by *Arch Phys Med Rehabil* (n = 3,683) and *Spine* (n = 1,915).

The 12 BCJ accumulated 15,434 citations in 724 articles, with an average of 20.21 citations per paper. The two most cited journals were also the two most productive (*Phys Ther* and *Arch Phys Med Rehabil*).

The average IF for each five-year period and the average IF for the entire period was calculated for BCJ (Table 3). Five journals had IF every year throughout the 25 years studied (*Phys Ther*, *Arch Phys Med Rehabil*, *Spine*, *J Am Geriatr Soc* and *JMPT*).

All of BCJ had an h-Index above 16. The *J Am Geriatr Soc* had an h-Index of 186, and was also the journal with the highest IF. In addition, the four journals with a h-Index over 80 (*Phys Ther*, *Arch Phys Med Rehabil*, *JOSPT* and *Spine*) were the only ones whose IF was higher than 1.

The calculation of Pearson's correlation coefficient between citation and productivity of the journals was 0.83 with a positive (0 < r < 1) and high correlation (CD= 69.03%).

A total of 3,396 keywords were used in the 2,237 articles. The links between BCJ and the keywords used was

Table 2. Main publication journal of the highly productive authors.

Highly productive authors*	Nº journals where they publish	Journal where they most publish	Nº published articles in main journal	Range of published articles in rest of journals
Fritz, Julie M	7	Phys Ther	7	1-6
Cleland, Joshua A	9	JOSPT	9	1-3
Hay, Elaine M	7	BMC Musculoskelet Disord	7	1-3
Lord, Stephen R	13	Arch Phys Med Rehabil	3	1-2
Bennell, Kim L	8	BMC Musculoskelet Disord	6	1-2
Sherrington, Catherine	9	Journal of Physiotherapy	3	1-2
Brennan, Gerard P	5	Phys Ther	5	1-4
de Bie, Rob A	9	BMC Musculoskelet Disord	3	1-2
Foster, Nadine E	5	BMC Musculoskelet Disord	5	1-3
Morris, Meg E	9	Arch Phys Med Rehabil / Phys Ther	2 /2	1
Haines, Terrence P	8	Medical Care / Phys Ther	2 /2	1
Hill, Keith D	8	Arch Phys Med Rehabil / Phys Ther	2 /2	1
Vicenzino, B	8	Br. J. Sports Med / JOSPT	2 /2	1
Whitman, Julie M	4	JOSPT	5	1-3

** Ordered by productivity, within the same productivity, the authors have been ordered alphabetically.*

Table 3. Impact Factor for journals in Bradford's nucleus.

Journal*	ISSN	Average IF 1990-1994	Average IF 1995-1999	Average IF 2000-2004	Average IF 2005-2009	Average IF 2010-2014	Average IF
Phys Ther	0031-9023	0.627	1.024	1.5134	1.921	2.861	1.589
Arch Phys Med Rehabil	0003-9993	0.666	1.138	1.423	1.943	2.380	1.510
JOSPT	0190-6011	-	0.574	1.023	1.756	2.774	1.532
BMC Musculoskelet Disord	1471-2474	-	-	1	1.594	1.802	1.465
Physiotherapy	0031-9406	-	-	-	0.595	1.557	1.076
Rev Bras Fisioter	1413-3555	-	-	-	0.338	0.604	0.471
Clin Rehabil	0269-2155	-	0.981	1.027	1.631	2.101	1.435
Spine	0362-2436	0.527	1.451	2.196	2.491	2.298	1.793
Disabil Rehabil	0963-8288	-	0.559	0.861	1.303	1.67	1.098
J Am Geriatr Soc	0002-8614	1.91	2.658	3.060	3.562	4.0832	3.055
J Geriatr Phys Ther	1539-8412	-	-	-	-	1.2385	1.239
JMPT	0161-4754	0.069	0.126	0.909	0.912	1.430	0.689

** Journals are ordered by productivity.*

analysed, finding they used 21 different keywords, being "Physical therapy" and "older people" the mostly used. The most important link was between *Arch Phys Med Rehabil* and the keyword "rehabilitation" (n = 114), followed by *Phys Ther* and the keyword "older people" (n = 63). One of the outstanding keywords was "exercise" used by the two most productive journals (Figure 1).

Discussion

The results have shown that the number of journals has increased in every quinquennium, being the most pro-

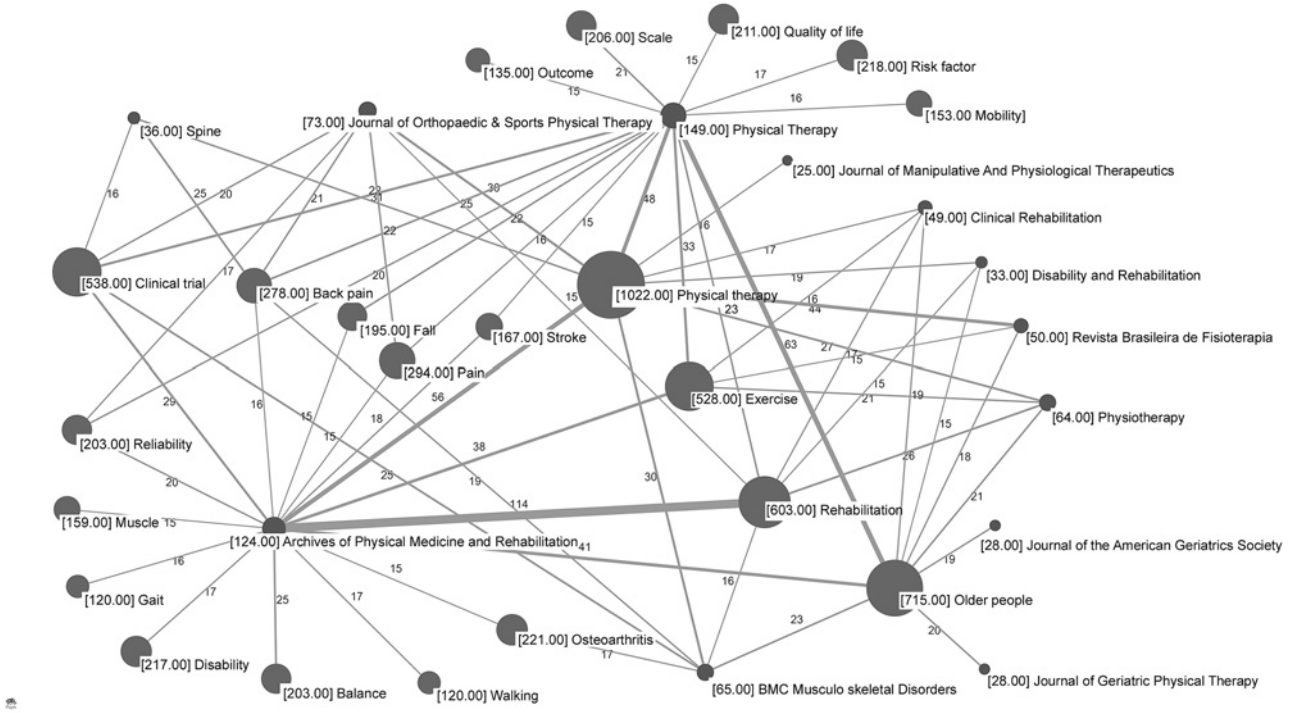

Figure 1.

ductive 2010-2014 and 2005-2009 periods. Scientific journals are the main channel for the dissemination of research results[47,48], the fact that there are more publishing journals in this area confirms that there is a growing scientific interest.

As in previous bibliometric studies on PT[38] or medicine[49], Bradford's distribution was applied showing core journals. Three out of the five most productive journals are considered specific to the area: *Phys Ther*, *JOSPT* and *Physiotherapy*[50-52]. This was also stated in a previous study[53], being the most frequently consulted journals, *Phys Ther* and *JOSPT*.

Despite not being PT specific, other journals such as *Arch Phys Med Rehabil, Clin Rehabil or Spine* have an advantageous position in our results. This may be due to the fact that aging is a multidisciplinary field and this usually allows authors to have various options for publishing[48].

Results show that most of the main journals are published in US, country where most of the highly productive institutions are from. These follows the pattern of other PT bibliometric studies[29,37,55-58]. US is followed by other highly developed countries such as UK or Australia. This is because they are well represented and consolidated in the WCPT[35] and this organization promotes and supports PT research.

In relation to the authors, the highly productive concentrate a high percentage of their articles in three journals, two of which are PT-specific journals (*Phys Ther* and *JOSPT*), while the rest of the articles are dispersed in another forty-three journals.

The journal where highly productive institutions more articles have published has been *BMC Musculoskelet Disord*, followed by *Phys Ther*. *Phys Ther* is considered one of the leading journals of the profession[59], which explains the advantageous position it has obtained. However, *BMC Musculoskelet Disord* does not appear in previous bibliometric analysis. In addition, financial contributions are necessary to publish articles in this journal. All of this may suggest that the most productive institutions have *BMC Musculoskelet Disord* as a "target" in multidisciplinary publications that do not fit into other more PT or aging specific journals.

In relation to impact indicators, other studies[39,60] found that *Arch Phys Med Rehabil* was the most cited publication source. Fell et al.[61] concluded this journal went to a second position regarding the citation, being *Phys Ther* on the first position. It is also the only specific PT journal with 500 or more citations. This indicates that PT research in aging is still closely linked to other areas of rehabilitation that are published in different journals[62].

Journals visibility has been studied by comparing bibliometric indicators[63,64]. Journals with higher IF are also those that have a high h-index. The IF is easy to manipulate with self-citations[65], but the h-Index is difficult to manipulate when its value is relatively high[66], so it can be assumed that the IF of BCJ was not potentially manipulated.

The IF is used to measure the quality of articles and researchers[67,68]. Our results allow PT researchers and professionals to quantify the prestige of scientific journals in order to know where they want to publish their results[54].

There are few previous PT bibliometric works that study the thematic of the journals[35,36]. In our results, the most productive journals have links to significant terms in aging such as: "exercise", "fall", "mobility", "quality of life" or "stroke". This terms, plus others like "walking", "balance" or "risk factor" and the fact that term "exercise" has important links with the two most productive journals (*Phys Ther* and *Arch Phys Med Rehabil*), strengthens the idea that exercise and movement are one of the most promising interventions to attenuate mobility loss[69] and are therefore fundamental in present and future PT aging research. This implicates that clinicians have more scientific evidence in order to use physical activity with their adult patients and help them to age in better conditions[17].

Nevertheless, the current study is not exempt from limitations: only choosing WoS and *Articles* for our analysis. However, WoS Core Collection includes the most important scientific publications in each subject area[70] and *Articles* are considered the most suitable in bibliometric research[21]; furthermore, there are quality problems in the bibliographic data and these are important when analysing authorship, either because the authors themselves do not always sign the papers in the same way or because of errors at processing the information. Finally, aging in population has continued to grow and scientific PT is developing, so further research should consider the following quinquenniums in order to establish further journal productivity trends.

Conclusions

To our knowledge, this is the first bibliometric analysis of PT in aging. Findings on this study have identified the 12 core journals which are considered the most outstanding in the field and, therefore, sought by authors and institutions to publish their work.

The number of publishing journals has increased in every quinquennium and productivity trends provide an indication of the greater scientific interest of PT in aging as a line of research. Collectively, the data indicated that PT-specific journals are being consolidated in terms of productivity and citation but other journals are still a significant research source since aging is a multidisciplinary rehabilitation field.

Finally, the results show that exercise and movement are one of the most outstanding interventions which implicates that clinicians have more scientific evidence in order to use physical activity with their patients and help them to age in better conditions, improve their quality of life and attenuate disability.

Conflict of Interest: The authors declare that there is no conflict of interest.

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