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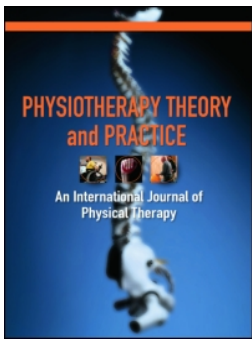
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Mapping the field of physical therapy and identification of the leading active producers. A bibliometric analysis of the period 2000- 2018

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ABSTRACT

Objectives: The objectives of the study were: 1) Describe the thematic structure and evolution of the field of physical therapy; 2) identify the main research producers (i.e. countries and institutions); and 3) compare their research output and citation impact.

Methods: Papers related to physical therapy indexed in Web of Science (2000–2018) were identified to delineate the field, using keywords, journals, and citation networks. VOSviewer software, advanced bibliometric text mining, and visualization techniques were used to evaluate the thematic structure. We collected data about the country and institutional affiliation of all the authors and calculated production and citation impact indicators.

Results: 85,697 papers were analyzed. Eleven thematic clusters were identified: 1) “health care and education”; 2) “biomechanics”; 3) “psychosocial, chronic pain and quality of life outcomes”; 4) “evidence-based physical therapy research methods”; 5) “traumatology and orthopedics”; 6) “neurological rehabilitation”; 7) “psychometrics and cross-cultural adaptation”; 8) “gait-balance analysis and Parkinson’s disease”; 9) “exercise”; 10) “respiratory physical therapy”; and 11) “back pain.” The United States, the United Kingdom, and Australia were the most productive countries. Netherlands, Norway, and Sweden had the highest citation impact.

Conclusions: Our bibliometric visualization approach makes it possible to comprehensively study the thematic structure of physical therapy. The ranking of producers has evolved and now includes China and Brazil. High research production does not imply a high citation impact.

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Bibliometrics; physical therapy; thematic structure; scientific production; scientific impact



Introduction


Bibliometrics in Physical Therapy

Bibliometrics is a research area that applies mathematical and statistical methods to study quantitative data from scientific publications (i.e. papers, books, and conference proceedings) and their citation links in order to study the impact of science as well as the mapping of scientific fields (Moed, Glänzel, and Schmoch, 2005; van Raan, 2019). Bibliometric studies focus on the analysis of the scientific output (i.e. the analysis of the number of publications produced by a research unit, like a university or a researcher) and their impact (i.e. number of citations that these publications have received) (Aksnes, Langfeldt, and Wouters, 2019). Although there is an ongoing debate about the real meaning of impact and its quantification, citations are often considered to provide

a measure of global scientific impact, which in turn is seen as a proxy for scientific quality, relevance and visibility (van Raan, 2019; Waltman, 2016).

Bibliometric methods have been applied to the study of the field of physical therapy in the past, including the identification of its core journals (Bohannon, 1987, 1999; Bohannon and Roberts, 1991; Costa et al., 2010; Maher, Moseley, Sherrington, and Herbert, 2001; Sewerniak, 1997; Vernaza-Pinzón and Álvarez-Bravo, 2011; Wakiji, 1997); the definition of its intellectual structure (Martínez-Fuentes et al., 2014); the identification of the bibliometric features of international and national journals in physical therapy (Coronado, Riddle, Wurtzel, and George, 2011; Coronado et al., 2011; Baño Aledo ME and Mirapeix, 2006; Kelly et al., 2018; Kuhlemeier, 1992; Martínez-González and Gómez-Conesa, 2003; Simon et al., 2014; Wiles, Matricciani, Williams, and Olds, 2012) or the

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geographical distribution of the authors of randomized clinical trials (RCTs) (Larsson, 2018). Bibliometric indicators have been used to study the factors affecting the citation impact of RCTs (Paci, Landi, Briganti, and Lombardi, 2015), or to compare the scientific output of physical therapy researchers in Brazil (Sturmer et al., 2013) and Italy (Vercelli, Ravizzotti, and Paci, 2018). However, there are still important gaps in the bibliometric literature around physical therapy: the systematic analysis of the dynamism involved in the discipline, its scientific evolution, its present status, and the definition and study of its thematic structure.

Studying the thematic structure of physical therapy

The research area of physical therapy has experienced a continual growth over the years, fueled especially by the expansion of post-graduate programmes during the 1980s (Nicholls, 2018) and the exponential increase of its research production (Benton and Benton, 2019; Moral-Munoz, Arroyo-Morales, Herrera-Viedma, and Cobo, 2018; Moseley, Elkins, van der Wees, and Pinheiro, 2019). Such expansion of the area makes it extremely difficult to obtain a comprehensive overview of the overall physical therapy-related scientific literature due to the increasing thematic diversity and multidisciplinary development. Despite these difficulties, in this study we have performed an advanced bibliometric study in order to systematically analyze the research area of physical therapy.

With this purpose in mind, it is paramount to first delineate the field and identify its thematic structure – which is defined by its shared conceptual systems as expressed through the terminology used within the discipline (Milojevic, Sugimoto, Yan, and Ding, 2011). This terminology can be captured by the most frequently used terms in the scientific literature of the field of knowledge. By applying bibliometric techniques, these terms can be grouped into specific research lines visible in semantic maps. Semantic maps, often known as co-word maps, have been used to identify and understand the thematic structure of different fields of science (Börner, Chen, and Boyack, 2003; Gläser, Glänzel, and Scharnhorst, 2017; Milojevic, Sugimoto, Yan, and Ding, 2011; Munoz-Ecija, Vargas-Quesada, and Chinchilla-Rodríguez, 2017). In technical terms, co-word analyses are based on the co-occurrence of the words from the titles, abstracts, or text in general extracted from the scientific publications of the field under study (Callon, Courtial, Turner, and Bauin, 1983).

Although co-word analyses have been previously used to study physical therapy (Benton and Benton, 2019; García Ríos, Moreno Lorenzo, Ruíz Baños, and Bailón Moreno, 2010; Moral-Munoz, Arroyo-Morales, Herrera-Viedma, and Cobo, 2018) these studies were based on conventional approaches (e.g. keyword delineation of the area) which present strong limitations in order to identify other latent areas in physical therapy (Zitt, 2015; Zitt and Bassecouard, 2006). In this study we apply a more sophisticated method to delineate the field of physical therapy, by uniquely combining semantic and citation-based approaches, which allow for a more comprehensive insight into the thematic structure of the field.

Moreover, to the best of our knowledge, a large-scale study of this type regarding the countries and institutions that are involved in physical therapy research, has not yet been conducted. Considering our large-scale scope, we also intend to provide a global identification of the most prominent actors (i.e. countries and institutions) in the field. The main aim of this study is to identify the thematic structure of the field of physical therapy by applying advanced bibliometric methods. The following sub-objectives are proposed to: 1) Describe the temporal evolution of the most important topics researched in physical therapy in the period 2000–2018; 2) Identify the main producers (i.e. countries and institutions), conducting research in physical therapy, and their thematic specialization; and 3) Compare the production and citation impact of the main producers.

Methods

Data collection

This study uses data from Web of Science (WoS), which is an international bibliographic database produced by Clarivate Analytics that indexes more than 20,000 mainstream scientific journals. Although there are other comprehensive scientometric databases currently available (Martín-Martín, Thelwall, Orduna-Malea, and Delgado López-Cózar, 2021; Visser, van Eck, and Waltman, 2021) Web of Science has a good coverage of the medical literature, and is one of the most used data sources for advanced bibliometric analyses due to its precise and complete metadata (Guerrero-Bote, Chinchilla-Rodríguez, Mendoza, and de Moya-Anegón, 2021; van Eck et al., 2013; Visser, van Eck, and Waltman, 2021). More specifically, we used the in-house version of WoS available at the Center for Science and Technology Studies (CWTS, Leiden University, Netherlands). This institution cleans and extensively harmonizes bibliometric data for advanced analytical purposes

(Waltman et al., 2012) which enables the identification of all the affiliations (i.e. institutional and geographical) of all the authors of the papers under study, and not just the first author. It also allows us to use a unique publication-level classification system (Waltman and van Eck, 2012) which is currently being implemented by WoS in its analytical services (Potter, 2020). These two features are key for this study. The precision and the reliability of the data and indicators used should be highlighted (Waltman et al., 2012).

We selected papers published in the period 2000–2018. The selection of this period is justified since for a robust citation analysis it is necessary to count on at least one full year after the last publication year in order to reliably count the citations for all the papers under study (Waltman, 2016). That means we used citation data until December 2019, for the set of publications published in the period 2000–2018. We decided not to include the year 2020 due to the potential effect of the COVID-19 pandemic on the thematic analysis proposed in this study. Arguably, it could be expected that the COVID-19 pandemic has radically changed the overall dynamics of scientific citation, and publication (Aviv-Reuven and Rosenfeld, 2021; Callaway, 2020) not only in science in general but also in the health sciences and in physical therapy in particular. From this viewpoint, this paper is deliberately taking a pre-pandemic perspective, setting the scene for future research in which the potential effects of the pandemic could be compared with the pre-pandemic period, particularly once the pandemic has finally settled down.

Delineation of physical therapy

In order to achieve the proposed objectives, first a delineation of the physical therapy field was carried out. The following two-step process (Zitt and Bassecoulard, 2006) has been applied in order to identify all the articles and reviews in the WoS that can be related to physical therapy:

Identification of the core set of papers in physical therapy

An initial group of core keywords have been used to identify a primary set of papers related to physical therapy: “physiotherapy,” “physical therapy,” “manual therapy,” “therapeutic exercise” and “exercise therapy.” Papers carrying any of these terms (in their titles, abstracts, and keywords) were considered as the *core set*, since all of them can be unambiguously

considered as belonging to physical therapy. These keywords were selected after being discussed with three experienced academic physiotherapists. We also truncated these keywords to collect all their variations.

Expansion of the initial set through journals and citation-based micro-fields

Despite the use of different keywords, not all papers related to physical therapy necessarily include those keywords mentioned above. In order to expand the initial core set, the following additional steps (Zitt, 2015) have been performed.

Journal expansion

The journals in which papers from the core set were published were analyzed. Firstly, from this set of journals, all those containing “physiotherapy” or “physical therapy” in their title were considered. Secondly, those journals with at least 25% of their papers coming from the core set were also identified. All the papers from those journals meeting at least one of these two criteria were collected and incorporated in the study.

Micro-Field expansion

Micro-fields are groups of papers connected by citation network relations and identified algorithmically, resulting in an advanced and fine grained publication-level classification system (Waltman and van Eck, 2012). By using this publication-level classification system -composed of 4,535 micro-fields- we can identify papers that are not identifiable through the keyword or journal based search strategies (Milanez, Noyons, and de Faria, 2016) described above, but that can be considered as being part of the physical therapy realm since they have a strong citation and conceptual relationship with the core set of papers. Specifically, we identified all micro-fields containing at least one paper from the core set, and we calculated the percentage of these papers within each of the micro-fields identified.

The identified micro-fields were manually checked for inclusion by examining their five most relevant keywords (algorithmically extracted from their titles and abstracts) as well as their five most relevant journals (Waltman and van Eck, 2012). All the papers from the included micro-fields were added to the previously identified sets.

Identification of main producers (actors) in physical therapy

Based on the expanded set of papers, the institutional and country affiliations of their authors were identified. Institutional names were harmonized based on the information of the Leiden Ranking database (Centre for Sciences and Technology Studies, 2020; Waltman et al., 2012). A full counting method (Waltman et al., 2012), which gives full weight to all actors in the paper (i.e. institutions or countries) was applied for the calculation of publications and average impact of the institutions and countries. Thus, if one paper has authors from more than one country, the paper fully counts for each of the countries. The following indicators were calculated: 1) Publication output (P): count of the total number of papers of a given country or institution; and 2) Mean Citation Score (MCS): measured as the number of citations excluding author self-citations that a specific country/ institution received until 2019, divided by its total number of papers (P).

Analysis of the main thematic structure in physical therapy

In order to understand the configuration of the research field, the thematic structure in physical therapy was studied algorithmically, by identifying the most important topics in the field. Topics are clusters of terms determined by a co-word analysis of the titles and abstract of the papers identified. These clusters of terms were extracted and selected using the VOSviewer software (version 1.6.11). VOSviewer is a free software to create, visualize and explore bibliometric networks, being particularly useful for visualizing the thematic structure of scientific disciplines (van Eck and Waltman, 2014). The software uses the following steps in order to create a term map (van Eck and Waltman, 2011).

1. Identification of nouns and noun phrases (nouns and adjectives) from the titles and abstracts, and the conversion of plural nouns into singular.
2. Selection of noun phrases based on their relevance, algorithmically calculated, which removes general words not related to one specific topic that can distort the structure of the map. Each relevant noun phrase or word is considered a term. After this step, we developed a thesaurus to account for the language inconsistencies of the terms (Cobo, López-Herrera, Herrera-Viedma, and Herrera, 2011) (e.g. homonyms and synonyms) and selected the final set of terms.

3. Mapping and clustering of the terms. Each term was represented by a node in a two-dimensional map. The location of each node was defined by the visualization of similarities mapping technique, where the distance between nodes indicates their relatedness. The more related they are, the closer they are located. The size of the nodes represents the occurrence frequency of the terms. In this study, we selected terms that appear in at least 250 papers. We chose this value after different trials with other co-occurrence values (i.e. 50, 100, 150, 200, and 500) we manually tested, in order to achieve a clear visualization.

4. Visualization of the mapping and clustering results. VOSviewer software grouped the terms into thematic clusters so that the most important topics could be visualized in different groups which indicate the cluster to which a node has been assigned. Each thematic cluster can be considered as a topic.

Six physiotherapists with different areas of expertise independently interpreted the initially obtained thematic map. These 6 interpretations were discussed by 2 authors until consensus was achieved. The reliability of this validation method is commented on here (Ahlgren, Pagin, Persson, and Svedberg, 2015; Calero-Medina and Noyons, 2008; van Eck and Waltman, 2014).

Temporal evolution of the thematic structure in physical therapy

The publication years of each of the papers identified were analyzed in order to calculate the *mean publication year* of each term (i.e. the average publication year of the papers carrying a given term). The visualization of the mean publication year for the different terms and topics allows for the identification of thematic trends during the period of analysis.

Country Thematic Specialization Analysis

The thematic specialization of countries was analyzed by creating a new score assigning weights based on the number of papers from a particular country using a specific term. We used R software -version 3.6.1 packages dplyr and ggplot2 (<https://www.R-project.org/>) a free software environment for statistical computing and graphics to carry out the statistical analysis and to generate the graphs related to production and impact (Wickham, 2016; Wickham, François, Henry, and Müller, 2020).

RESULTS

Delineation procedure

A total of 27,558 papers were identified in the first step, which was the identification of the core set of papers using keywords. Following the methodology explained in the journal expansion set, a total of 2,789 journals were identified, from which we included 16 journals (Supplemental File 1), adding 12,332 papers. Finally, a total of 1,134 micro-fields were identified as having at least one paper from the core set. We included 13 micro-fields (Supplemental File 2) adding 60,150 papers, reaching a final expanded set of 85,697 different articles and reviews (27,558 coming from the core set, 12,332

coming from the journal expansion, and 60,150 coming from the micro-field expansion), that can be considered as representing the field of physical therapy (Figure 1).

Thematic structure of physical therapy

The VOSviewer analysis of the terms from the titles and abstracts of papers revealed eleven thematic clusters (topics), illustrated in Figure 2: 1) “health care and education”; 2) “biomechanics”; 3) “psychosocial, chronic pain and quality of life outcomes”; 4) “evidence-based physical therapy research methods”; 5) “traumatology and orthopedics”; 6) “neurological rehabilitation”; 7) “psychometrics and cross-cultural

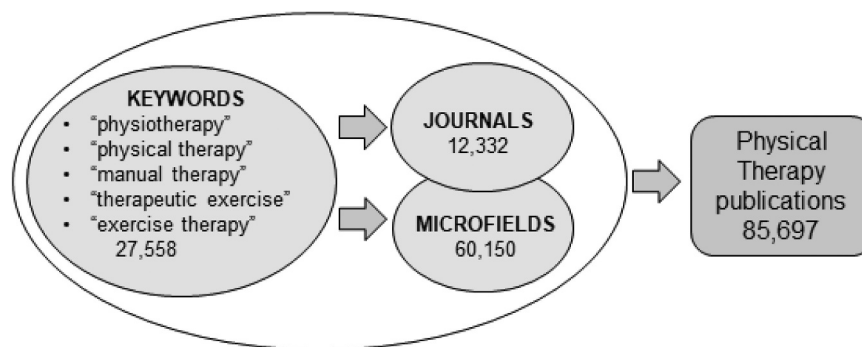


Figure 1. Delineation of the physical therapy field.

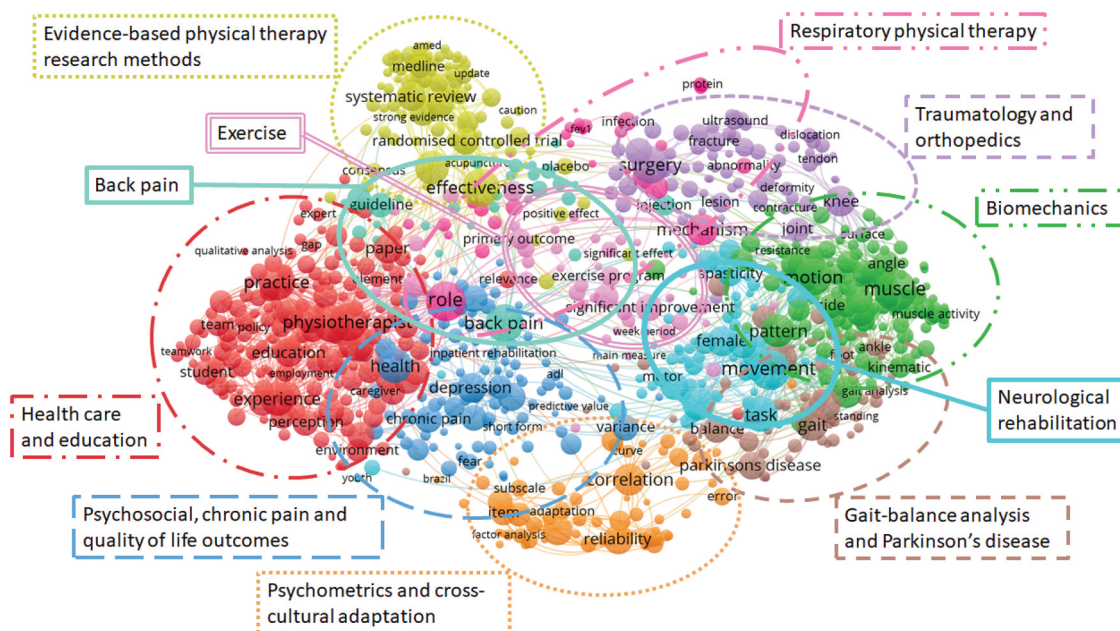


Figure 2. Thematic structure of the physical therapy discipline. Term map indicating eleven thematic clusters of terms (topics). Each node of the network represents a term wherein: 1) the size of the node indicates the occurrence of the term (i.e., the number of times that the term occurs); 2) the distance between nodes indicates their relatedness (i.e., the more related the terms, the closer they are located); and 3) each node is included within a labeled ovoid indicating the thematic cluster to which it has been assigned.

adaptation”; 8) “gait-balance analysis and Parkinson’s disease”; 9) “exercise”; 10) “respiratory physical therapy”; and 11) “back pain.”

Eight of the eleven thematic clusters relate to different areas of physical therapy practice. Two other thematic clusters are related to specific research methods in the field (i.e. “evidence-based physical therapy research methods” and “psychometrics and cross-cultural adaptation”). The last one relates to “health care and education,” referring to the education of both health professionals and patients.

It is relevant to note the disposition of thematic clusters in the map, knowing that the closer, the more related they are in the articles analyzed. Thus, on the left side of the map we find the topic of “health care and education” slightly mingled with “psychosocial, chronic pain and quality of life outcomes,” and “back pain.” Also visible in the map is the proximity of the thematic cluster of “back pain” to that of “exercise.” On the right side of the map there are topics related to “biomechanics,” “traumatology and orthopedics” and “neurological rehabilitation.” The last one is touching the thematic cluster of “exercise” and the one related to Parkinson’s disease. The thematic cluster of “respiratory physical therapy” appears closer to the topic of “exercise.” Finally, thematic clusters related to methods are located in opposite places in the map: “evidence-based physical therapy methods” appears at the top while “psychometrics and cross-cultural adaptation” appears at the bottom.

Regarding the temporal evolution of the topics, Figure 3 shows a clear recent trend in the number of papers related to the cluster of “evidence-based physical therapy research methods,” since most of the terms in this cluster are often used in publications from recent years. Figure 3b shows the mean number of citations

received by each term. Again, the terms related to the thematic cluster of evidence-based physical therapy research methods are among the most cited ones, together with some other terms related to back pain, exercise, and chronic pain in the central part of the map.

Main producers in physical therapy

A total of 156 countries contributed to the 85,697 papers identified and a total of 2,061 institutions producing more than 5 papers in physical therapy were identified. The countries that have contributed most to research in physical therapy in the period 2000–2018 are in decreasing order: 1) United States; 2) United Kingdom; 3) Canada; 4) Australia and 5) Germany. Table 1 shows the list of the 20 most productive countries ranked by the number of papers along with the ranking of these countries regarding the impact measured by the mean citation score.

The temporal evolution physical therapy research production of countries shows a general growth, which is exceptional in the case of China and Brazil, 5th and 7th respectively in the ranking of producers in the last year of the analysis. Both countries experienced a growth of around 3000% from 2000, with 2007 (Brazil) and 2008 (China) as the landmark years for this change.

Regarding the institutions, the five most productive institutions were: 1) University of Sydney (1,646 papers, 1.9% of the total); 2) University of Toronto (1,557 papers, 1.8%); 3) University of Queensland (1,498 papers, 1.7%); 4) VU University of Amsterdam (1,326 papers, 1.5%); and 5) Karolinska Institute (1,038 papers, 1.2%). The University of Washington, Harvard University, and Maastricht University had a higher impact per paper. In general, a higher mean citation

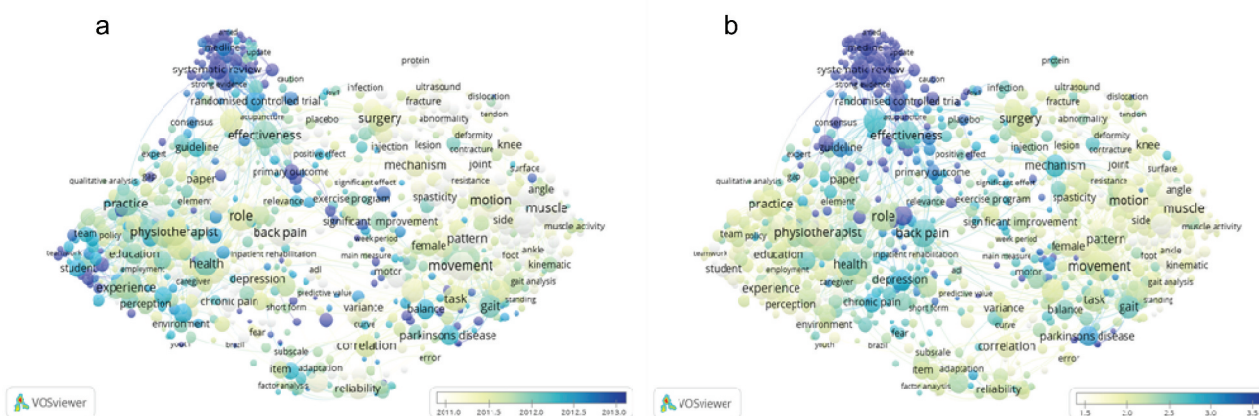


Figure 3. Term map.

(a) Color indicates the mean publication year in which a term was used. Terms used from 2012 onwards are shown in dark color, while terms more used before 2011 are shown in bright color. (b) Color indicates the mean number of citations received by a term. The most cited terms are shown in dark color.

impact is not necessarily linked to higher productivity (Butler, 2003) for both countries and institutions (Figures 4 and 5). Within the most productive countries, the Netherlands, Norway, Sweden, Denmark and the United Kingdom are those with the highest average impact per paper.

Regarding the thematic specialization by country, some countries are highly specialized in one or two thematic clusters. For example, the United Kingdom, Australia, and the Netherlands have a strong focus on “health care and education” and “evidence-based physical therapy research methods.” Germany focuses quite substantially on “traumatology and orthopedics.” The Republic of Korea has a strong focus on “biomechanics,” and Japan on both of the latter. There are also countries like the United States and Canada, which are more evenly specialized across different thematic clusters.

DISCUSSION

Main findings of the study

This study aimed at identifying the thematic structure of the field of physical therapy, its main research producers (i.e. countries and institutions) and their development over time, by means of an advanced bibliometric methodology. We have identified eleven main thematic clusters (i.e. topics). The analysis of the temporal evolution of these topics reveals an increase in the scientific production related to “evidence-based physical therapy research methods.” This suggests an important move

within the research community in physical therapy toward the use of systematic reviews and RCTs study designs which are basic in: 1) evidence-based physical therapy implementation (World Confederation for Physical Therapy – European Region, 2015); and 2) the improvement of clinical practice (Benton and Benton, 2019). This topic is also the most cited showing a larger scientific impact of these research designs.

Regarding the production of the countries, the rapid growth of China and Brazil could be explained by their policies to increase their research funding and international collaboration (Gonzalez-Brambila, Reyes-Gonzalez, Veloso, and Perez-Angon, 2016). This increase is especially remarkable in China, where physical therapy is still not a well-developed profession (Jones and Skinner, 2013). Finally, the average impact of the countries, may have been affected by their specialization. Germany and the Republic of Korea are two very productive countries in the field, but they are strongly specialized in two thematic clusters with a declining interest in production. This fact could explain their relative lower impact (i.e. they produce on topics that are no longer among the most relevant for other colleagues, who seem to focus more now on the topic of “evidence-based physical therapy research methods”). The strong focus of Australia and the Netherlands on this thematic cluster could also help to explain the higher average impact of the production from these countries.

Strengths and weaknesses in relation to previous studies

To the best of our knowledge, this study is the most comprehensive delineation and identification of topics in the physical therapy field; not only for the size of its sample of identified articles, but also for the advanced methodology applied in the delineation and analysis of the publications. There are few studies about the thematic structure of physical therapy using co-word analysis and visualization methods. Benton and Benton (2019) analyzed around 42,000 papers in two different periods also using VOSviewer. Some topics found in the period 2008–2017 are similar to our findings: those including terms concerning psychometrics, respiratory physical therapy, and evidence-based practice. Differences may be due to their choice of Scopus as data source, which has a different coverage to WoS. Different to ours, Benton and Benton (2019) only used keywords for the field delineation of physical therapy, and such an approach was also applied by García Ríos, Moreno Lorenzo, Ruíz Baños, and Bailón Moreno (2010), who also found topics related to “back pain,”

Table 1. 20 Most productive countries and ranking by productivity and impact in the period 2000–2018.

Country	P	Ranking Production	MCS	Ranking Impact
United States	24,960	1	22.75	7
United Kingdom	9,335	2	24.73	5
Australia	7,886	3	21.50	8
Canada	7,567	4	24.44	6
Germany	5,351	5	16.37	14
Netherlands	4,721	6	28.77	1
Brazil	3,494	7	10.03	18
Republic of Korea	3,314	8	6.79	20
Japan	3,150	9	11.85	16
Sweden	2,995	10	24.88	3
Italy	2,906	11	19.02	12
China	2,786	12	11.56	17
Spain	2,282	13	16.63	13
France	2,258	14	19.31	11
Belgium	2,038	15	21.14	9
Turkey	1,986	16	9.06	19
Switzerland	1,814	17	19.49	10
Denmark	1,518	18	24.75	4
Norway	1,420	19	27.32	2
Taiwan	1,362	20	16.04	15

P—publication output (i.e., number of articles per country); MCS—mean citation score (i.e., number of citations received by a country divided by the papers of the country; Ranking production—position of the country within the list of most productive countries; Ranking impact—position of the country ordered by MCS value within the 20 most productive countries.

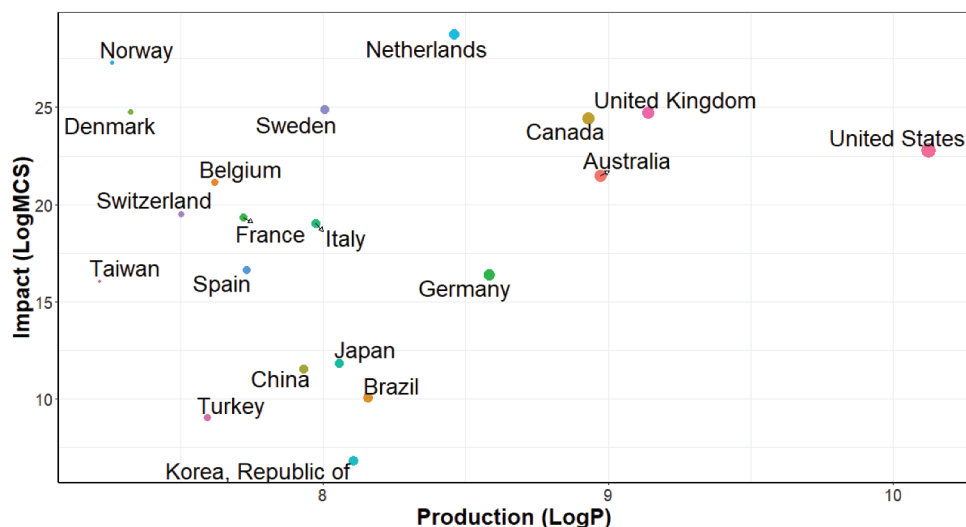


Figure 4. Relation between productivity and impact of the 20 most productive countries. Production data have been transformed to a logarithmic scale due to their skewed distribution, in order to improve the visualization.

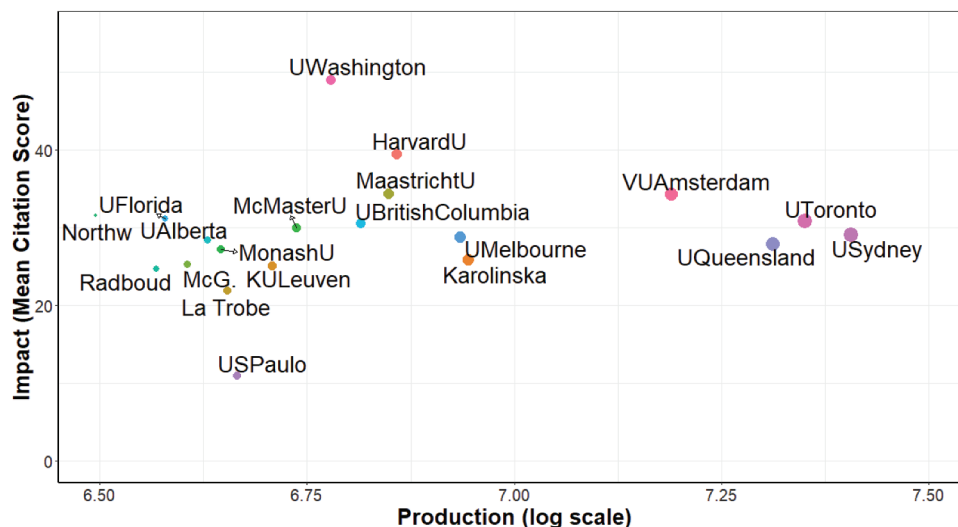


Figure 5. Relation between productivity and impact of the 20 most productive institutions. Production data have been transformed to a logarithmic scale due to their skewed distribution, in order to improve the visualization.

“stroke,” “knee” and “gait,” even though the temporal overlap regarding our study is of only five years. Moral-Munoz, Arroyo-Morales, Herrera-Viedma, and Cobo (2018) used a field delineation based only on journals to study physical therapy in the period 2001–2013, identifying thematic clusters such as “psychometrics,” “education,” “evidence-based practice,” “pain” and “biomechanics,” that partially coincide with our results.

Milanez, Noyons, and de Faria (2016) and Zitt (2015) claimed that the use of only keywords and journals (Benton and Benton, 2019; García Ríos, Moreno Lorenzo, Ruíz Baños, and Bailón Moreno, 2010; Moral-Munoz, Arroyo-Morales, Herrera-Viedma, and Cobo,

2018) is a less precise approach for field delineation, typically implying a lower recall potential compared to our approach. Two reasons explain this lower recall potential: 1) not all papers about physical therapy necessarily contain any of the selected terms, and 2) these papers are published in many different journals, sometimes also multidisciplinary journals (e.g. PloS One, Nature, Science, etc.).

Regarding the identification of the main producers in physical therapy, Larsson (2018) analyzed a sample of 2,959 clinical trials published in the period 2015–2016 indexed in the Physiotherapy Evidence based Database (PEDro). Larsson only identified the country affiliation

of the first and last author of each trial, while in our study we identified the country and institutional affiliation of all the authors of the analyzed papers. This is a strong advantage of our study to better capture the real scenario of producers in the context of increasing international collaboration dynamics (Wiles, Matricciani, Williams, and Olds, 2012). Both studies show that the United States is the main producer, and twelve countries are coincident within the fifteen most productive, but not in the same order. This is not unexpected considering the different periods, approaches and databases analyzed. The different nature of the research reported in the analyzed papers is also important, as our study includes also qualitative and observational studies and not only clinical trials. This inclusion is important to reflect the real status of the overall landscape of research in physical therapy (Jette, Delany, and Lundberg, 2019).

Significance and contribution of the current study

This bibliometric study, through data-mining and visualization techniques, demonstrates that an advanced bibliometric methodology is effective in improving the understanding of a complex research field (Börner, 2010) such as physical therapy. We have applied knowledge from social sciences to biomedical sciences, providing a picture with a comprehensive overview of our field (Thijs, 2019). It can be used for the monitoring and evaluation of the evolution of the dynamics of thematic structure (i.e. topics) and its producers (i.e. countries and institutions), enabling future comparisons and further analyses about the drivers of disciplinary dynamics visualized. This is especially relevant in a moment of history when the COVID-19 pandemic has had a disruptive impact on the citation and publishing dynamics in every field of science (Callaway, 2020; Else, 2020), but especially on biomedical sciences (Aviv-Reuven and Rosenfeld, 2021).

Bibliometric studies typically represent fundamental first steps to the analysis, reflection and development of future strategies in a discipline (Noyons, 2001; Noyons and Calero-Medina, 2009; Thijs, 2019). One example of the usefulness of the information about topics is that it can assist policy makers and researchers in the identification of gaps of knowledge in the current scientific landscape, supporting the development of new research lines and priorities. It also enables the assessment of whether research is adjusted to societal health needs, comparing the topics we find with the burden of diseases (Cassi et al., 2017; Yegros-Yegros, van de Klippe, Abad-Garcia, and Rafols, 2020). For that purpose, the identification of productive countries is paramount, as the

most powerful ones can set trends in research and introduce geographical biases in physical therapy research (Kowal, Sorokowski, Kulczycki, and Żelaźniewicz, 2022). Moreover, the identification of leading countries and organizations enables the study of the features that are behind their success. Such features can be related to funding, collaboration and mobility policies, methodological quality of research, composition of research teams in terms of age, experience and gender, or even human and social capital of researchers (Aksnes, Langfeldt, and Wouters, 2019; Abramo, D'Angelo, and Di Costa, 2018; Habicht, Lutter, and Schröder, 2021; Sugimoto et al., 2017). All these aspects can be studied in relation to research production and scientific impact by means of bibliometric approaches. Policy makers can then extract bibliometric evidence to support research policies oriented toward the promotion of collaboration with those countries or organizations who are leading the field, in order to increase their own production or impact (Sugimoto et al., 2017). Besides, as impact is not always related to production, policy makers could use this information to change their research evaluation policy, in order to promote other scientific and societal values instead of mere productivity, such as methodological quality, socially relevant research, gender equity or diversity in scientific workforce (Habicht, Lutter, and Schröder, 2021; Sugimoto and Larivière, 2019; Yegros-Yegros, van de Klippe, Abad-Garcia, and Rafols, 2020). An increase in diversity can change the focus of the topics of research and the way of reporting information in articles, all of which impact clinical practice (Sugimoto et al., 2019). Funding allocation policies can be also informed by this kind of study, which is especially relevant as funding can substantially change research agendas and thematic profiles (Mitchell, McClure, Olivier, and Watson, 2009). Furthermore, policy makers can use studies like ours to create a benchmark and test the results of the new policies.

Finally, the advanced methodology adopted in this study establishes an analytical framework for the thematic structure of physical therapy (Zitt and Bassecoulard, 2006), incorporating a novel publication-level classification approach to supplement other more traditional keyword and journal-based approaches to comprehensively delineate the field. The relevance of such incorporation must be noted, since this type of publication-level classification approach is currently being adopted by Clarivate (the producer of Web of Science (<https://clarivate.com/blog/introducing-citation-topics/>)) suggesting that other bibliometric data providers (e.g. Dimensions, Scopus, or OpenAlex) could potentially also incorporate these tools

in the future development of their databases. Therefore, these types of publication-level classification approaches will arguably become more prominent in the near future for the delineation of academic fields and topics. Our study therefore represents the very first attempt at using and incorporating such approaches in the study of physical therapy.

Future research

Upcoming research could address questions like the relation between the output and the impact of the research of countries to the size and features (e.g. gender and age) of their workforce -in terms of clinicians and researchers- and to their funding. Particularly relevant would be the study of how funding and research policies relate to the level of specialization of countries. Another research question for future inquiry is how these findings would relate when compared to a physical therapy specific database (e.g. Physiotherapy Evidence Database- PEDro). Finally, a broader definition of impact rather than just citation analysis will be required in this field due to the increasing interest in translational research in health sciences.

Limitations

Despite the important strengths of our methodology, there is no unique and agreed way to delineate and visualize fields of knowledge (Gläser, Glänzel, and Scharnhorst, 2017), so we followed the recommendation of combining bibliometric network visualizations with expert judgment. When experts and visualizations are in agreement and point in the same direction, they corroborate each other (van Eck and Waltman, 2014). Another limitation is the database we used, as WoS is mostly focused on articles published in English (Mongeon and Paul-Hus, 2016). Also, VOSviewer only recognizes terms in English, so we used the English translations of the title and abstract in the co-word analysis, provided by the publishing journal, for those papers written in other languages. Moreover, despite the sophisticated methodology employed in the field delineation, it is of course possible that some articles related to physical therapy could still be missing. Finally, this kind of study cannot explain drivers behind some of the dynamics and patterns that we have shown (e.g. reasons for the particular specialization of countries) which would require dedicated approaches to delve into them.

Conclusion

Our advanced bibliometric delineation and visualization approach makes possible the study of the thematic structure in physical therapy, unveiling eleven main topics in the field. The topic with the strongest increase in production is the one related to “evidence-based physical therapy research methods,” which is also the topic attracting most attention from the scientific community, as captured by the high number of citations. The main producers in the field of physical therapy are located in Northern Europe and North America, but this dynamic is changing, with countries like China and Brazil rapidly catching up. The degree of thematic specialization of countries varies substantially, with some countries exhibiting a strong focus on some topics (e.g. Germany and Republic of Korea) while others maintain a more diverse research profile in the field (e.g. US and Canada). The most productive countries and institutions are not necessarily related to a high average citation impact.

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