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### **Citation**

Carballo-Costa, L., Michaleff, Z. A., Costas Comesana, R., Quintela-Del-Rio, A., Vivas-Costa, J., & Moseley, A. M. (2022). Evolution of the thematic structure and main producers of physical therapy interventions research: a bibliometric analysis (1986 to 2017). *Braz J Phys Ther*, 26(4). doi:10.1016/j.bjpt.2022.100429

Version: Publisher's Version

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**Note:** To cite this publication please use the final published version (if applicable).

## ORIGINAL RESEARCH

## Evolution of the thematic structure and main producers of physical therapy interventions research: A bibliometric analysis (1986 to 2017)



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Received 25 October 2021; received in revised form 12 April 2022; accepted 28 June 2022

Available online 12 July 2022

### KEYWORDS

Bibliometrics;  
 PEDro database;  
 Physical therapy;  
 Scientific impact;  
 Scientific production;  
 Thematic structure

### Abstract

**Background:** Bibliometric studies are used to analyse and map scientific areas, and study the scientific output and impact of institutes and countries.

**Objectives:** Describe the thematic structure and evolution of the field of physical therapy interventions using articles indexed in Physiotherapy Evidence Database (PEDro). Also, identify and compare the main producers (countries, institutions) over time (research output, citation impact).

**Methods:** Eligible articles were those indexed in PEDro (1986-2017) and matched to Web of Science. VOSviewer software, bibliometric text mining, and visualisation techniques were used to evaluate the thematic structure of the included articles. We collected data about authors' country and institutional affiliation, and calculated bibliometric indicators (production, citation impact).

**Results:** A total of 29 090 articles were analysed. Eight topics were identified: "neurological rehabilitation"; "methods"; "exercise for prevention and rehabilitation of lifestyle diseases"; "assessment and treatment of musculoskeletal pain"; "physical activity", "health promotion and behaviour change"; "respiratory physical therapy"; "hospital, primary care and health economics"; "cancer and complementary therapies". The most productive countries were United States, United Kingdom, Australia, and Canada. The most impactful countries were United

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States, France, Finland, and Canada. The most productive institutions were University of Sydney, VU University of Amsterdam, University of Queensland, and University of Toronto.

*Conclusions:* The thematic structure of physical therapy interventions has evolved over time with “neurological rehabilitation”, “methods”, “exercise related to lifestyle diseases”, and “physical activity” becoming increasingly important. Main producers of this research were traditionally located in North America and Europe but now include countries like China and Brazil.

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## Introduction

Bibliometric research focuses on the analysis of quantitative data extracted from scientific publications to study science dynamics and research performance.<sup>1</sup> One of the strongest values of bibliometric studies is that they can be used to assess, analyse, and map scientific areas, and compare the scientific output and impact of researchers, institutes, countries and research fields.<sup>1</sup>

Bibliometric methods have been used to study the fields of rehabilitation and physical therapy, reporting an exponential growth in the number of scientific publications in both fields.<sup>2-5</sup> The most cited articles<sup>6</sup> and publication trends in rehabilitation<sup>7</sup> have also been evaluated. For physical therapy, a profession that makes a substantial contribution to the field of rehabilitation and has strong foundations in evidence-based practice, bibliometric studies have focused on identifying the core journals,<sup>8,9</sup> and the countries and institutions publishing this research.<sup>4,10</sup>

The thematic structure of a field can be defined by shared conceptual systems as expressed through terminology used within the field,<sup>11</sup> with groups of identified concepts clustered into topics. Four previous studies<sup>4,12-14</sup> have attempted to describe the thematic structure of physical therapy using different delineation methodologies: one study focused on journals to delineate the research in physical therapy,<sup>13</sup> while others delineated the field of physical therapy by identifying keywords related to the field.<sup>4,12</sup> The main limitation of these previous approaches is that they fail to create a comprehensive delineation of the thematic structure of a knowledge field, particularly regarding the broad identification of the whole spectrum of articles related to the field.<sup>15</sup> We recently addressed this limitation by conducting a high-quality delineation of physical therapy<sup>14</sup> based on keywords, journals, and citation analysis in Web of Science,<sup>16</sup> but validation using an independent data set is required.

In this study we aim to describe the thematic structure of physical therapy using the Physiotherapy Evidence Database (PEDro). The use of PEDro presents two advantages for this bibliometric analysis: first, it is the largest and most comprehensive physical therapy research interventions specific database developed by experts.<sup>17,18</sup> Secondly, PEDro has strict eligibility criteria, indexing only randomised controlled trials, systematic reviews, and evidence-based clinical practice guidelines.<sup>19</sup>

This study aimed to use bibliometric methodology to describe the thematic structure of the field of physical therapy interventions using a pool of articles indexed in PEDro. Specifically, we aimed to identify the most important topics

covered in PEDro for the period 1986 to 2017 and determine how the thematic structure has evolved across three periods: 1986 to 1997, 1998 to 2007, 2008 to 2017. A secondary aim was to identify which countries and institutions publish physical therapy interventions research, and compare the main producers over time in terms of their research output and citation impact.

## Methods

### Study design and defining the pool of eligible articles

This bibliometric study was conducted in PEDro and included only randomised controlled trials, systematic reviews, and clinical practice guidelines. Each article from PEDro was linked to the in-house version of Web of Science database, from here on referred to as Web of Science, to retrieve the citation and affiliation metadata (countries, institutions). The matched articles in the two databases formed the pool of eligible articles which were then used to describe the thematic structure of the physical therapy field. The criteria for inclusion were: (1) published in the period 1986 to 2017 (to enable a comparison among three equal time periods); (2) published in a peer-reviewed journal; (3) completed the indexing process in PEDro (i.e., confirmation of eligibility, allocation of indexing codes and, for trials, rating using the PEDro scale); and, (4) each article extracted from PEDro needed to be matched with Web of Science database.

### PEDro database

The PEDro database was selected because of its completeness in indexing articles reporting physical therapy interventions. Articles are identified for inclusion in PEDro through the use of sensitive searches of other bibliographic databases (Medline, Embase, CINAHL, AMED, Cochrane Library), citation tracking of indexed systematic reviews, guideline websites, and communication from PEDro users. Eligibility for indexing is confirmed based on criteria for each study design (i.e., trials, reviews, and guidelines), and indexing codes are then selected for each article. The detailed eligibility criteria for each study design is available from the PEDro website.<sup>19</sup>

### Extraction of included articles from PEDro database

Data were extracted from the 2 July 2019 update of PEDro. The bibliographic data downloaded for all articles included

the authors, title, journal name, year, volume, issue, pages, abstract, and identifiers - Digital Object Identifier (DOI), PubMed Identification Number (PMID), and PEDro identification number. No language restriction was applied. For publications not in English, the English translation of the title and abstract provided by the publishing journal was used in the analyses.

### Matching the articles extracted from PEDro with Web of Science database

The data extracted from PEDro were matched with the Web of Science database available at the Centre for Science and Technology Studies (Leiden University, Netherlands). This version of the Web of Science database includes enhancements like the standardisation of address information that enables the accurate identification of the countries and institutions<sup>20</sup> that produced the research. The matching between PEDro and Web of Science records was done using the Digital Object Identifier (DOI) or the PubMed Identification Number (PMID). The articles that could be matched from PEDro to Web of Science formed the final pool of articles that were then used to answer our research questions. The entire pool was subdivided into three equal periods based on publication year (1986 to 1997, 1998 to 2007, 2008 to 2017) to analyse the temporal evolution of the thematic structure and research production.

### Analysis of the thematic structure

Advanced bibliometric text mining and visualisation techniques were used to evaluate the thematic structure of the included articles.<sup>21</sup> Text mining uses computer software to extract terms from documents to identify signal words.<sup>22</sup> This technique was applied to the title and abstract in our data set. If an article did not have an abstract, text from the title only was used in the analyses. A co-word analysis was conducted, based on the assumption that the core contents of a scientific field can be represented by a set of signal words. The higher the occurrence of the signal word in the included articles, the more relevant it is to the topic to which it refers.<sup>11</sup>

Freely available VOSviewer software<sup>23</sup> (version 1.6.11) was used to run the co-word analysis and its visualisation. The main steps<sup>24</sup> were:

1. VOSviewer selected and extracted the main nouns and noun phrases (nouns and adjectives) from the titles and abstracts of the included articles. The software converted plural terms (e.g., “behaviours”) into singular terms (e.g., “behaviour”). Very general words that do not relate to one specific topic (e.g., “week”) were automatically omitted. Each relevant noun or noun phrase was included as a “signal word” (e.g., “physical activity”).
2. Two authors (LCC and AM) reviewed the signal words and developed a thesaurus to account for language inconsistencies (acronyms, homonyms, and synonyms) to create a final set of signal words.<sup>25</sup>
3. For the period 1986 to 2017, we determined that signal words needed to appear in at least 70 articles to be included in the visualisation. The threshold for signal

word occurrences was determined after trials to select the one providing the clearest delineation, and it was modified for the temporal analyses (1986 to 1997, 1998 to 2007, 2008 to 2017) to a level adapted to the number of articles in each period.

4. VOSviewer grouped the signal words to be visualised into “topics”. Each signal word was represented by a node on a two-dimensional map. The location of each node was defined by the visualisation of similarities mapping technique, where the distance between nodes indicates their relatedness (i.e., the more related the words, the closer they are located).
5. Six physical therapists with expertise in different areas of practice independently interpreted the maps, generating a label for each topic. These six interpretations were collated and discussed by three authors (LCC, AM and ZM) until consensus was achieved. This method of interpreting and labelling the visualisations has previously been reported to be a reliable approach.<sup>23,26,27</sup>

### Identification of the main producers of physical therapy research articles

For each article in the pool, the institution and country affiliation of all authors was identified. We used the full counting method,<sup>20</sup> which gives equal weight to all institutions and countries who contributed to the article. For instance, if one article has authors from Spain and Australia, this article fully counts both for Spain and Australia, regardless on the actual number of authors.

To measure and compare the performance of countries and institutions publishing trials, reviews, and guidelines evaluating physical therapy interventions, we calculated indicators of publication output and impact using the Web of Science database. Publication output was measured using the number of articles (P) indicator. This indicator was calculated by counting the total number of articles for a specific country or institution. The average citation impact was measured by the mean citation score (MCS), which is the number of citations (C) that a particular country or institution receives divided by the total number of articles assigned to it (P). P and MCS data have been transformed to a logarithmic scale due to their skewed distribution to improve the visualisation. Citations per article were counted until the end of 2018 as at least one full year after publication is required to obtain robust data. Author self-citations were excluded.

R (free software for statistical computing and graphics<sup>28</sup>, version 3.6.0) was used to conduct the statistical analysis and to generate the figures related to the production and impact indicators.

## Results

This study included a total of 29,090 articles in the analyses, 2,734 articles for the period 1986 to 1997, 7,315 articles for 1998 to 2007, and 19,041 articles for 2008 to 2017. The selection process is illustrated in Fig. 1.

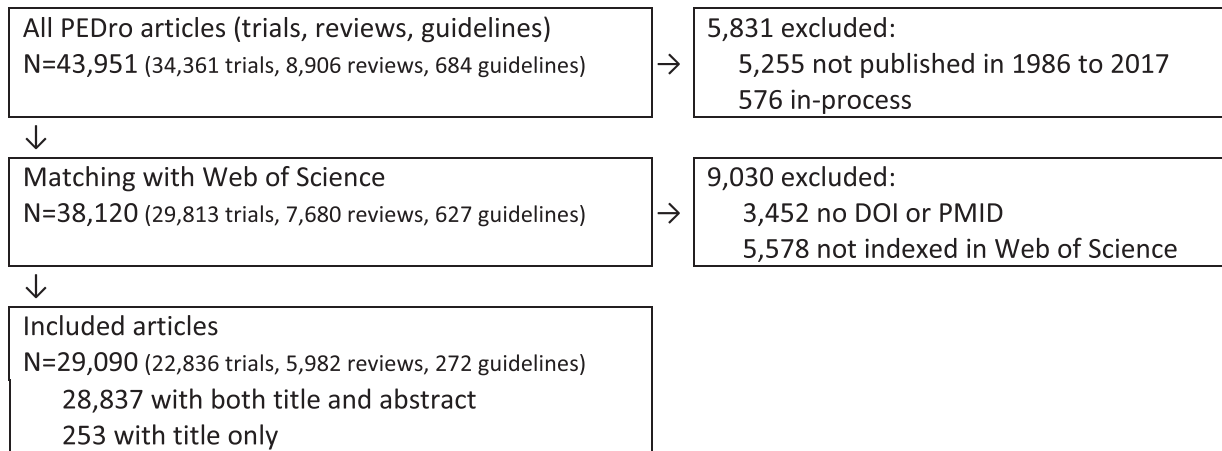


Figure 1 Stages in identifying the pool of articles used in this study.

**Thematic structure 1986 to 2017**

Eight topics were identified for the full period 1986 to 2017 (Fig. 2): “neurological rehabilitation”; “methods”;

“exercise for prevention and rehabilitation of lifestyle diseases” (lifestyle diseases are also known as non-communicable diseases like diabetes, obesity, or cardiovascular diseases); “assessment and treatment of musculoskeletal

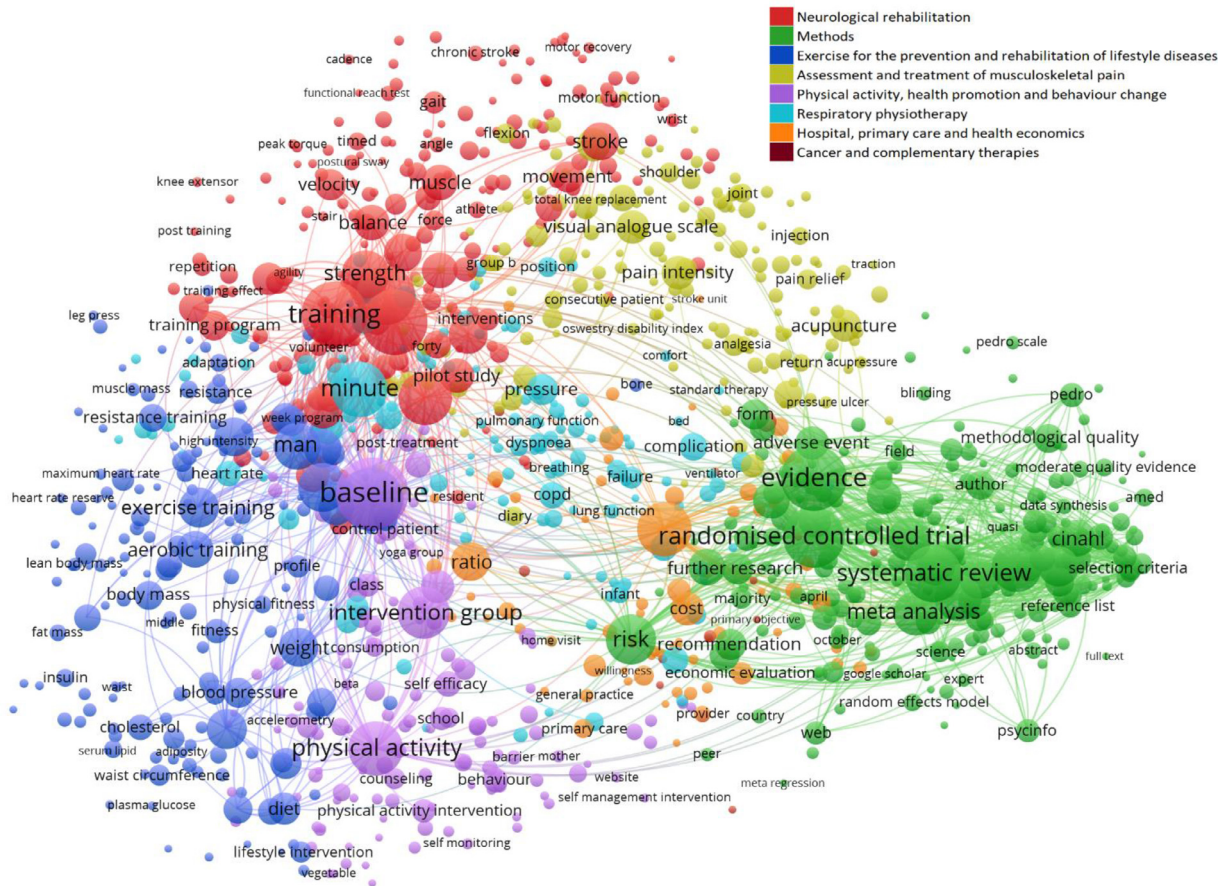


Figure 2 The thematic structure of physical therapy for articles reporting interventions published from 1986 to 2017. The eight topics identified are presented by colour coded groups of signal words. Each node (circle) within the network represents a signal word wherein: (1) the size of the node indicates the occurrence of the word (i.e., the number of times that the word occurs, the larger the node the more times it occurred), (2) the distance between nodes indicates their relatedness (i.e., the more related the terms, the closer they are located), (3) the colour of the node indicates the topic to which a node has been assigned. The results are based on the analysis and interpretation of signal words frequency and scores calculated by the software, but also the position of the nodes (signal words) in the map. The frequency analysis of the signal words is reported in the table 3 of supplementary material.

**Table 1** 20 most productive countries and ranking by productivity and impact.

Country	P	logP	Citations	MCS	logMCS	Ranking P	Ranking MCS	Ranking MCS 20
United States	8,614	3.94	450,541	52.30	1.72	1	6	1
United Kingdom	3,772	3.58	160,840	42.64	1.63	2	14	6
Australia	2,937	3.47	102,491	34.90	1.54	3	24	12
Canada	2,273	3.36	112,515	49.50	1.69	4	10	4
Netherlands	1,733	3.24	74,677	43.09	1.63	5	13	5
Germany	1,385	3.14	51,171	36.95	1.57	6	23	11
Brazil	1,200	3.08	21,669	18.06	1.26	7	64	18
China	1,189	3.08	23,787	20.01	1.30	8	55	17
Sweden	1,086	3.04	40,390	37.19	1.57	9	21	10
Italy	1,003	3.00	40,413	40.29	1.61	10	19	9
Spain	948	2.98	26,928	28.41	1.45	11	35	14
South Korea	870	2.94	10,514	12.09	1.08	12	79	20
Denmark	742	2.87	23,621	31.83	1.50	13	30	13
Turkey	673	2.83	10,983	16.32	1.21	14	70	19
Norway	663	2.82	27,045	40.79	1.61	15	17	7
Taiwan	572	2.76	12,008	20.99	1.32	16	52	16
Finland	543	2.73	27,439	50.53	1.70	17	9	3
Japan	537	2.73	13,097	24.39	1.39	18	42	15
France	535	2.73	27,533	51.46	1.71	19	7	2
Belgium	529	2.72	21,483	40.61	1.61	20	18	8

P—publication output (i.e., number of articles per country); logP—logarithmic value of P; MCS—mean citation score (i.e., number of citations received by a particular country divided by the total number of articles assigned to it); logMCS—logarithmic value of MCS; Ranking P—position of the country within the list of most productive countries; Ranking MCS—position of the country ordered by MCS value within the total number of countries; Ranking MCS 20—position of the country ordered by MCS value within the 20 most productive countries. P and MCS data have been transformed to a logarithmic scale due to their skewed distribution, to improve the visualisation.

pain”; “physical activity, health promotion, and behaviour change”; “respiratory physical therapy”; “hospital, primary care and health economics”; and “cancer and complementary therapies”. Seven of the eight topics relate to areas of physical therapy practice, while the 8<sup>th</sup> represents the group of terms related to the methods used in research.

### Thematic structure by period (1986 to 1997, 1998 to 2007 and 2008 to 2017)

Topics evolved when the three periods were considered separately (supplementary material, Fig. 1). There were nine topics in the 1986 to 1997 period, seven in 1998 to 2007, and eight in 2008 to 2017. The two topics present in all three periods and for 1986 to 2017 overall were “exercise for the prevention or rehabilitation of lifestyle diseases” and “respiratory physical therapy”. Colours of topics are assigned consistently across all four maps, with variations in the theme indicated by a variation in the colour shade. For example, the topic of “assessment and treatment of musculoskeletal pain” appears in two periods (1998 to 2007 and 2008 to 2017) and for 1986 to 2017 overall, but in the period 1986 to 1997 it is divided into two smaller ones related to pain (illustrated in variants of the yellow colour): “treatment of pain” and “assessment and treatment of low back pain”. The topics related to “economy” (shades of orange) also evolved over time. In 1986 to 1997 this topic includes terms related to “hospital and health economics” but evolved to “hospital, primary care and health economics” in 1998 to 2007 (maintaining this denomination in 1986 to 2017 overall; Fig. 2), and disappears in 2008 to 2017. Topics related to “rehabilitation

after orthopaedic surgery” and “education and chronic conditions” disappeared after the period 1986 to 1997. The theme “exercise for older people” appears in 1998 to 2007, while “neurological rehabilitation” and “methods” emerged in 1998 to 2007 and remained in 2008 to 2017. The topic related to “physical activity, health promotion and behaviour change” first appeared in 2008 to 2017.

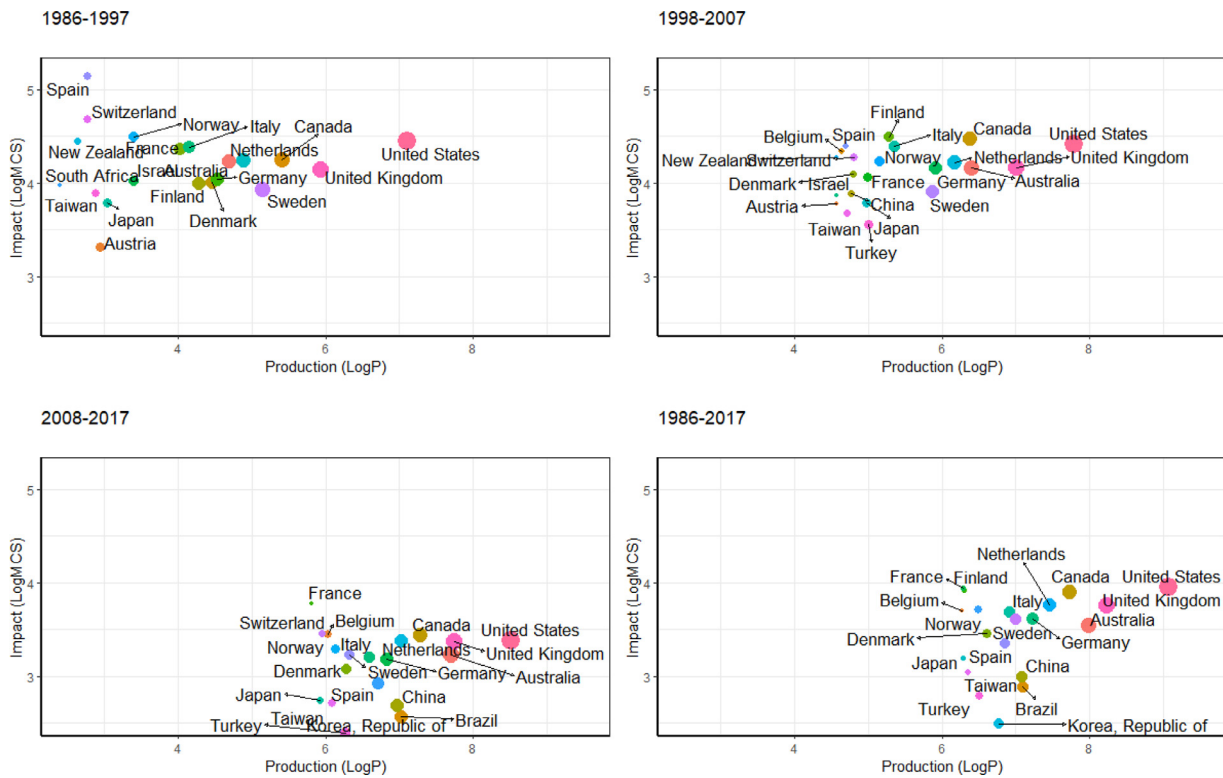
### Main producers of physical therapy research from 1986 to 2017

From 1986 to 2017, 108 countries published at least one article regarding physical therapy interventions. Table 1 lists the number of articles (P) and the ranking (Ranking P) for the 20 most productive countries. Data for other countries are provided in Table 1 of the supplementary material.

The temporal evolution of publication output (P) for the 10 most productive countries is shown in supplementary material. There was a substantial increase in productivity for all countries from 1986 to 2017. The change in productivity for China and Brazil is noteworthy as both countries did not commence their production until the early 2000’s but are ranked fifth and sixth, respectively, in 2017.

### Main producers by average publication impact and output

Consideration of publication impact (MCS) in conjunction with publication output (P) provides a more detailed view of productivity. Of the 20 countries with the highest publication output (Table 1), the five most impactful countries are: United States, France, Finland, Canada, and Netherlands.



**Figure 3** The relationship between productivity and impact for the 20 most productive countries (1986 to 2017, 1986 to 1997, 1998 to 2007, 2008 to 2017). P and MCS data have been transformed to a logarithmic scale due to their skewed distribution, to improve the visualisation.

Production and impact for the 20 most productive countries is plotted in Fig. 3 for 1986 to 2017 (bottom right panel) and in three periods (1986 to 1997, 1998 to 2007, and 2008 to 2017). For all countries, a general trend of higher production over time is evident. Austria, South Africa, New Zealand, Switzerland, and Israel are present in the earlier period(s), but drop from the 20 most productive countries in 2008 to 2017. In contrast, Belgium, China, and Turkey appear in 1998 to 2007, and Brazil and the Republic of Korea appear in 2008 to 2017.

The included articles were produced by 2,590 institutions. The five most productive institutions are: University of Sydney (Syd. in Fig. 4), VU University of Amsterdam (VU), University of Queensland (Qld.), University of Toronto (Tor.), and University of Maastricht (UM (NL)). However, Stanford University (Stan.), Duke University (Duke), and the University of Washington (UW) had the highest impact. Fig. 4 illustrates the growth in production across time for the 20 most productive institutions, and the relationship between their production and impact.

## Discussion

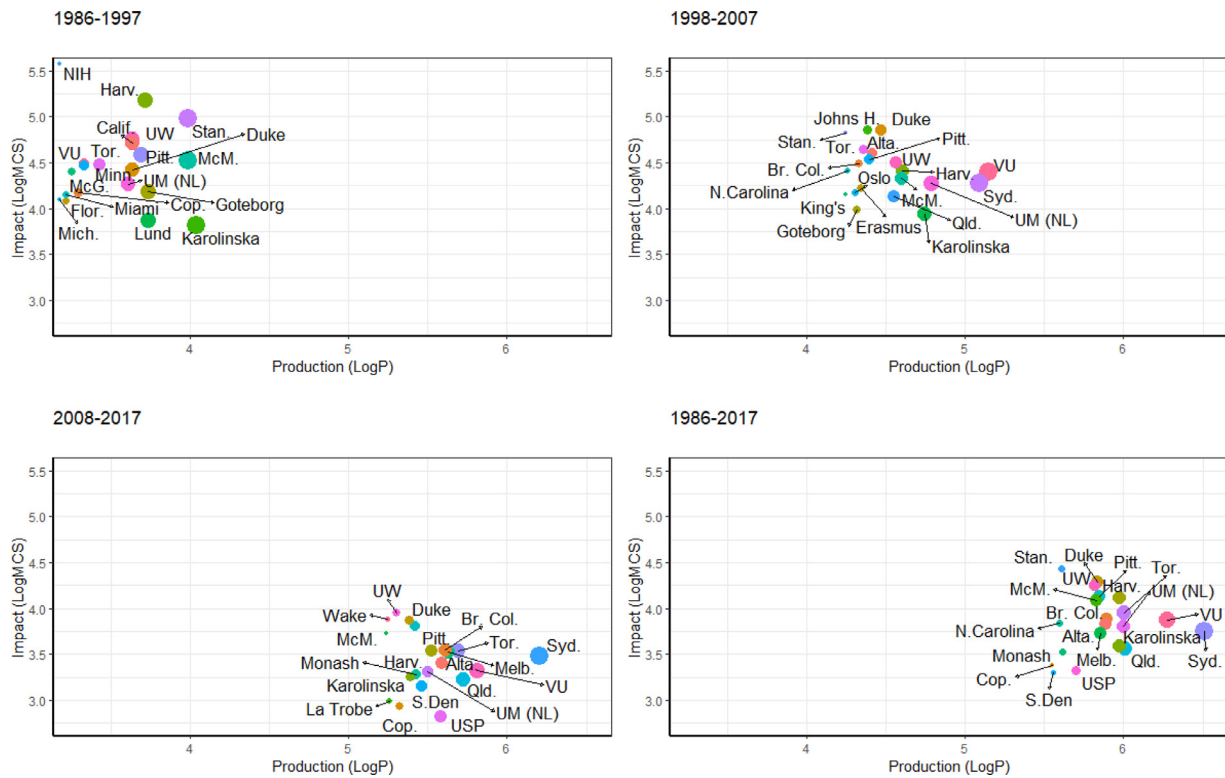
### Summary of the main findings

This study used bibliometrics to describe the thematic structure, research productivity, and impact for the field of physical therapy interventions from 1986 to 2017 using a pool of articles indexed in PEDro and matched to Web of Science.

Eight topics were identified: “neurological rehabilitation”; “methods”; “exercise for prevention and rehabilitation of lifestyle diseases”; “assessment and treatment of musculo-skeletal pain”; “physical activity, health promotion, and behaviour change”; “respiratory physical therapy”; “hospital, primary care, and health economics”; and, “cancer and complementary therapies”. The countries that contributed the largest number of articles were the United States, United Kingdom, Australia, Canada, and Netherlands. However, the United States, France, Finland, Canada, and Netherlands had the highest average impact (citations per article). The most productive institutions were the University of Sydney, VU University of Amsterdam, and the University of Queensland, while Stanford University, Duke University, and the University of Washington had the highest citation impact. The temporal evolution in the thematic structure, production, and impact was tracked over three periods (1986-1997, 1998-2007, 2008-2017).

### Strengths and limitations

Data linkage between PEDro and the Web of Science database allowed us to analyse the country and institutional affiliation of physical therapy articles using advanced bibliometric indicators to identify and compare the output and the impact of the main producers of physical therapy interventions research. Use of the in-house version of the Web of Science database from the Centre for Science and Technology Studies (CWTS, Leiden University) enabled the reliable and precise identification of geographical and



**Figure 4** The relationship between productivity and impact for the 20 most productive institutions (1986-2017, 1986-1997, 1998-2007, 2008-2017). P and MCS data have been transformed to a logarithmic scale due to their skewed distribution, to improve the visualisation.

Alta., University of Alberta; Br. Col., University of British Columbia; Calif., University of California, Los Angeles; Cop., University of Copenhagen; Duke, Duke University; Erasmus, Erasmus University Rotterdam; Flor., University of Florida; Goteborg, University of Gothenburg; Harv., Harvard University; Johns H., Johns Hopkins University; Karolinska, Karolinska Institute; King's, King's College London; La Trobe, La Trobe University; Lund, Lund University; McG., McGill University; McM., McMaster University; Melb., University of Melbourne; Miami, University of Miami; Mich., University of Michigan; Minn., University of Minnesota, Twin Cities; Monash, Monash University; N. Carolina, University of North Carolina, Chapel Hill; NIH, National Institutes of Health; Oslo, University of Oslo; Pitt., University of Pittsburgh; Qld., University of Queensland; S. Den, University of Southern Denmark; Stan., Stanford University; Syd., University of Sydney; Tor., University of Toronto; UM (NL), Maastricht University; USP, University of São Paulo; UW, University of Washington, Seattle; VU, VU University Amsterdam; Wake, Wake Forest University.

institutional affiliation for all authors<sup>29</sup> and is recognised as a robust source of quantitative data from scientific publications because of the rigorous cleaning and homogenising procedures used. We are confident of the precision and reliability of the impact indicators used (e.g., mean citation score), and the use of size-independent indicators (e.g. the mean) enables the comparison of scientific impact between producers (countries and institutional level) independent of their overall production.

Like other bibliometric studies, we made several decisions to create the visualisations. For example, the threshold for signal word occurrences was set at 70 occurrences for the global period 1986 to 2017. As there is no an agreed way for the interpretation of the visualisation of the fields<sup>30</sup> it is recommended to combine bibliometric network visualisations with expert interpretation, so we adapted the threshold for each period to reflect the number of articles included. This choice can impact on the level of detail observed in the maps and therefore could influence the final result. The bias can be minimised by seeking the opinions of experts to identify the appropriate level of visualisation and

having a high-level agreement in the interpretation of results,<sup>23</sup> both of which were used in our study. Despite the strengths of Web of Science, there are limitations including the database being orientated to articles published in English<sup>31</sup> and a mismatch between the articles and journals indexed by the databases used in this study (5,578 articles indexed in PEDro (12.7%) could not be matched to Web of Science and were excluded from the analyses). Also, PEDro excludes qualitative, observational and other research designs so this study only reflects the status of research in physical therapy interventions. Lastly, our results may differ if the analysis were to be repeated including those designs or the most “current” coverage of the PEDro database.

### Strengths and weaknesses in relation to previous studies

While our study evaluated the thematic structure of physical therapy over a shorter time period (i.e., 30 years) compared to previous studies (40-69 years),<sup>4,12-14</sup> ours is the first study to use a physical therapy-specific database (PEDro) to define



a large (N=29,090) pool of articles. The eight topics identified in this study have some similarities with the two previous studies that employed similar visualisation methods,<sup>4,14</sup> particularly the identification of “respiratory physical therapy” and “research methods”,<sup>4,14</sup> and “exercise” and “neurological rehabilitation”.<sup>14</sup> The main differences in the findings may be due to the previous studies identifying topics that do not relate to the effects of physical therapy intervention (i.e., “psychometrics”, “education”, “professional issues”).<sup>4,14</sup> This disparity can be explained by the different coverage of Web of Science and Scopus (all research methods) compared to PEDro (trials, reviews, and guidelines evaluating physical therapy interventions only) and the different methodologies used to gather the pool of articles (e.g., use of keywords<sup>4</sup> versus a more comprehensive approach of keywords, journals and micro fields<sup>14</sup>). Despite PEDro only indexing specific study designs, the procedures used to locate and index articles<sup>32</sup> is extensive and overcomes the issue of using keywords or specific journals to generate the pool of articles.

The main producers (institutions and countries) of physical therapy research are consistent with previous work.<sup>4,10,14</sup> The University of Sydney leads the ranking of most productive institution,<sup>4,14</sup> and the United States, United Kingdom, and Australia are identified amongst the most productive countries.<sup>10,14</sup> However, our results differ to those by Larsson et al.<sup>10</sup> who found China and South Korea to rank higher than Australia or the United Kingdom. This difference may be explained by our evaluation using a more representative dataset and the use of rigorous methods to identify the country and institutional affiliation for all of the authors.<sup>20</sup> Lastly, our findings highlight that the main producers of research do not always have the highest impact. This finding is important as it suggests that the mere measurement of output is not adequate to describe research performance.

### Meaning of the study and future research

Our study establishes a framework to evaluate the thematic structure of physical therapy interventions reported in the literature. Visualisation methods based on bibliographic data allowed us to identify the most important research topics in physical therapy, improving the understanding of its thematic structure and historical evolution. This information can be used by stakeholders to identify new research directions as well as priorities or gaps in the current knowledge base. Future studies could examine the influence of individual level factors, such as sex or research experience, on impact and output. Lastly, bibliometrics can also be used to evaluate how the literature indexed on PEDro is covered across other more comprehensive bibliographic databases<sup>33</sup> to achieve more knowledge about the scientific activity in physical therapy. The most current coverage of the database could be the subject of future research, particularly to assess the effects the COVID-19 pandemic may have had on the scientific production in the field of physical therapy.

### Conclusion

The thematic structure of research in physical therapy interventions reported in trials, reviews, and guidelines has

evolved showing the increasing importance of the topics related to “neurological rehabilitation”, “methods”, “exercise related to lifestyle diseases”, and “physical activity”. The main producers of this research were traditionally located in North America and Europe, but now include other countries such as China and Brazil. The most productive countries and institutions do not necessarily obtain the highest average citation impact.

### Declarations of competing interest

None.

### Acknowledgements

We thank Dr. Nicola Fairhall, Dr. Mark Elkins, and Dr. Adrian Traeger (University of Sydney) for their valued interpretations of the visualisations. Dr. Juliana Oliveira (University of Sydney) for her comments and support.

The research stay at the University of Sydney -where this work was designed- was partially funded by the Predoctoral Research Grant 2019 of the Colexio Oficial de Fisioterapeutas de Galicia, Galicia, Spain. Funding for open access charge: Universidade da Coruña/CISUG.

### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.bjpt.2022.100429](https://doi.org/10.1016/j.bjpt.2022.100429).

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