



## Research article

# The professional network underlying cerebral palsy intervention research based on systematic reviews and meta-analyses published in international journals: authors' communities, institutional networks, and international collaboration<sup>☆</sup>

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## ABSTRACT

Cerebral palsy (CP) is a well-researched area of medical science, health science and special education. The growing number of publications every year makes difficult to monitor the progress of this research domain, therefore there is a broad interest for conducting systematic reviews and meta-analyses of interventions in international peer-reviewed scientific journals.

Our goal is to analyze the scientific activity of authors who published systematic reviews and meta-analyses of CP intervention studies. To identify the active researchers, institutions, and countries, we used scientometric and bibliometric indicators that assess their productivity, collaborations, and the citations (utilization/usefulness of their studies), also paying attention to the institutional background and the network structure of national and international collaboration.

We used Scopus to search for articles and included systematic reviews and meta-analyses of intervention studies, a total of 180 works, in our sample.

Our results showed active and large communities of prolific authors and groups of authors with diverse institutional background. Most institutions are universities, hospitals, but we found various other organizations among them. Most of the universities are leading educational institutions according to international rankings; some of them are among the top-ranking ones. In geographical terms, the North American, Australian, and European regions are the most active and most interconnected ones. We assume organizations other than scientific collaboration networks also play a major role in the productivity and dissemination of scientific knowledge in this research area. As an example, we could mention the network, including the US, Australian and European registers. Authors living and working in the Far East, the Middle East or in South America also started to publish relevant articles in the 2010s. The research network structuring scientific knowledge in this area is flourishing.

## 1. Introduction

Cerebral palsy (CP), which has always been around in human history (Brandenburg et al., 2019; Panteliadis et al., 2013), is a globally known and researched area of medical science, health science, and special education (Blair et al., 2018). The research of both the disorder and possible interventions is diverse, thanks to specialists and their communities' conducting studies and practicing at numerous universities, hospitals, and institutions worldwide. Identifying and treating each CP case requires well-coordinated collaboration and the expertise and professional

experience of specialists representing various scientific disciplines, e.g., paediatricians, neurologists, orthopaedic surgeons, therapists, pedagogues, and other specialists (Rosenbaum, 2015). Following different traditions, various approaches were developed at the international level centered around universities and hospitals, which initiated and made numerous collaboration efforts to identify and treat disorders with an intention to structure, further develop and innovate knowledge in this specific area. Nonetheless, some regions seem to pay more attention to exploring the disorder and enriching our knowledge about it. In Europe, Australia and the United States institutionalized societies were

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established, like SCPE (Arnaud, 2018), ACPR (McIntyre et al., 2018), and ADDM (Christensen et al., 2014) to harmonize register databases set up to record and follow up cases, to enrich and refine our knowledge and insight, to develop, improve and disseminate training, and to facilitate communication and collaboration between specialists (Arnaud, 2018; Christensen et al., 2014; McIntyre et al., 2018). The US and the Australian organizations (ADDM and ACPR, respectively) are based on sharing work between the institutions of the respective country, while the European organization (SCPE) is founded on institution-level collaboration between multiple countries. The US organization covers several specialist areas, while its Australian counterpart is specialized in a single area: cerebral palsy. The agents of institution-level collaboration are, however, always individuals: researchers, medical doctors, rehabilitation specialists and representatives of several other professions. Many of them also publish studies in some of the most important international peer-reviewed academic journals, which serve as reference points for the professional areas.

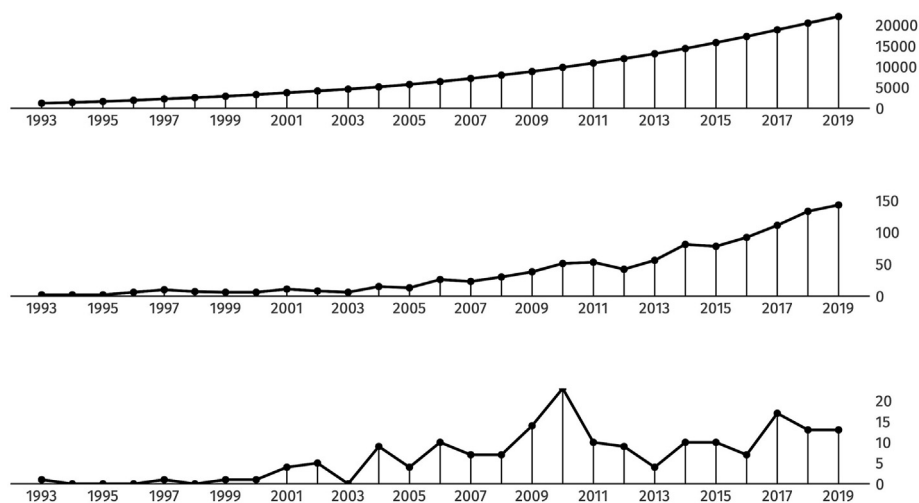
The number of studies, both of those published on basic research and those on interventions serving medical and rehabilitative purposes, is increasing year by year (Figure 1). The sheer number of these studies, however, often leads to problems in practice, because the assessment of the usefulness, the efficacy and/or the adverse effects of the interventions could be hard for medical and rehabilitation professionals. This problem was addressed by evidence-based medicine (EBM) and practice (EBP), that are gaining more and more importance in the last decades. Part of this movement, the huge amount of scientific studies lead to increase the demand for reviewing empirical studies in various ways. For example, in the case of cerebral palsy intervention research review literature, there are many systematic reviews and meta-analyses of published intervention studies that give insights into what we know about the effectiveness of the published interventions (see e.g. Novak et al., 2013; Novak et al., 2019; see Figure 1).

Reviewing of the literature has various analytical traditions, amongst them some of the most used in the literature, that worth mention from the viewpoint of our study are systematic reviews and meta-analyses, scoping reviews, bibliometric and scientometric analyses. What is common is the sample of the investigation in case (eg. the publications itself), but the aims, scope and the used analytical methods and tools differ in various ways. Our study focuses on the bibliometric and scientific analysis of cerebral palsy interventions' systematic reviews and meta-analyses. The methods we used differ from systematic and scoping review methodologies, and from the newest content and text analyses methods. The analysis of the bibliometric data of the studies published in international peer-reviewed journals allows us to assess the productivity

of the authors, their institutions, and countries, how much they are known and recognized within the community as measured by the number of citations, and their participation in professional collaborations. And it may also shed light on the interrelations existing in the area, be it the network of professional collaborations, or co-citations resulting from thematic similarities of the specific topic. Our study, therefore, analyses the publishing activity of the authors of CP intervention research meta-analyses and systematic reviews via scientometric and network analyses of bibliometric data. Why do we focus on the community of authors of meta-analyses and systematic reviews? These works are useful to practitioners, because they provide them with fast access to information on evidence-based CP interventions, and they also save time the specialists would otherwise spend searching for and looking up information. It is also important to know which interventions have become obsolete, and meta-analyses and systematic reviews are appropriate tools to filter such interventions out (Mandinach, 2012; Provost and Fawcett, 2013).

Systematic reviews and meta-analyses have well-established and rigorous methodological background aiming to answer mainly two key questions: what works (how effective are interventions) and what is general (how widely used, common and robust are the investigated studies) (Gurevitch et al., 2018). Scoping reviews often aim analyzing the scientific literature to map the concepts underpinning the investigated domain from the views of the primary sources and types of evidence available (Arksey & O'Malley, 2005). The aim of the analysis is therefore, could be revealing how research develops in the area, clarifying concepts in the literature, identifying key topics, methods, issues related to a concept, analyzing and identifying knowledge gaps (Khalil et al., 2016). Overall, scoping reviews try to present a broader overview of scientific evidence in a scientific domain, often irrespective of study quality, and is useful in analyzing emerging concepts, identifying and clarifying gaps in the literature (Khalil et al., 2016).

Bibliometric analyses often aim to identify knowledge gaps and knowledge clusters in the investigated sample that may require more attention from the scientific community (Haddaway et al., 2016; James et al., 2016). These kinds of studies could answer questions of what and who published (sometimes in what contexts) in the selected knowledge domain (e.g. scientific publications), and builds on the metadata of the publications, rather than the textual content (full text) contained within them. Bibliometric analyses aim showing quantified and aggregated results of agents (publications, authors, institutions and countries), and often show connections, clusters amongst them, depending on the research question (Zupic and Čater, 2015). This analytical view allows identify from the most connected and cited actors to the less connected, disconnected, isolated actors in the selected sample of papers, revealing



**Figure 1.** Top: Number of CP studies in the Scopus database (aggregated number up to the given year); Middle: Number of systematic reviews and meta-analyses in the sample (aggregated number up to the given year; Bottom: Number of articles published in the given year and included in our study).

the state-of-the art and the development of the field or set of concepts (Zupic and Čater, 2015; Vincenot, 2018). Our analyses focus on this, not on the (full-text) textual content of the reviewed articles.

The above mentioned analysis methods have progressed well in the recent decades. The recent advances in big data, computational power, advanced visualization methods and network analysis provide well-established tools and ways to use in the analysis and help to understand the structure and mechanisms of the investigated domain (Zupic and Čater, 2015).

Our study focuses on the various agents - authors, institutions and on their collaborations - of the published interventions. Our goal is to provide some insights into the underlying network structure of the scientific community, their scientific productivity and collaboration efforts in the given time span (1993–2019).

At the time of the submission of the manuscript, we don't know any review papers published with similar background, context and goals (bibliometric and scientometric analysis methods of systematic reviews and meta-analyses of cerebral palsy intervention research, insights from empirical data on production of authors, their institutions and countries). There are some studies that have some overlapping study population and analytical perspectives (Wu et al., 2020; Danis and Kutluk, 2021), but they differ in various aspects. Wu et al. (2020) investigates the brain imaging literature of children with cerebral palsy between 1984 and 2019, Danis and Kutluk (2021) analyze the evolution of cerebral palsy publications and provides insights of the global productivity of the field between 1980 and 2019 (Danis and Kutluk, 2021; Wu et al., 2020). Our study is therefore could be a substantial contribution to the knowledge of the scientific community.

Most of our analyses use the productivity and the citation number – i.e., visibility and recognition – indicators, since these metrics are often used to determine the excellence and usefulness of specific authors, institutions, and countries' contribution. Data extracted from articles are also considered when measuring and evaluating scientific performance. We have bibliometric, scientometric and network science tools to calculate the indicators.

## 2. Methods

### 2.1. The sources of our analyses and the search strategy

Our sources were systematic reviews and meta-analyses of cerebral palsy intervention studies. We came across Novak's work (Novak et al., 2013), which structures systematic reviews and the first publication of research articles published earlier, in the early phase of our search. The authors identified a total number of 64 different intervention approaches. As their article intended to give an exhaustive review, we made it one of our points of reference, and from that point on we extended our search for articles, taking into consideration the existing category system and the search strategy they developed. We searched the health science section of the Scopus database (Guido et al., 2015; see Kondilis et al., 2008; Wang et al., 2019) for articles, using the names of the specific categories, e.g., 'bimanual training' or 'strength training,' in combination with 'cerebral palsy.' We checked each article we found and included only those systematic reviews and meta-analyses in our analysis where the full text was available. Finally, this search strategy produced a sample consisting of 180 articles (see in the Appendix).

### 2.2. Analyses, procedures, indicators, and visualization

Our analyses used bibliometric metadata to break down our findings by article, author, institution, and country (see Wang et al., 2019). Of all the data available to us, we used the total number of articles published, and the total and yearly average numbers of citations associated with the articles. Regarding the authors, we considered the H index and the M quotient (see Hirsch, 2005) calculated from the data, as well as the number of the authors' articles, the total number of citations of their articles and the date when their first article was published. The analyses of institution and country data were based on the authors' affiliation details. When calculating the institution data, we analyzed the universities based on the 2019 ARWU (Academic Ranking of World Universities), THE (Times Higher Education World University Rankings)

**Table 1.** The first 10 most frequently cited reviews in our sample, listed by the number of citations.

Citations	Title	Authors	Year	Citations/Year
531	A systematic review of interventions for children with cerebral palsy: State of the evidence	Novak, I.; Mcintyre, S.; Morgan, C.; Campbell, L.; Dark, L.; Morton, N.; Stumbles, E.; Wilson, S. A.; Goldsmith, S.	2013	75,86
271	A systematic review of the effectiveness of strength-training programs for people with cerebral palsy	Dodd, K. J.; Taylor, N. F.; Damiano, D.	2002	15,06
229	A systematic review of the effects of early intervention on motor development	BlauwHospers, C.; HaddersAlgra, M.	2005	15,27
204	A systematic review on the diagnosis and treatment of primary (idiopathic) dystonia and dystonia plus syndromes: Report of an EFNS/MDS-ES Task Force	Albanese, A.; Barnes, M. P.; Bhatia, K. P.; FernandezAlvarez, E.; Filippini, G.; Gasser, T.; Krauss, J. K.; Newton, A.; Rektor, I.; Savoirdo, M.; VallsSole, J.	2006	14,57
197	The impact of augmentative and alternative communication intervention on the speech production of individuals with developmental disabilities: A research review	Millar, D. C.; Light, J.; Schlosser, R. W.	2006	14,07
192	Effects of neurodevelopmental treatment (NDT) for cerebral palsy: An AACPD evidence report	Butler, C.; Darrach, J.; Adams, R.; Chambers, H.; Abel, M.; Damiano, D.; Edgar, T.; Msall, M.; SamsonFang, L.; Stott, N. S.; Law, M.; Leach, J.; Goldstein, M.; ODonnell, M.; McLaughlin, J.	2001	10,11
171	Selective dorsal rhizotomy: Meta-analysis of three randomized controlled trials	McLaughlin, J.; Bjornson, K.; Temkin, N.; Steinbok, P.; Wright, V.; Reiner, A.; Roberts, T.; Drake, J.; ODonnell, M.; Rosenbaum, P.; Barber, J.; Ferrel, A.	2002	9,50
156	Practice Parameter: Pharmacologic treatment of spasticity in children and adolescents with cerebral palsy (an evidence-based review): Report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society	Delgado, M. R.; Hirtz, D.; Aisen, M.; Ashwal, S.; Fehlings, D.; McLaughlin, J.; Morrison, L. A.; Shrader, M. W.; Tilton, A.; VargusAdams, J.	2010	15,60
156	Systematic review and meta-analysis of therapeutic management of upper-limb dysfunction in children with congenital hemiplegia	Sakzewski, L.; Ziviani, J.; Boyd, R.	2009	14,18
147	Constraint-induced movement therapy in the treatment of the upper limb in children with hemiplegic cerebral palsy	Hoare, B.; Wasiak, J.; Imms, C.; Carey, L.	2007	11,31

and QS (Quacquarelli Symonds) rankings (Marginson, 2014; Rauh-vargers, 2013). These three rankings are among the most well-known ones. They are recognized and widely used in scientific life to rate universities, even though the application of these rating systems is not always free of problems (Olcay and Bulu, 2017). Using the bibliometric data of the articles, we produced graphs showing the authorial collaborations and the bibliographical connections between authors, institutes, and countries. Of the quantitative network analysis indicators of the co-authors' graphs, the degrees of the vertices (authors, institutions, countries) were considered. We used the number of direct co-authorship links of the vertices to calculate this indicator. In the visual representations of co-authorship collaborations and bibliographic connections, it is the degree of the vertices that define a node's size, while its colour reflects the total number of citations associated with it.

### 3. Results

Our search resulted in a sample of 180 systematic reviews by 580 authors. These reviews were published in 73 international peer-reviewed journals between 1993 and 2019. Table 1 shows some important details of the most frequently cited, i.e., the most frequently used systematic reviews. Special attention should be given to the outstanding citation number in the first row: the work by Novak et al. (2013) was cited in 531

articles, which substantially exceed the citation number of the reviews following it.

Additionally, we must also note the date of publishing the above-mentioned review as compared to the dates when the other reviews were published. Except for one, all of them were published earlier, yet it still achieved a higher number of citations. This suggests that the professional community considers this review a particularly important work. And this is not a coincidence since Novak et al. published a meta-analysis of earlier intervention studies, and their meta-analysis was made by analyzing earlier systematic reviews of said studies. Their work can be viewed as a milestone. They categorized and evaluated the published interventions and complemented them with a systematic communication traffic lights system based on the evidence supporting them. The importance of this review is highlighted in the relevant yearly average number of citations in the last column, which shows that the rate at which this review is used is also significantly higher than that of the other articles.

#### 3.1. Authors and communities of authors

The agents of cerebral palsy research and intervention studies are the authors who work in concert to strive to document and publish their work. Authors can be described in terms of how intensively they participate in projects (how many studies they took part in), productivity

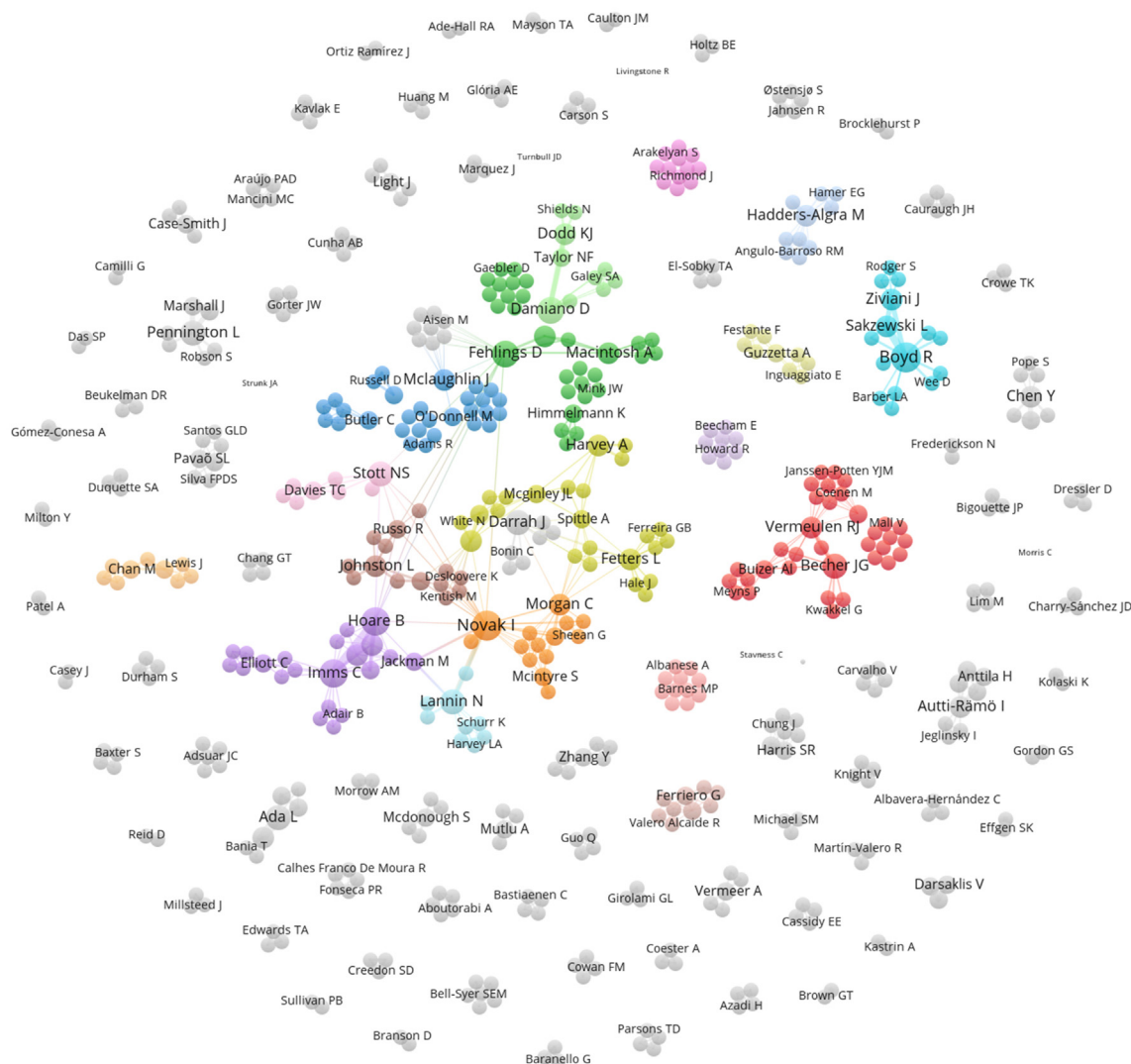


Figure 2. The co-authors' graph based on our sample. The node colour shows how many times the author was cited.

**Table 2.** The first 20 most frequently cited reviews in our sample, listed by the total number of citations.

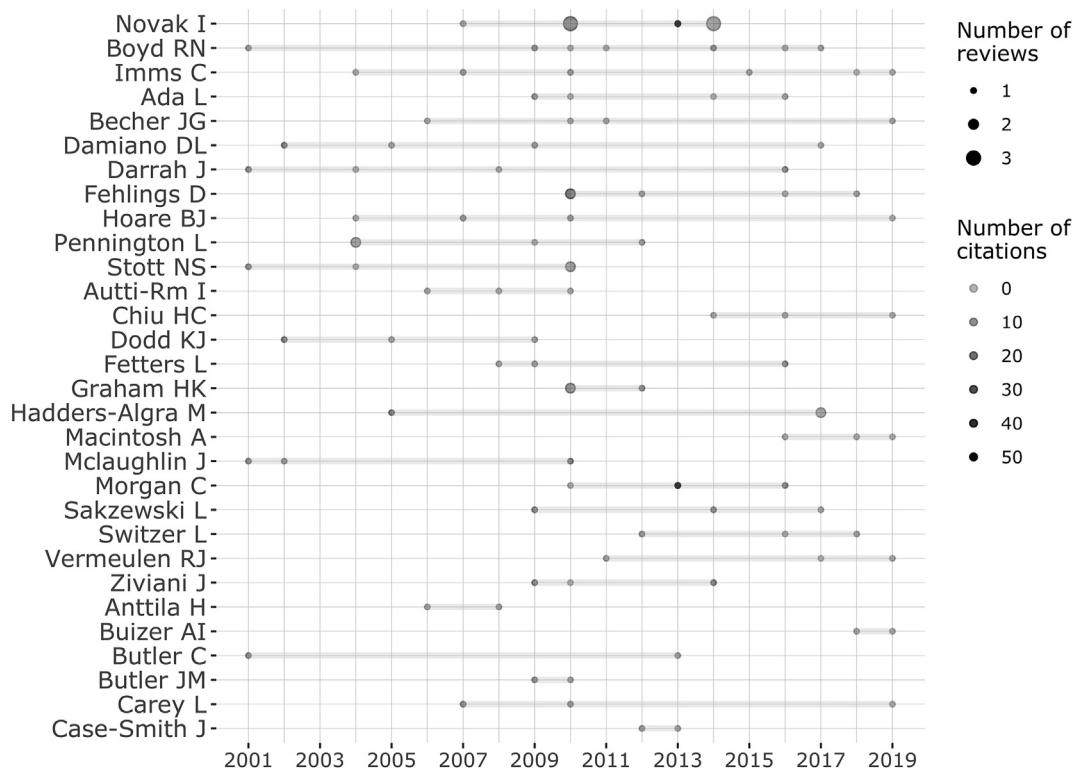
Author	H index	M quotient	Total number of citations	Number of studies	Publishing since
Novak I	8	0,57	801	8	2007
Boyd R	7	0,35	443	7	2001
Hoare B	5	0,29	420	6	2004
Imms C	4	0,24	342	6	2004
Fehlings D	5	0,45	301	5	2010
Damiano D	5	0,25	697	5	2001
Ada L	4	0,33	168	4	2009
Lannin N	4	0,27	233	4	2006
Becher JG	4	0,27	125	4	2006
Pennington L	4	0,24	182	4	2004
Darrah J	4	0,20	344	4	2001
Stott NS	4	0,20	302	4	2001
Johnston L	3	0,43	78	3	2014
Chen Y	3	0,43	69	3	2014
Switzer L	3	0,33	88	3	2012
Vermeulen RJ	3	0,30	60	3	2011
Morgan C	3	0,27	613	3	2010
Graham HK	3	0,27	210	3	2010
Harvey A	3	0,27	53	3	2010
Ziviani J	3	0,25	283	3	2009

(how many articles they authored), citation number (how many times their articles were cited) and their collaboration. This section sums up the most important findings related to them based on our sample. As mentioned before, we identified 580 authors. Figure 2 shows the co-authors' collaboration structure. Those authors who tend to be in a central position based on their collaboration connections (hub vertices) are shown closer to the center, while those participating in fewer co-

authorship collaborations appear farther from the center. The authors formed 87 groups – or, using network science terminology, connected components, i.e., induced subgraphs – in which at least two authors were in a co-author connection with each other. We also found six authors who did not co-author any studies and worked alone. The largest induced subgraph of co-authors contains 174 authors (30% of all authors), while the second largest subgraph comprises 34.

The intensity of the authors' collaboration and the underlying structural relationships can, however, be better perceived if we consider only those authors who took part in collaborations including two or more co-authors (see Figure 4 for the co-authors' graph). This shows which authors are more active and more embedded. The following sections will investigate what the analyses of the bibliometric data of these authors' articles can reveal about these individuals in terms of their productivity and number of citations. Due to a lack of space, we are going to include the first thirty authors' productivity- and citation-based data and analyses.

Table 2 summarizes the data of the most productive and recognized authors. Here we can see both their productivity and how many times they were cited. The former is indicated by the number of their articles, the latter by their total citation number, i.e., the number of articles which cite an article authored or co-authored by the given person. The H index and the M quotient relate to both productivity and citation numbers. H index reflects an author's productivity and how many times his works are cited. It shows that the author has published as many studies as the value of the H index, and each of these works was cited at least as many times as this value. So, this indicator shows both the author's productivity and their publicity/recognition (at least as measured based on the utilization of their works). However, career length expressed in terms of regular publishing of articles also plays an important role in a scientist's life. Therefore, to be able to make more accurate observations while comparing the work of various authors, we divided the H index representing the authors' productivity and citations by the number of their active years. This new value is indicated by the M quotient (see Hirsch, 2005). Our table shows how this value can be interpreted and used. If, for instance, we compare Fehlings and Stott's productivity and citations, we



**Figure 3.** Tendencies in the authors' productivity and how many times they are cited.

can see that although the former started to publish later, she achieved the latter's total citations number within a shorter period. We can also see the extent to which Novak is leading in the total number of citations. Table 2 also gives us an idea about the relation between the authors' H index and the start of their publication activities. Two authors can boast of high H index values (Novak: 8, Boyd: 7), while most authors have a 3 or 4 H index, and some have a number 5 H index. We can observe a difference in the beginning of the publication activities with authors having a 3 or 4 H index, as there are some among them who started to publish later but already have achieved an H index of 3. We can assume that the professional relevance and added value of their reviews must be high from the perspective of cerebral palsy intervention research.

The data in Table 2 and the visual presentation of the authors' trends in Figure 3 show how the citation numbers of individual authors have changed since they started to publish articles.

Figure 3 helps understand the major tendencies in this specific scientific area. The figure only shows data relating to the first thirty authors, so we cannot see the productivity and citation patterns of earlier efforts. We can track how the intention to compare and structure studies (intervention studies) gathered momentum in the 2000s and then led to a boom in the number of reviews at around 2010. Amongst the first 30 authors, some have long publication presence, started publishing at the beginning of the 2000s (e.g. Boyd and Hays, 2001; Butler et al., 2001; Damiano and Dejong, 2009; Darrah et al., 2004), some have shorter (e.g. Dodd et al., 2002; McLaughlin et al., 2002; Stott and Piedrahita, 2004). As for the next wave, there are more authors (e.g. Hoare and Imms, 2004; Pennington et al., 2004; Autti-Rämö et al., 2006; Reeuwijk et al., 2006; Anttila et al., 2008; Sakzewski et al., 2009; Ziviani et al., 2010; Butler et al., 2010; Novak et al., 2013; Hadders-Algra et al., 2017; Hoare et al., 2019). Amongst them, some authors published in a short time span (e.g.

Anttila et al., 2008; Butler et al., 2010). The coordinating efforts of research and collaboration led to a series of meetings (as in 2004; see Blair and Cans, 2018) and publications (e.g. Rosenbaum et al., 2007), that were important drives in the field's development. Figure 3 shows how the cumulative research progress of the scientific research community reached publication peak in 2009 and 2010; some authors from these years (Huang et al., 2009; Butler et al., 2010; Fehlings et al., 2009). The research effort has not declined since it, new authors started to publish (e.g. Case-Smith et al., 2013; Chiu and Ada, 2016; Buizer et al., 2019; Macintosh et al., 2019), and an important research review (review of systematic reviews and meta-analyses) published in 2013 (Novak et al., 2013). Figure 4 shows its importance as represented in the scientific collaboration network of the authors. This review gave a boost to and improved the field, the research efforts continue to progress. Figure 3 only shows the top 30 authors. However, all other authors' effort is important and contribute to the understanding and development of the scientific knowledge of the disease.

In conclusion, it is important for the researchers and practicing specialists active in this area to know that they can come across the articles of these authors more frequently, and that they should read these authors' works and use what they can learn from them to develop their research and practice further.

### 3.2. Institutions and the institutional network

We identified 283 institutions in our sample based on the affiliations specified in the systematic reviews. These institutions include 166 universities, 49 hospitals, 11 research institutes, and 10 rehabilitation centres. In addition, we also found a few polyclinics, government, non-government and not-for-profit organizations, schools, educational

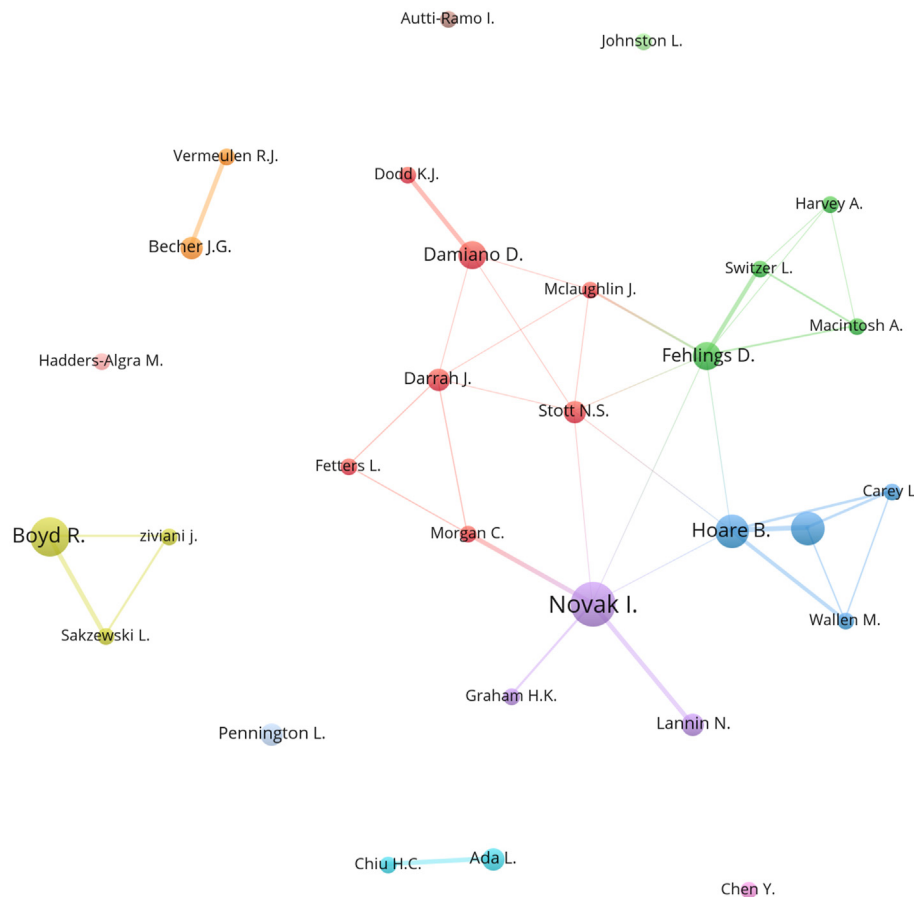


Figure 4. Interrelation patterns of co-authorship collaborations where a minimum of two co-authors were involved. The colour of the nodes is an indication of how many times the specific author was cited.

centres, several foundations, and asset manager organizations, and companies developing health care technologies among them (see Table 3). 63% of the universities are listed in the 2019 QS rankings, 66% in the ARWU and 67% in the THE rankings. Just to supplement the above information on the educational and research excellence of these universities, we wish to add that 20% of them are in the Top 100 universities in the 2019 ARWU rankings and 19% of them are in the Top 100 in the QS ‘Best Universities’ list, including 3% which are among the Top 10 universities. Regardless of all that, we can also see that the genuine added value in this specialist field comes from the practical and structuring – including publication – activities of and collaborations between the specialists working at the universities, research institutes, various healthcare institutions, government, not-for-profit and for-profit organizations.

If we take a closer look at the productivity of the institutions – arranging them by the number of articles published (Table 4) and by the number of citations thereto (Table 5) based on the data available to us –, we will find mostly Australian, US and Canadian institutions, and two Dutch, one Chinese and one German universities among the most productive ones. Each of the universities appearing in our tables is among

the top universities based on the most well-known rankings (QS, ARWU, THE). In addition to universities, we can also find hospitals, research institutes, healthcare institutes, rehabilitation centres and non-profit organizations. As we mentioned before, institutional diversity is a significant characteristic of the samples, but an analysis of the leading institutions gives us an idea about the rate at which universities take part in research.

The structural pattern of the authors' institutional background, including the interrelations within and the embeddedness and extension of the leaders' group, as well as the several isolated institutional groupings can be clearly seen on the left graph of Figure 5 showing the institutional background of the authors' co-authorship collaborations. The visual analysis of the network can also be used to realize what an important role embeddedness plays in scientific performance. We can find some extremely productive authors and institutions among the more embedded ones, i.e., those authors and institutions which are in a central position within the network of co-authorship collaborations and are surrounded by a denser author population.

In addition to the above, the network structure of the interconnections we can identify based on the bibliographic coupling

**Table 3.** The institutions specified by the authors as their affiliations, listed by country.

	University	Hospital	Polyclinic	Research institution	Rehabilitation centre	Health centre	Not-for-profit organization	Government organization	School	Other institution	Total
United States	42	10			3	2	1	2	1	2	63
United Kingdom	21	13	1		2				3	4	44
Australia	14	6		7		1	4			3	35
Canada	7	5			2				1	1	16
Spain	13	2								1	16
Netherlands	6	1	3		1		1			2	14
Brazil	10				1					1	12
Italy	5	3		2						1	11
Finland	3			1				2		1	7
Germany	4		1		1					0	6
Norway	2	2						1		0	5
Sweden	4	1								0	5
China	3	2								0	5
Belgium	3									1	4
Iran	4									0	4
France	2		1							0	3
New Zealand	2									1	3
Israel	2									1	3
Turkey	3									0	3
Sou	1	1								0	2
Slovenia	1									1	2
Philippines	1	1								0	2
Taiwan	2									0	2
India				1						1	2
Egypt	1	1								0	2
Greece	1									0	1
Netherlands	1									0	1
Hong Kong	1									0	1
Ireland	1									0	1
Switzerland		1								0	1
Czechia	1									0	1
Japan	1									0	1
Bulgaria	1									0	1
Portugal	1									0	1
Columbia	1									0	1
Denmark	1									0	1
Mexico								1		0	1
<b>Total</b>	<b>166</b>	<b>49</b>	<b>6</b>	<b>11</b>	<b>10</b>	<b>3</b>	<b>6</b>	<b>6</b>	<b>5</b>	<b>14</b>	<b>283</b>

**Table 4.** The productivity of the institutions based on the number of articles published.

Institution	Publications	Citations	Country	Type of institution	THE	ARWU	QS
University of Queensland	14	486	Australia	university	69	54	48
University of Sydney	11	469	Australia	university	60	80	42
University of Notre Dame	10	779	Australia	university	174	301-400	212
La Trobe University	9	579	Australia	university	324	301-400	397
University of British Columbia	8	213	Canada	university	37	35	47
Royal Children's Hospital	7	485	Australia	hospital	-	-	-
University of Toronto	7	233	Canada	university	21	24	28
University of Melbourne	6	499	Australia	university	33	41	39
University of Newcastle	6	137	Australia	university	332	401-500	214
Murdoch Children's Research Institute	6	243	Australia	research institution	-	-	-
Cerebral Palsy Alliance	6		Australia	non-profit organization	-	-	-
University of Southern California	6	292	United States	university	66	55	115
University of Washington	6	588	United States	university	28	14	66
University of Alberta	6	209	Canada	university	132	101-150	109
Monash Medical Centre	5	193	Australia	health centre	-	-	-
Australian Catholic University	5	275	Australia	university	404	501-600	801-1000
University of Groningen	5	252	The Netherlands	university	79	65	120
VU University Amsterdam	5	112	The Netherlands	university	167	101-150	231
Sunny Hill Health Centre for Children	5	158	Canada	rehabilitation centre	-	-	-
Sichuan University	5	32	China	university	765	151-200	601-650

THE = Times Higher Education World University Rankings.

QS = Quacquarelli Symonds' World University Rankings.

ARWU = Academic Ranking of World Universities, Shanghai Ranking Consultancy and Center for World-Class Universities of Shanghai Jiao Tong University.

yields further data about the leading institutions in this field (see Figure 6). This arrangement makes it easy to see why collaborations are not the only factor considered when determining scientific performance. Which scientific works are used, and the reasons why they are used play just as a determinant role in the operation of specific scientific areas as productivity or collaborations? Bibliographic coupling can help, on the one hand, with identifying authors and institutions close to each other in the intellectual space, and on the other hand, with identifying the actors

in the so called 'hot areas' of the scientific field, i.e., the researchers, institutions and countries spearheading research in that area. Based on our present work, some examples are the University of Sydney, the University of Notre Dame, the University of Melbourne or, for instance, the Royal Children's Hospital. The list is not exhaustive. In summary, the authors' affiliation data allows us to conclude that the most active cerebral palsy intervention research centres are in Australia, the United States and Canada, and the presence of the network of European institutions is

**Table 5.** The productivity of the institutions based on number of citations.

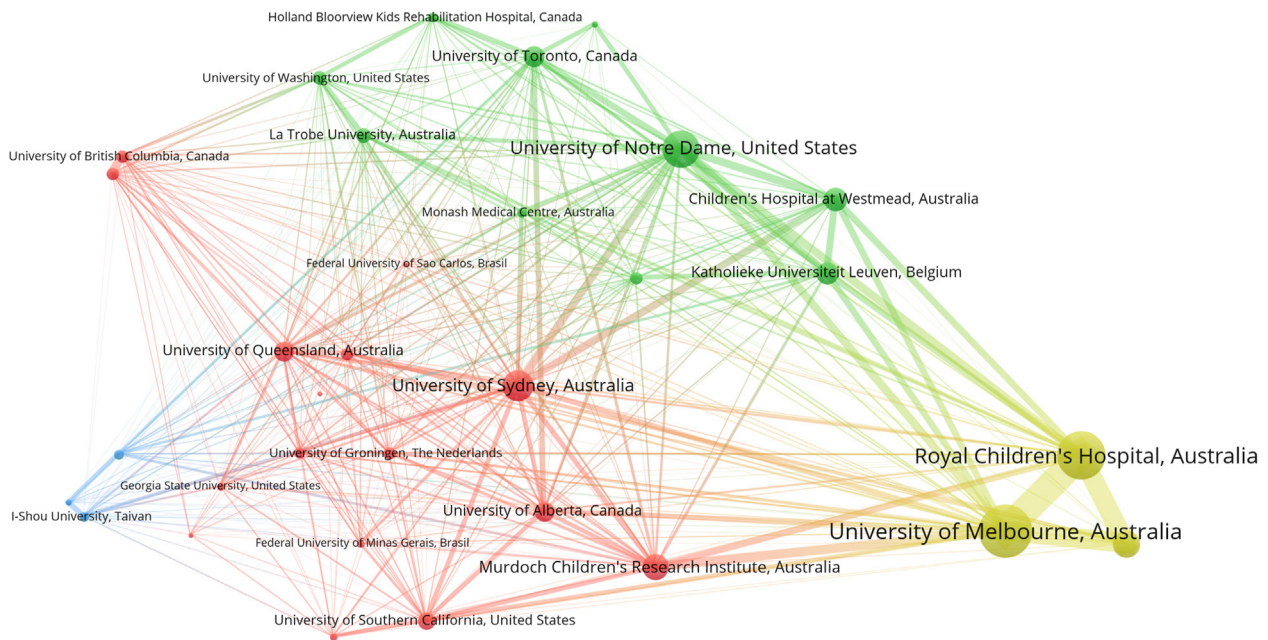
Institution	Publications	Citations	Country	Type of institution	THE	ARWU	QS
University of Notre Dame	10	779	Australia	university	174	301-400	212
University of Washington	6	588	United States	university	28	14	66
La Trobe University	9	579	Australia	university	324	301-400	397
University of Melbourne	6	499	Australia	university	33	41	39
University of Queensland	14	486	Australia	university	69	54	48
Royal Children's Hospital	7	485	Australia	hospital	-	-	-
University of Sydney	11	469	Australia	university	60	80	42
Sichuan University	5	32	China	university	765	151-200	601-650
University of Southern California	6	292	United States	university	66	55	115
Australian Catholic University	5	275	Australia	university	404	501-600	801-1000
University of Groningen	5	252	The Netherlands	university	79	65	120
Murdoch Children's Research Institute	6	243	Australia	research institution	-	-	-
University of Toronto	7	233	Canada	university	21	24	28
University of British Columbia	8	213	Canada	university	37	35	47
University of Alberta	6	209	Canada	university	132	101-150	109
Monash Medical Centre	5	193	Australia	health centre	-	-	-
Sunny Hill Health Centre for Children	5	158	Canada	rehabilitation centre	-	-	-
University of Newcastle	6	137	Australia	university	332	401-500	214
VU University Amsterdam	5	112	The Netherlands	university	167	101-150	231
Cerebral Palsy Alliance	6		Australia	non-profit organization	-	-	-

THE = Times Higher Education World University Rankings.

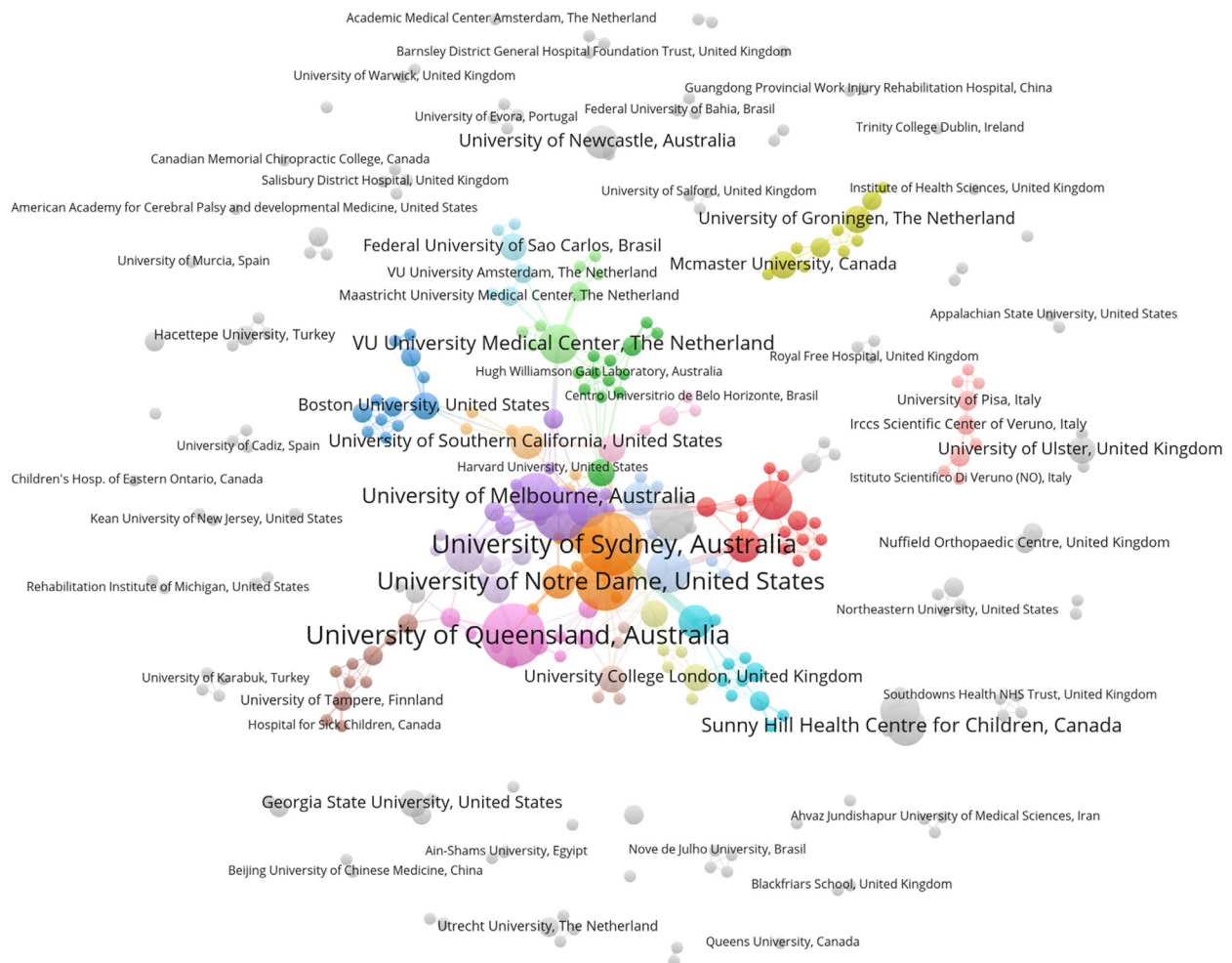
QS = Quacquarelli Symonds' World University Rankings.

ARWU = Academic Ranking of World Universities, Shanghai Ranking Consultancy and Center for World-Class Universities of Shanghai Jiao Tong University.





**Figure 5.** The institutional network of authors striving to establish a systematic structure of cerebral palsy intervention research, based on co-authorship collaborations.



**Figure 6.** The institutional network of authors striving to establish a systematic structure of cerebral palsy intervention research, based on the bibliographic coupling between their articles. Only those authors are shown who have published at least three articles.

also significant. The national and international networks of the authors and their collaborations Authors and institutions from a total of 37 countries are active in cerebral palsy research. Figure 7 shows the most important tendencies. On the one hand, we can observe a growing number of intervention studies. The first systematic review in this field was published in the United Kingdom in the early 1990s. It was followed by reviews from US and Canadian authors, later joined by Dutch researchers, who started to organize the studies reporting on CP research. Researchers from a growing number of countries began to publish in this area, clear evidence of increasing international interest. The first wave of this phenomenon, up to the mid-2000s, was marked by the involvement of researchers from countries like Spain, Belgium, Finland, Germany, Italy, and Czechia. Apart from them, we also have an author from an Israeli institution. During the next major wave, starting from the mid-2000s, structuring cerebral palsy intervention research further intensified, and the rate of publishing new systematic works increased, too. It is assumed that the parallel tendencies focusing on definitions (see Blair and Cans, 2018) and researching population-based registers (see Blair et al., 2018) also played a role in this. The number of published articles was the highest around 2010. The intensive structuring period was followed by publishing a major work in 2013 (see Novak et al., 2013), which systematically reviewed the previous efforts. As we mentioned before, Novak et al. (2013) identified a total of 64 interventions in 2013 after reviewing the systematic reviews and meta-analyses published up to

that point. It was a major contribution to enriching knowledge in this specific area (see the number of citations) and laid the path for future research. This can be clearly seen on Figure 7, as their review was later cited significantly more times than several other systematic reviews. Another wave of articles followed that. The publishing activity of authors predominantly from English-speaking countries, such as Australia, the US, the UK, and Canada increased, but we can also find articles from Brazilian, Chinese, Taiwanese, Turkish, Filipino, Egyptian, Indian, and Japanese authors, and researchers of other nationalities published at this time. We can see to what extent research in this area turned international, although the Anglo-Saxon presence continues to be predominant.

The international group of authors increased mainly through collaborations, which can be tracked on to figure showing the country-level network of co-authorship collaborations (Figure 8) and on the map, which also shows collaborations (Figure 9). The data clearly reflect the above-mentioned Anglo-Saxon dominance. This in part from the intensive collaborations between US and Australian authors, and in part from the pattern and extent of the extensive collaborations between the United States, Canada, and the United Kingdom, and between Australia and the United Kingdom. The graph of collaborations between these countries suggests that the intense and frequent collaboration seems to form a core collaboration subnetwork. Besides, we can also see that cerebral palsy intervention research becomes more and more international.

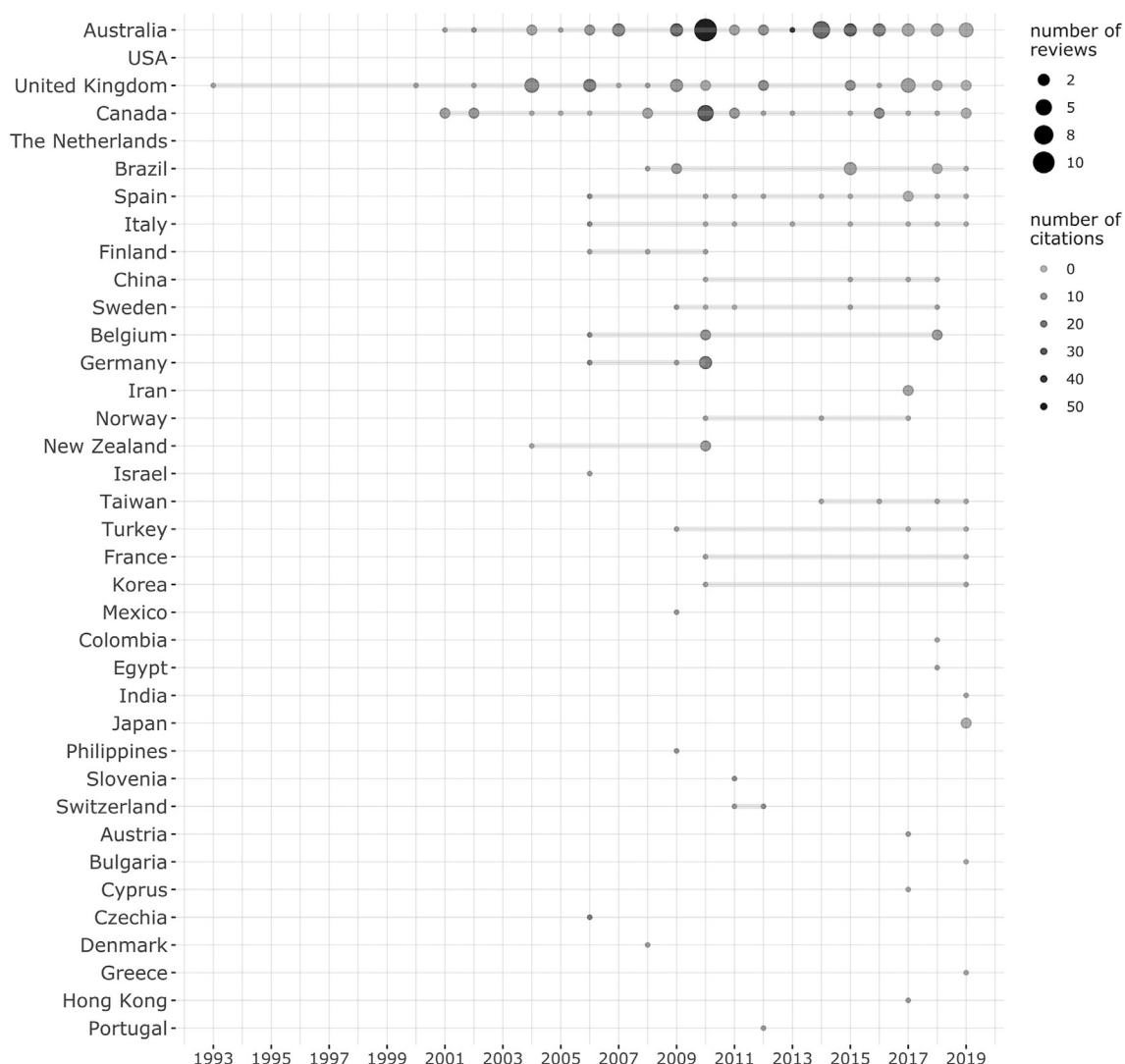


Figure 7. Distribution tendencies of how productive the authors are and how often they are cited, broken down by country.

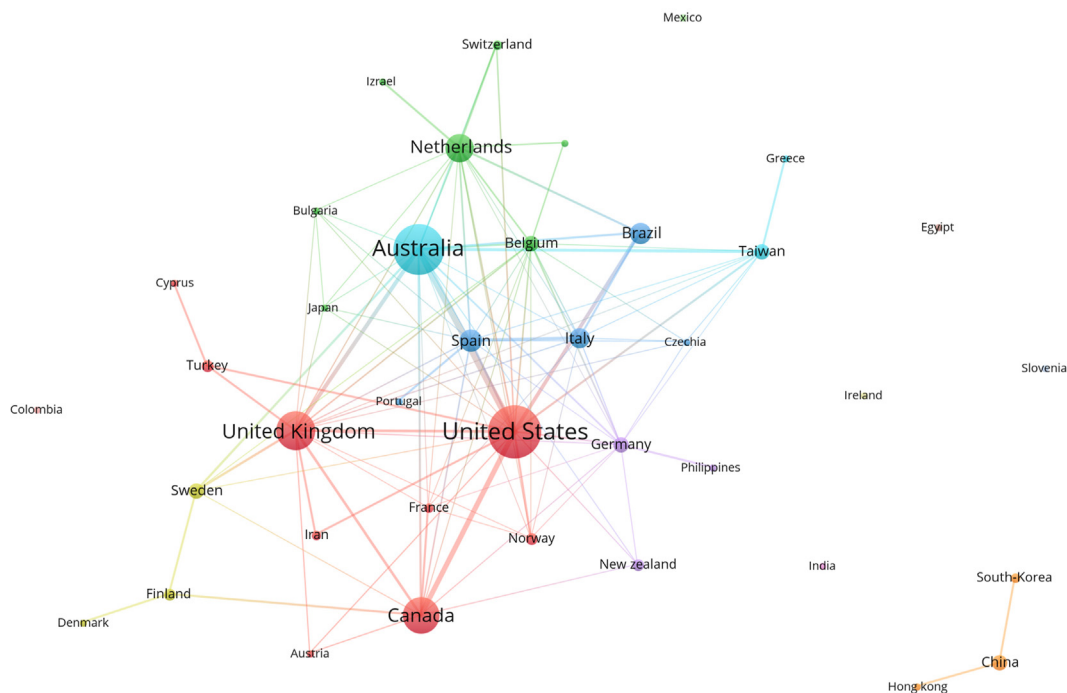


Figure 8. Breakdown of co-authors' collaborations by the country of their affiliation.

4. Discussion and conclusion

We aimed to analyze the bibliometric metadata of systematic reviews and meta-analyses of cerebral palsy intervention studies using scientometric and network analytic methods. We investigated the scientific activity of authors, their institutions and countries, focusing exclusively on their productivity, collaborations, and citation numbers. Our intention was to outline the tendencies and the current state of research in the field of cerebral palsy intervention studies. As one of the most important results of our work, we identified which authors, institutions and countries spearhead research in this scientific area based on the above factors. These data can serve as a point of reference for both researchers and

practitioners, since the authors included in our sample strived to structure research work done in this area, bearing in mind the evidence-base nature of intervention efficacy. Our analysis shows who are productive and recognized authors, identifies the particularly productive and recognized ones, and tells us who are in a central position or, on the opposite, in a peripheral position within the co-authorship network. It also reveals that there are some new authors who started to publish later but reached the same level of citations in a shorter time frame than some of their recognized peers who started to publish articles earlier. In terms of the total number of citations, Novak's performance is outstanding in cerebral palsy intervention research. She appears to be the most active and embedded author based on our analysis. We found a multitude of

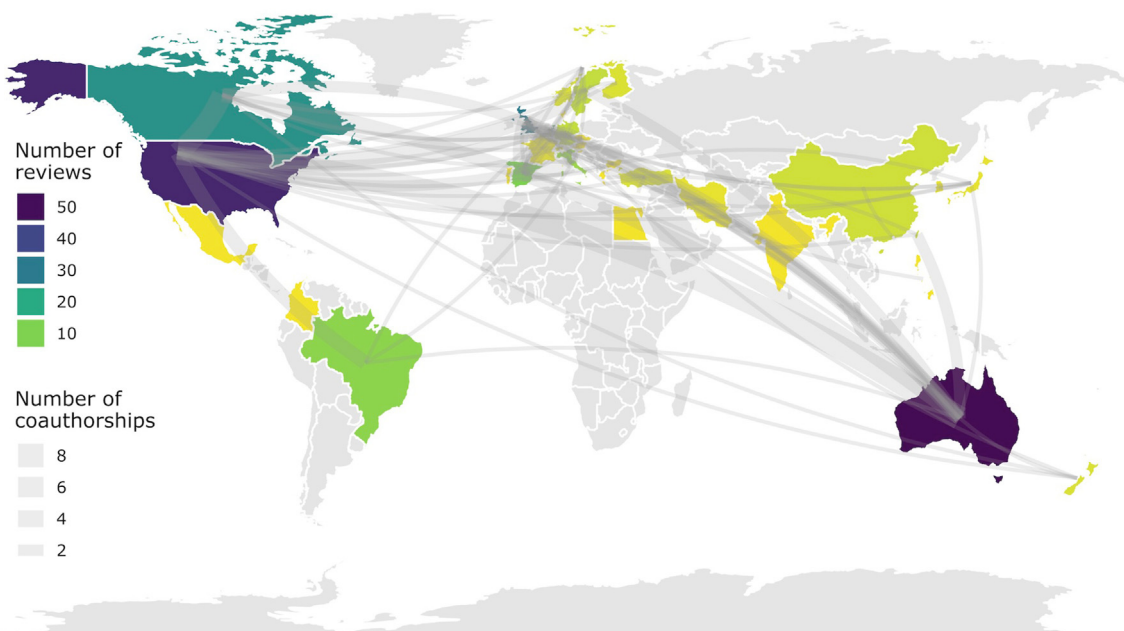


Figure 9. Countries and their co-authorship collaborations based on the authors' affiliation.

institutions behind the authors of cerebral palsy intervention studies, including universities, hospitals, and various other organizations. The composition of the institutions varies by country. According to international rankings (ARWU, QS, THE), most of the universities occupy prominent places on international lists. Some are among the highest-ranking ones. In addition to universities, we can also find hospitals, research institutes, healthcare centres, rehabilitation centres and not-for-profit organizations. As we mentioned before, institutional diversity is a significant characteristic of the samples, but an analysis of the leading institutions gives us an idea about the rate at which universities take part in research. We concluded that the institutional network is diverse and comprises several subnetworks forming around universities as their central nodes. Furthermore, the subnetworks consisting of universities, hospitals and other institutions also show diversity. Their participation ratio differs in different collaborations. Geographically, it is the North American, Australian, and European regions that drive the structuring of CP intervention studies, although researching the area became much broader in the 2010s, when authors from the Far East, the Middle East and South America also started publishing articles in this field. This means that we can expect further increase in the number of authors, which is an important development as the disorder is present in all geographic regions, including areas where they have not been able to pay the necessary attention and allocate the required resources to its treatment. Collaborations between the leading countries are also reflected in the membership networks of the organizations aiming at harmonizing CP registers. The ADDM is a society of US institutions, the ACPR is an Australian institutional network the SCPE is a European initiative. Obviously, there are a few other registers in addition to the above (Blair et al., 2018). Registers have outstanding importance with respect to research. They can be one of the most important data sources of evidence-based practice, as they can contain not only the patient information of the affected people but also specify the interventions used and their outcome, which can serve as the basis of new analyses. In addition to that, the authors' and institutions' collaboration network we identified also gives us an insight into the trends of defining the term 'cerebral palsy.' An inchoate professional network seems to be taking shape out of the collaborations underlying the principal ambition in this area, i.e. the need for a practical and concept-based definition, which first rose to prominence in the 2000s and has been a central issue ever since: while analyzing the literature, we found a number of authors referring to workshops and intentions aimed at harmonizing the definition of the term 'cerebral palsy,' which required international discourse and joint efforts. The definitions harmonized this way are viewed as professional reference points. This can also be seen in the definitions referenced in the articles. In summary, the authors', and institutions' networks we identified give us an insight into the leading knowledge structuring efforts of the scientific communities active in this area, which forms one of the central drives of evidence-based practice.

## 5. Limitations

Because of the analysis methods of our work - bibliometric and scientometric analysis of empirical data derived from published systematic reviews and meta-analyses indexed by publication database (Scopus) - our empirical analyses focus only on the metadata of the systematic reviews and meta-analyses in case, not on the content of them. We have not analyzed the full text of the reviewed papers, our goal wasn't analyzing the scientific content of the reviewed papers and their authors. Therefore, our literature search strategy only involved the search for the papers' metadata, not the full-text of the articles; overall, we haven't access to the details (full text contents) of the reviewed articles. Content and text analysis was outside of the scope of this paper.

Besides this, our study aims weren't analyzing textual contents of the abstracts. We used the articles metadata to extract authors, their institutions and countries to assess their productivity, collaborations and impact.

Also, our main goal was to analyze the systematic review and meta-analysis literature of the intervention research literature base, not the intervention research literature itself (for recent bibliometric reviews of the underlying cerebral palsy research literature see Danis and Kutluk, 2021; Wu et al., 2020). Our results, therefore, may provide a different lens to the same publication population. Both the analyses of the intervention research literature and the review literature of these publications are useful and could complementary to each other, providing useful insights and contributions to the scientific knowledge of the area.

## Declarations

### Author contribution statement

Henriett Pintér, PhD: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Franciska Gál: Contributed reagents, materials, analysis tools or data.

Pál Molnár, PhD: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Conducted network, bibliometric and scientometric analysis; Created data and network visualizations; Contributed reagents, materials, analysis tools or data; Wrote the paper.

### Funding statement

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### Data availability statement

We will upload used data to public repository and update our submission later.

### Declaration of interest's statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

## APPENDIX

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