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Asia now surpasses Europe in spine research productivity: An analysis from 1976-2020.

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Abstract

Study Design: Bibliometric Review

Objective: This study aims to understand the worldwide research productivity trends in spine-related research over the past five decades.

Summary of Background Data:

Methods: We evaluated original research articles published in four prestigious journals on spine research (European Spine Journal, Journal of Neurosurgery: Spine, Spine, and The Spine Journal) from 1976 to 2020. For one year of each decade, the origin of the first and the senior author was assigned to their region of origin. For the year 2020, a detailed analysis of countries and states of origin was performed, and the number of articles was normalized by registered MDs per country (per 10,000 population).

Results: We included a total of 4,436 articles and 8,776 authors for analysis. From 1976 to 2020, the percentage of publications originating from North America decreased (77% – 38%). In contrast, Asian contributions drastically increased (3% – 36%), whereas articles originating from Europe only slightly raised (20% – 22%). In 2020, the USA was the most productive country worldwide (34% with most articles from New York (19%), followed by China (16%) and Japan (10%). After normalization to registered MDs (per 10,000 population), the USA proved to have the highest number of articles. Besides this, India now ranked fourth and Egypt eighth in terms of the most productive countries per MDs.

Conclusion: North America contributed the largest share of all articles published in the last five decades. Asia, which ranks second in 2020, has overtaken Europe. Normalization to registered MDs can be a helpful tool to reflect a country's research productivity more accurately.

Keywords: Authorship, Research productivity, Spine surgery, Region distribution

Level of Evidence: 3

Mini Abstracts

Authorship trends of four prestigious spine-related journals were analyzed from 1976 to 2020. For 2020, detailed analysis and normalization to registered MDs were performed. North America contributed the largest share of all articles published in the last five decades. Asia, which ranks second in 2020, has overtaken Europe.

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Introduction

Research productivity in the spine field has increased tremendously over the past decades [1–3], reflected by the rapid growth of surgical spine procedures performed each year. By 2017, approximately 5.2 million surgical procedures were performed annually, and this number is predicted to rise to 7.6 million by 2022 [4]. In addition, market research also confirmed the growing global trend. For example, the medical implants market is flourishing in the Asia-Pacific region and will continue to do so until 2025 [5]. Therefore, there is high pressure to make continuous developments in the field of spine research for clinicians, researchers, and the industry.

Previous studies have shown that most spine-related research articles originated from first world countries. The United States of America (USA) was leading in the number of publications, but Asian countries like Japan and China are catching up [6]. This is an overall trend across other medical fields such as neurosurgery [6], psychiatry [7], and nuclear medicine [8]. A recently published *Nature* article revealed that China was the world's largest producer of scientific articles in 2016, according to statistics compiled by the US National Science Foundation (NSF) [9].

There are bibliometric studies regarding the regional distribution of authorship in spine research published in the past [2,3,6,10]. However, these studies did not report detailed information on worldwide regional distributions by countries and states for 44 years and did not do so for more than one specific journal [2,3,6,10,11]. Therefore, we also provide the most recent data from the year 2020 and, additionally, none of these studies compared the ratio of published articles per registered medical doctor (MD) in each country.

Our study aims to analyze research productivity across regions and countries in four prestigious spine-related journals over the past five decades and specify those data by detailed analyses in relation to registered MDs per country/region.

Material and Methods

Data Collection

We conducted a bibliometric analysis. Four peer-reviewed spine research journals (*European Spine Journal, Journal of Neurosurgery: Spine, Spine, The Spine Journal*) were considered for analysis over the last five decades. These journals were chosen because they ranked high in the Journal Citation Report [12]. In addition, to improve the comparability of our results we chose journals that were also included in studies of other authors [3,13,14]. For this purpose, one year of each decade was selected: 1976, 1986, 1996, 2006, 2016, and 2020. Thus, *Spine* was analyzed from 1976, the *European Spine Journal* from 1992, *The Spine Journal* from 2001, and the *Journal of Neurosurgery: Spine* from 2004. An interval of ten years was chosen since this method has been used by most previous studies evaluating authorship trends [16,17].

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All primary research articles (original research articles, clinical trials, systematic and non-systematic reviews, case reports) from selected years were included in the dataset using Microsoft Excel version 16.0, 2019 (Microsoft Corporation, Redmond, WA) for data collection. Other articles, such as letters, editorials, announcements, memorandums, authors' comments, and others like short articles as "Images of Spine Care" were excluded from the analyses. The selected articles were allocated to a specific region and country (and states for those in the USA) by identifying the origin from the first author since they are often the principal authors of these articles. The origin of the author was manually identified for every article from each journal's homepage.

A total of 57 countries were included in our analysis over the whole period. For the detailed breakdown in 2020, a total of 45 countries were included. The countries in which the corresponding author resided were grouped into regions as proposed by Brinker et al. [13]:

(1) North America: United States of America (USA) and Canada.
(2) Latin America: Mexico, Central, and South America.
(3) Asia: All Asian countries east of Turkey, the Middle East, and Israel.
(4) Europe: Russia and Turkey were designated as Europe.
(5) Oceania: Australia and New Zealand
(6) Africa

For normalization of articles to registered MDs (per 10,000 people) for each country (and state in the USA), the most recent data for each country was obtained online from the World Health Organisation (WHO) [18] and the most recent data for actively licensed physicians in the United States [19].

Statistical analyses

To determine the statistical significance of the changes over time, two-tailed z-tests were used due to the sufficiently large sample size. A p-value of <0.05 was considered significant. Statistical analyses were performed using Python programming language (Python Software Foundation, Version 3.7.4, www.python.org). The z-tests were conducted using the package statsmodels.stats.proportion.proportions_ztest from SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python [20].

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Results

A total of 4,436 articles were included for analysis. All journals had a steady increase in publications over time except for *Spine* (Table 1).

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Analysis per Region

In the ten-year periods analyzed (from 1976 to 2020), North America contributed the most articles (1,790 articles, 40.4%). Asia accounted for the second-highest number of articles (1,260 articles, 28.4%), followed by Europe (1,210 articles, 27.3%). Oceania, Latin America and Africa provided only a minority of all articles (0.5 - 2.4 %), as shown in Figure 1. The percentage of publications originating from North America decreased significantly from 1976 to 2020 (76.7% to 38.0%, $p < 0.001$), whereas both Asian (3.3% – 35.6%, $p<0.001$) and European (20.0% – 22.1%, p 0.786) contributions increased over this period. In 2020, North America contributed the largest share of articles (459 articles, 38.0%), followed by Asia (430 articles, 35.6.7%) and Europe (267 articles, 22.1%), as observed in Figure 1.

Analysis by Countries and States

At the global level, the top three countries contributing the most articles in 2020 were as follows: the USA (416 articles, 34.4%), China including Taiwan (189 articles, 15.6%), and Japan (125 articles, 10.3%), as shown in Figure 2A (Table 2, Table 1 supplementary material, http://links.lww.com/BRS/B833). Furthermore, we normalized the number of published articles to registered MDs (per 10,000 people) of each country (Figure 2B). After normalization, the ranking did not change. The USA is still first (16 articles per MDs/10,000 people), followed by China (9.5 articles per MDs/10,000 people) and Japan (5.0 articles per MDs/10,000 people).

However, because of this normalization, India, for example, is now in the top five countries with 2.7 articles per MD/10,000 population compared with before when it was ranked 12th (Table 1 supplementary material, http://links.lww.com/BRS/B833), as illustrated in Figure 2B and Table 2.

North America and the States of the United States of America

The distribution of publications in 2020 was analyzed in more detail for individual countries and states. For North America, 90.6% (n = 416) of all articles came from the USA and 9.4% (n = 43) from Canada (Figure 3A, Table 2). Within the USA, publications primarily came from New York (19%, n = 79) and California (12%, n= 50) (Figure 3C, Table 3). For both countries and all states in the USA, the number of published articles was normalized to registered MDs/10,000 population. New York was still the most productive state with 1.6 articles per MDs/10,000 population, California took second place with 1.3 articles per MDs/10,000 people, and Illinois was the third most productive state with a total of 31 articles and 0.7 articles per MDs/10,000 people (Figure 3 B, D; Table 3, Table 2 supplementary material, http://links.lww.com/BRS/B833).

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Asia

For Asia, 44% (n=189) of the analyzed articles originated from China (including Taiwan), followed by Japan (29.1%, n=125) and South Korea (11.9%, n=51), as shown in Figure 4A (Table 4 and Table 3 of the supplementary material, http://links.lww.com/BRS/B833). After normalization to registered MDs, most articles still originated from China and Japan (9.5 articles per MDs/10,000 people and five articles per MDs/10,000 people, respectively). In addition, India was the third most productive Asian country in 2020 with 2.7 articles per MDs/10,000 population (Figure 4B, Table 4). Data for all analyzed countries in Asia are shown in Table 3 supplementary material, http://links.lww.com/BRS/B833.

Europe

In 2020, the 295 articles from Europe were primarily from Germany (14.6%, n = 43), the Netherlands (12.9%, n = 38) and France (11.5%, n = 34) as seen in Figure 5A, Table 5, and Table 4 supplementary material, http://links.lww.com/BRS/B833.

In Europe, the Netherlands and Germany were still the most productive countries after normalization to registered MDs (1 article per MDs/10,000 people). However, it is noteworthy that Turkey ranked ninth and rose to third place by normalization to registered MDs (0.7 articles per MD/10,000 population). (Figure 5B, Table 5, and Table 4 supplementary material, http://links.lww.com/BRS/B833).

Discussion

Our results show that there is a remarkable increase in spine-related research productivity from 1976 to 2020. The USA remains the leading country in spine-related research, but Asia is now the second most productive region, followed by Europe. We also illustrated that there was a decrease in published articles from the USA and a sharp increase in research productivity in Asian countries, especially China, Japan, and South Korea, since 1976. These Asian countries are now within the top five worldwide contributors to spine-related research. China is a rapidly developing country with the largest population globally, home to over 50,000 orthopaedic surgeons and 6,000 neurosurgeons [21]. Recently, Robert Tijssen, the Chair of Science and Innovation Studies (Leiden University, Netherlands), attributes Chinas' gains to two decades of policy-driven solid growth in science and higher education [22].

We found four studies also focusing on productivity in spine-related research and analyzing the distribution of published articles by regions and countries. The study by Ding et al. from 2016 includes a large number of articles (6,920) from five highly cited spine research related journals (*The Spine Journal*, *European Spine Journal*, *Spine*, *Journal of Neurosurgery: Spine*, and *Journal of Spinal Disorders and Techniques*) of four years (2009 to 2013) [14]. An even more extensive study from Wei et al. 2016 analyzes a total of 13,115 articles from the same five journals over a more extended period (2004 to 2013) [3]. Brinker

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et al. analyzed all published articles of one year of each decade of 30-years (1985 to 2015), similar to what we did but only in one journal (*Spine*) [13]. The most recent study was published in 2020 by Hollenberg et al.. Their article focused on spine articles from 2006 to 2015 in a general orthopaedic journal (The Journal of Bone & Joint Surgery)[11].

In our study, we assigned all countries to the same regions as Brinker et al. [13]. Their study reports that North America contributed the most research articles (51%) in the journal *Spine* (1985 to 2015). Europe contributed the second most (25%) and Asia the third most (21%). Other studies reported on top countries with the highest research productivity until 2013 but did not assign their results to different regions[3,14]. However, both studies showed North America is the leading region (USA 39%), followed by China and Japan and the European countries [3,14]. These values corroborate our overall results over 44-years (1976 to 2020) reasonably well – North America is the most productive region, followed by Asia and Europe. In the breakdown by country, we showed that most of Asia's articles in 2020 came from China (44%), Japan, and South Korea, according to the results with formerly published studies [3,14]. To our knowledge, a detailed overview of research productivity of the different states of the USA has only been done by Brinker et al. [13]. However, compared to our study, they have the same results detailing New York and California as the most productive states. For Europe, Brinker et al. showed that most articles are published in the United Kingdom (21%), followed by Germany (14%), and the Netherlands (12%) [13]. Other studies demonstrated that Germany (4%), the UK (3%) and Italy (3%) [14] and Germany (6%), the Netherlands (3%), and France (3%) [3] were the three countries with the highest research productivity. In our study, however, we see a slightly different trend – Germany has the largest proportion (15%) of published articles in Europe, followed by the Netherlands (13%) and France (12%) in 2020.

Unlike other studies, we analyze 44 years of research productivity, focusing on detailed regional distribution, especially in North America. Moreover, to the best of our knowledge, we provide the most recent data from 2020. All of the studies mentioned above indicate that North America is the most productive region in spine-related research [3,13,14].

The other novelty of our study is the standardization of published articles to the number of registered MDs. To consider the population size, we standardize our data to the number of registered MDs per 10,000 population. This data is regularly published on the WHO webpage [18] and easily accessible. On a global level, our results show that the USA, China, and Japan are still the most productive countries even after standardization to registered MDs in 2020. To our knowledge, this has not been done before in the field of spine research. A previous study normalized the numbers of articles only to population or assigned them to high and low-income countries [14]. However, regions with a high population may have a low number of physicians and *vice versa*.

Moreover, Global Health Observatory (GHO) data for 2018 shows that over 45% of WHO Member States reported having less than ten physicians per 10,000 people [18]. For example, the USA had 26 MDs per 10,000 people, China and Japan had 20 and 25 respectively MDs

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per 10,000 population in 2018, whereas some European countries like Italy and France show a significantly higher density of physicians (80 and 65 respectively). In contrast to this, other countries with considerable population size, like India, had only nine MDs per 10,000 population [18]. To show an example of how the consideration of this fact can affect the productivity rate, India is mentioned: It ranked only 12th on a global level in terms of total productivity with 23 published articles. However, normalizing to the total nine registered MDs/10,000 population, India's rank improved dramatically to fourth in the world. Hence, a standardization might reflect the research productivity of a country better than the total number of published articles.

This study has some limitations. We analyzed four journals in total, and spine research published outside these four spine-specific journals was not studied. Besides this, data is only collected for one year within the 10-year intervals and may not fully represent trends for the years in between. Another limitation is evaluating the authors' countries of origin, which are only analyzed for the first author since this position in authorship is often considered the most important and representative. Finally, the normalization to registered MDs per country might reflect the research productivity per country better than the GDP or total population. However, a downside of this method is that we only included registered MDs, so PhD researchers, for example, are not taken into count. Besides this, we standardize to all registered MDs and not just MDs working in the particular field of spine research.

Our results suggest that research output worldwide has increased tremendously in the field of spine-related research. North America is still the most productive region, but Asian countries have overtaken Europe in contributing the most spine-related research in 2020. The ratio to registered MDs/10,000 people is a helpful tool to possibly better reflect the research productivity of a country.

Acknowledgements

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Key Points

1. North America contributed the largest share of all articles published in the last five decades
2. Asia contributed the second and Europe the third most articles in 2020
3. Normalization to registered MDs might reflect a country's research productivity more accurately

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Figure Legends

Figure 1. Total number of articles by region over time.

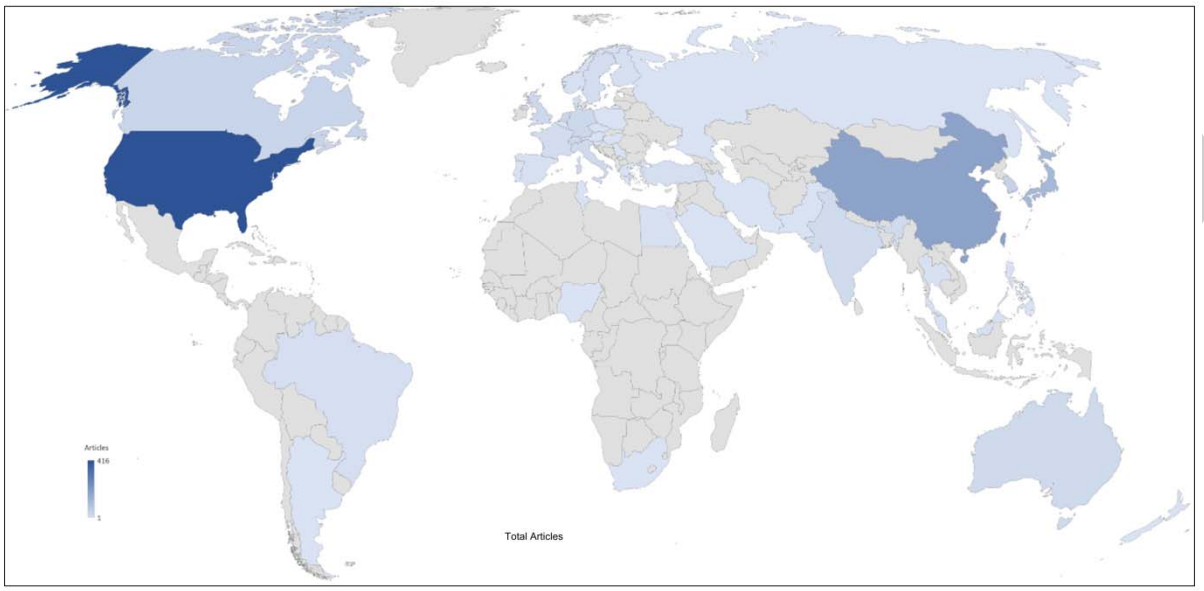

Figure 2. World maps showing the countries distribution of published articles in 2020. **A** - Total numbers of articles. **B** – Articles normalized to registered MDs. The darker the color, the higher the number of articles published in that country. Grey indicates that no articles were published in a country.

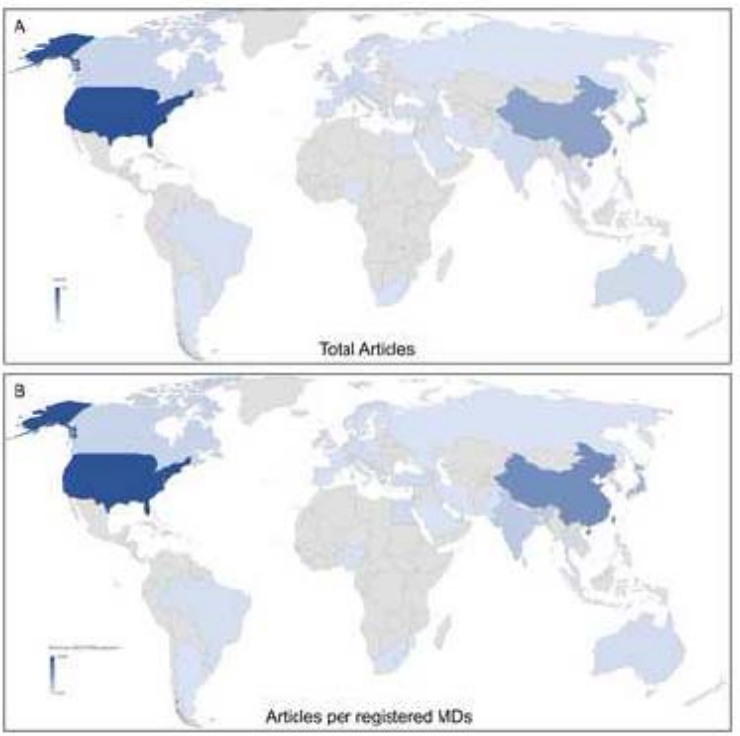

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Figure 3. Regional distribution of published articles in North America and the United States of America in 2020. **A** - Total numbers of articles in North America. **B** – Articles normalized to registered MDs in North America. **C** - Total numbers of articles in the USA. **D** – Articles normalized to registered MDs in the USA. The darker the color, the higher the number of articles published in that country or state. Grey indicates that no articles are published in a country or state.

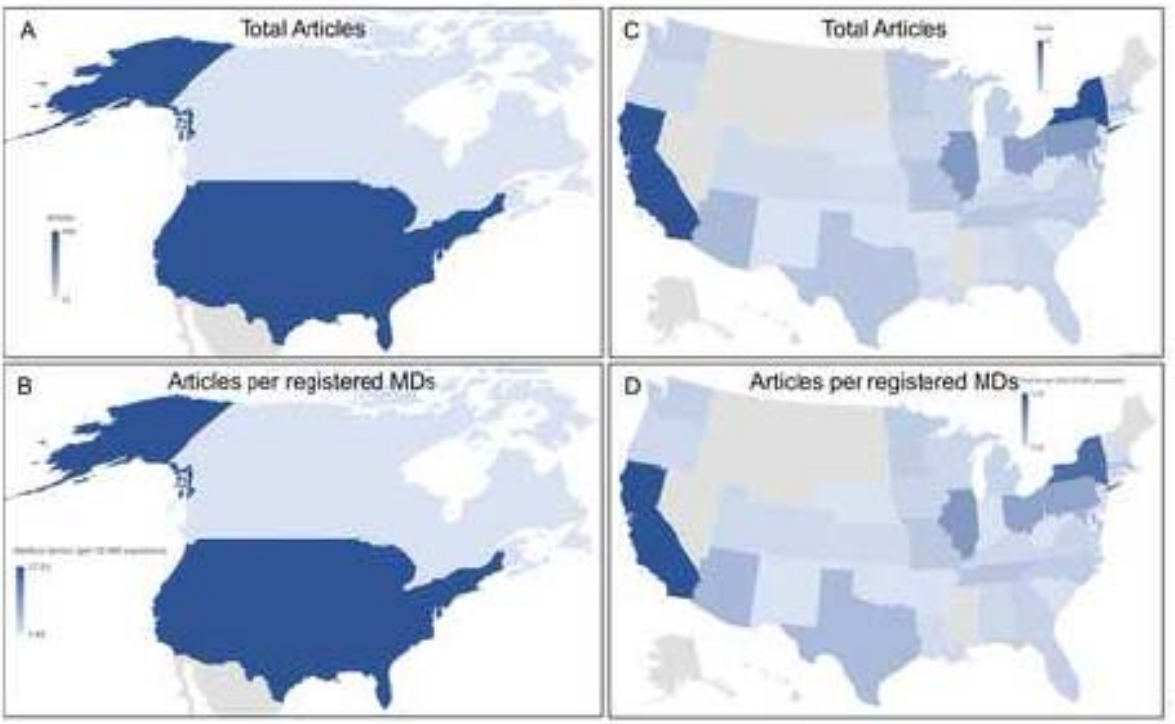

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Figure 4. Regional distribution of published articles in Asia in 2020. **A** - Total numbers of articles. **B** – Articles normalized to registered MDs. The darker the color, the higher the number of articles published in that country. Grey indicates that no articles are published in a country.

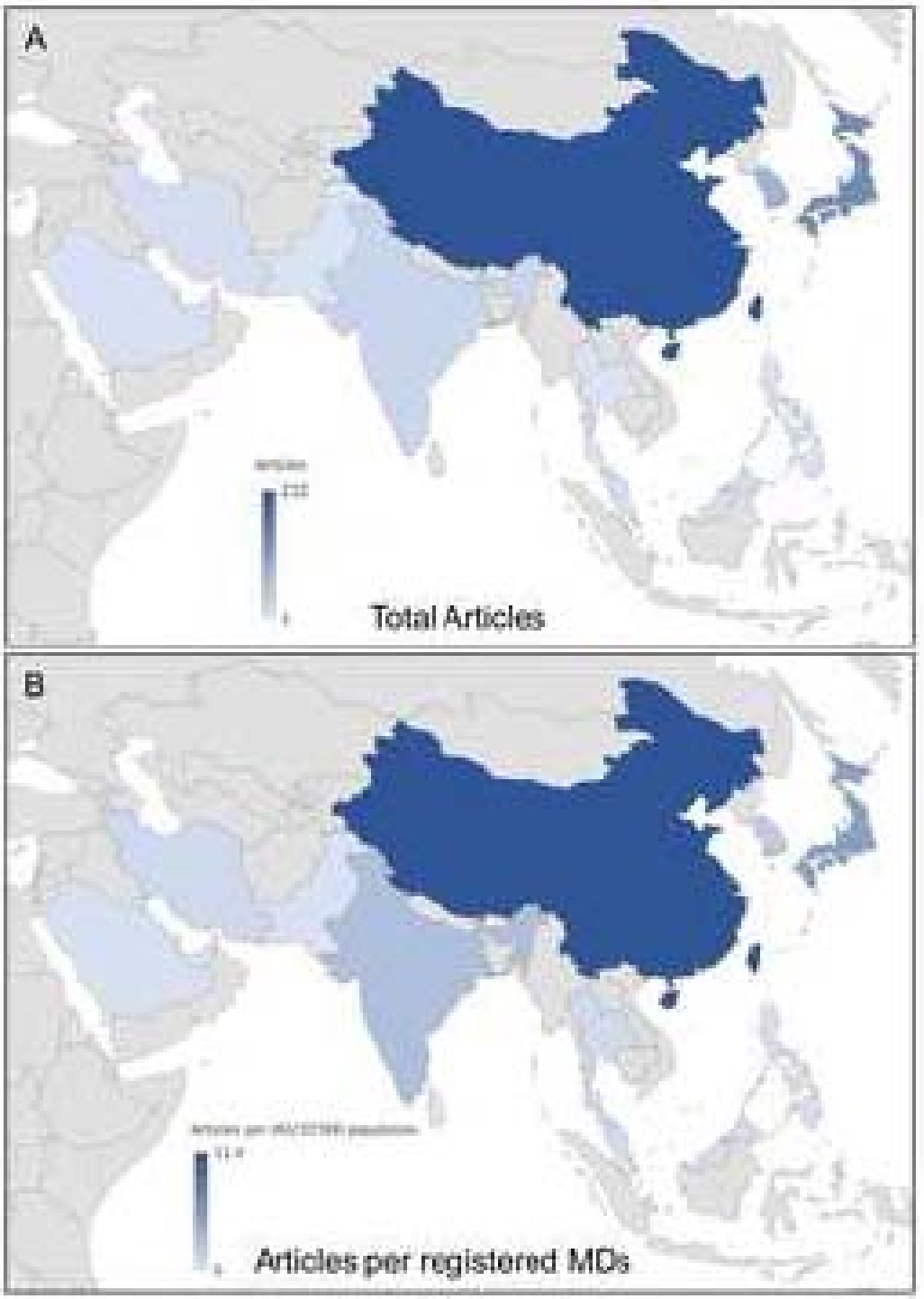

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Figure 5. Regional distribution, in total numbers, of published articles per country in Europe in 2020. **A** - Total numbers of articles. **B** – Articles normalized to registered MDs.The darker the color, the higher the number of articles published in that country or state. Grey indicates that no articles are published in the country.

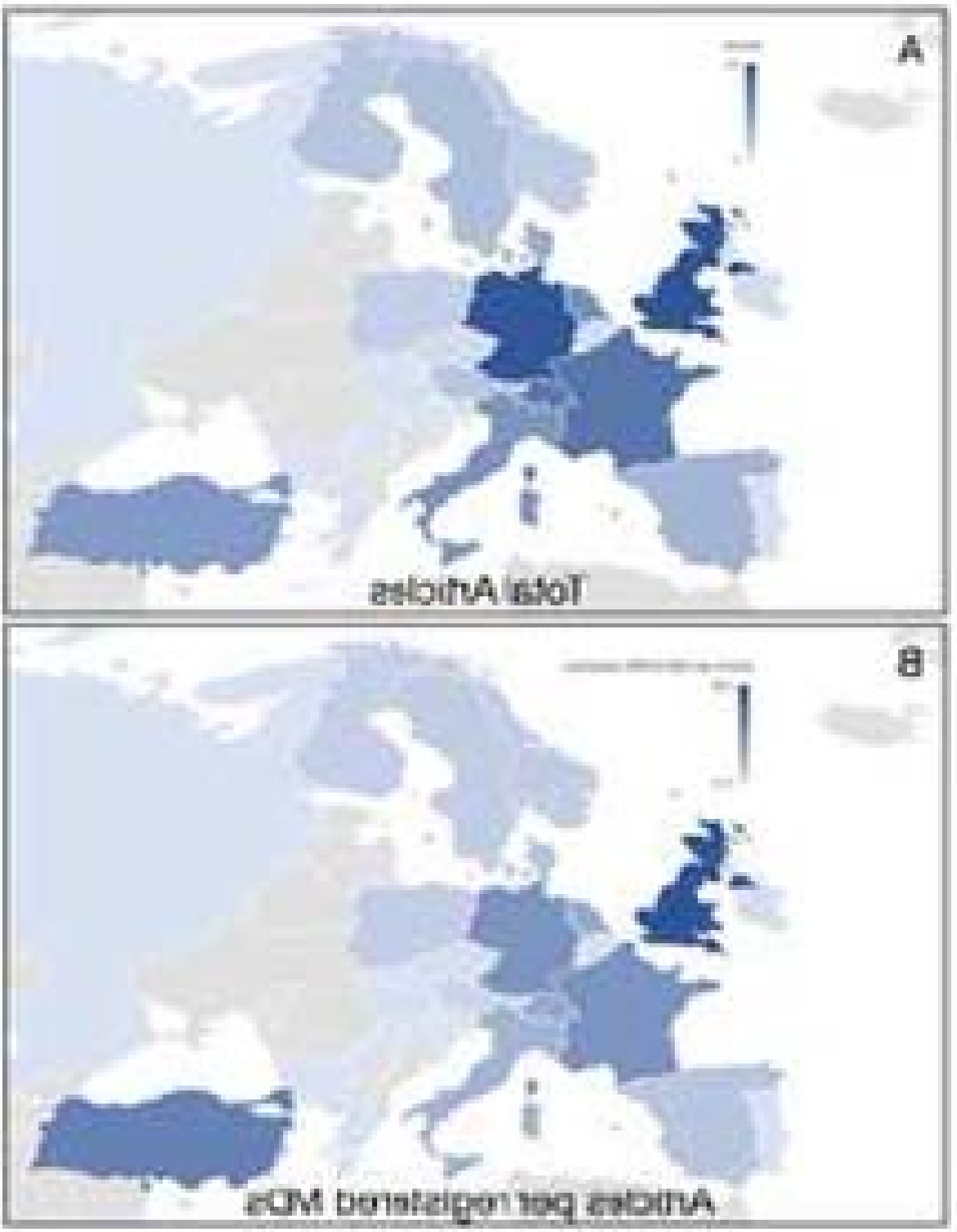

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Table 1. The number of publications distributed by journal over time (1976 to 2020). n.a. = not applicable

Journal	1976	1986	1996	2006	2016	2020
Spine	30	217	414	612	460	441
European Spine Journal	n.a.	n.a.	76	202	473	315
The Spine Journal	n.a.	n.a.	n.a.	116	211	219
Journal of Neurosurgery: Spine	n.a.	n.a.	n.a.	182	234	234
Total	**30**	**217**	**490**	**1112**	**1378**	**1209**

Table 2. Top 10 countries worldwide with the highest numbers of published papers in 2020, absolute and standardized to the registered medical doctors (MD). Table sorted from highest to lowest number of publications.

Rank	Country	*N*	%	Rank	Country	Medical doctors (per 10,000 population)	Articles per MD/10,000 population)
1	USA	416	34.4%	1	USA	26.0	16.0
2	China	189	15.6%	2	China	19.8	9.5
3	Japan	125	10.3%	3	Japan	24.8	5.0
4	South Korea	51	4.2%	4	India	9.3	2.7
5	Canada	43	3.6%	5	Canada	24.4	1.8
6	Netherlands	38	3.1%	6	South Korea	36.8	1.4
7	Germany	34	2.8%	7	Netherlands	37.1	1.0
8	UK	30	2.5%	8	Egypt	7.5	0.9
9	Australia	28	2.3%	9	Germany	43.0	0.8
10	Italy	27	2.2%	10	Thailand	9.2	0.8

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Table 3. Top 10 of the States of the United States of America with the highest numbers of published articles in 2020, absolute and normalized to registered medical doctors (MD). Table sorted from highest to lowest number of publications.

Rank	**State**	***N***	**%**	**Rank**	**State**	**Medical doctors (per 10,000 people)**	**Articles per MD/10,000 people**
1	New York	79	19.0	1	New York	49.9	1.6
2	California	50	12.0	2	California	39.9	1.3
3	Maryland	31	7.5	3	Illinois	37.3	0.7
4	Massachusetts	31	7.5	4	Pennsylvania	44.5	0.6
5	Pennsylvania	28	6.7	5	Maryland	50.1	0.6
6	Illinois	25	6.0	6	Massachusetts	51.9	0.6
7	Ohio	17	4.1	7	Texas	29	0.4
8	Minnesota	12	2.9	8	Ohio	41.5	0.4
9	Texas	12	2.9	9	Tennessee	36	0.3
10	Tennessee	11	2.6	10	Minnesota	44.5	0.3

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Table 4. Top 10 Asian countries with the highest number of published articles in 2020, absolute and standardized to registered medical doctors (MD). Table sorted from highest to lowest number of publications.

Rank	**Country**	***N***	**%**	**Rank**	**Country**	**Medical doctors (per 10,000 population)**	**Articles per MD/10,000 population**
1	China	189	44.0	1	China	19.8	9.5
2	Japan	125	29.1	2	Japan	24.8	5.0
3	South Korea	51	11.9	3	India	9.3	2.7
4	India	25	5.8	4	South Korea	36.8	1.4
5	Singapore	13	3.0	5	Thailand	9.2	0.8
6	Israel	8	1.9	6	Singapore	22.9	0.6
7	Thailand	7	1.6	7	Malaysia	15.4	0.4
8	Malaysia	6	1.4	8	Philippines	6.0	0.2
9	Lebanon	2	0.5	9	Israel	54.7	0.1
10	Iran	1	0.2	10	Lebanon	21.0	0.1

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Table 5 Top 10 European countries with the highest numbers of published articles in 2020, absolute and standardized to registered medical doctors (MD). Table sorted from highest to lowest number of publications. UK = United Kingdom

Rank	**Country**	***N***	**%**	**Rank**	**Country**	**Medical doctors (per 10,000 people)**	**Articles per MDs/10,000 people)**
1	Germany	43	14.6	**1**	Netherlands	37.1	1.0
2	Netherlands	38	12.9	**2**	Germany	43.0	1.0
3	France	34	11.5	**3**	Turkey	18.1	0.7
4	UK	30	10.2	4	Switzerland	43.3	0.6
5	Italy	27	9.2	5	France	65.3	0.5
6	Switzerland	27	9.2	6	UK	58.2	0.5
7	Denmark	17	5.8	7	Denmark	42.3	0.4
8	Sweden	16	5.4	8	Sweden	43.3	0.4
9	Turkey	13	4.4	9	Italy	80.1	0.3
10	Finland	10	3.4	10	Finland	46.4	0.2

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