Multiple Sclerosis Journal
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Mult Scler published online 25 September 2014
DOI: 10.1177/1352458514540357

The online version of this article can be found at:
http://msj.sagepub.com/content/early/2014/09/11/1352458514540357

Published by:
SAGE
http://www.sagepublications.com

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European Committee for Treatment and Research in Multiple Sclerosis

Americas Committee for Treatment and Research in Multiple Sclerosis

Pan-Asian Committee for Treatment and Research in Multiple Sclerosis

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MULTIPLE SCLEROSIS JOURNAL | MSJ

Research Paper

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1–11

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Abstract

Background and objectives: The aim of this paper is to analyse the scientific research on multiple sclerosis using a bibliographic analysis of articles published during the period 2003–2012.

Methods: The items under study were obtained from the Science Citation Index-Expanded (SCI-E) database, which was accessed through the Web of Science (WOS) platform. All records with the term 'multiple sclerosis' in the title, plus all articles published in the journals *Multiple Sclerosis* and *Multiple Sclerosis Journal*, were analysed.

Results: A total of 9778 articles, with 160,966 citations, were retrieved on multiple sclerosis, and the majority of the articles were published in *Multiple Sclerosis Journal* (n = 1511). The articles were published in journals belonging to 135 different subject areas, with the greatest number of papers falling under the category of clinical neurology. The countries that published the largest numbers of articles were the United States (US) (n = 2786), Italy (n = 1263), the United Kingdom (n = 1147) and Germany (n = 1018). International collaborations produced 20.4% of the papers.

Conclusions: We emphasise the progressive growth of publications worldwide, the publication of articles in a wide variety of journals covering numerous subject areas, and the research leadership of Western countries, most notably European countries, the US and Canada.

Keywords: Multiple sclerosis, articles, citations, impact factor, scientific collaboration

Date received: 17 February 2014; revised: 9 May 2014; accepted: 20 May 2014

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Introduction

Multiple sclerosis (MS) is a chronic neurologic disease characterised by inflammation, demyelination, gliosis and neuronal loss. It strikes young adults and is eventually disabling for many patients.[1] Although the causes of MS are still unknown, thanks to global research efforts, clear clues concerning the factors that influence the risk of developing MS are emerging.

The prevalence of MS in the population has doubled over the past 15 years, and the proportion of women who suffer from this disease compared to men has increased. MS affects more than 400,000 individuals in the United States (US), around 600,000 people in Europe and as many as 2 million people worldwide.[2]

An indicator of the social health importance of the disease is the number of articles on this disease that have been published in scientific journals. In January 2014, the PubMed database included 42,397 articles classified using the medical subject headings (MeSH) term 'multiple sclerosis'. Of these articles, 2952 articles reported clinical trials, including 1131 randomised controlled trials, 6821 review articles and 198 meta-analyses. Moreover, the growth of this research can be considered exponential: A total of 116 works from 1950 were included in the database, while there were 572 by 1990. In 2012, this figure rose to 2277. Some bibliometric studies have analysed the bibliometric profile of research on this disease in particular countries and during specific time periods, but these features are currently unknown at the global level.[3–6]

The aim of this article is to analyse the scientific research on MS using a bibliographic analysis of the

articles included in the Web of Science databases (WoS) during the period 2003–2012. The identification of some of the bibliometric characteristics of scientific research on MS can help young researchers better understand the field and/or acquire more knowledge concerning the current research trends, their impact and ongoing scientific collaboration.

Methods

The items under study were obtained from the Science Citation Index-Expanded (SCI-E) database, which was accessed through the WoS platform maintained by Thomson Reuters. The study period was limited to the decade 2003–2012. All records with the term 'multiple sclerosis' in the title, plus all articles published in the journals *Multiple Sclerosis* and *Multiple Sclerosis Journal*, were analysed. We also limited the search to Document Types=Article. The search was conducted in the field 'title' of the records for higher accuracy in the results.

The records obtained were transferred to a Microsoft Access database, which allowed us to manage the information contained in the records and to extract bibliometric indicators.

The main productivity indicators that were identified included the annual evolution of papers published, the growth rate in the decade, the journal distribution and the subject area distribution. The main identified indicators of scientific production included the annual evolution of published papers, the growth rate, the journal distribution and the subject area distribution. The growth rate in the decade 2003–2012 (percentage change from 2003 to 2012) is calculated as follows: (papers published in 2012– papers published 2003/ papers published in 2003) × 100.

As indicators of impact, the number of citations that each article received was also determined, as well as the average number of citations per paper and journal; the impact factors of the journals were extracted from the Journal Citation Reports (2012 edition) (JCR). To determine the average number of citations per paper, we divided the total number of citations received by the number of articles published. The citation window corresponds to the citations received by each article since joining the SCI-E until the end date of the bibliographic search.

In order to determine the international collaboration, the country of origin of authors was assigned using the information provided in the 'Address' field, as the WoS database includes in each record the institutions of all authors publishing the articles, including department, institution and country. The analysis of scientific collaboration among countries was performed using social network analysis (SNA). The Pajek software, which was designed for the analysis and visualisation of networks, was used for the construction and graphical representation of the collaboration between countries.[7] The collaboration index between authors was determined by calculating the mean number of signatories per work.

Results

General data

During the 2003–2012 period, 9778 articles were retrieved in WoS on MS; of these articles, 41.3% were published in the first five-year period, and 58.7% were published in the second five-year period. The highest number of articles was published in 2012. These articles received 160,996 citations. The growth rate from 2003 to 2012 was 82.18%. Figure 1 shows the evolution of the number of published articles and citations.

Journals

The papers were published in 1124 journals, of which 27 journals published more than 50 articles (Table 1). The journal that published the largest share of the articles was *Multiple Sclerosis Journal* (n = 1511), while four other journals published more than 300 articles each: *Journal of Neuroimmunology* (n = 419), *Journal of the Neurological Sciences* (n = 381), *Neurology* (n = 309) and *Journal of Neurology* (n = 304). *Multiple Sclerosis Journal* received the greatest number of citations (n = 19,888), followed by *Neurology* (n = 10,143) and *Annals of Neurology* (n = 8889). However, the ratio of citations (C) per article (A) in the most productive journals was greater for *Annals of Neurology* (C/A=62.2), followed by *Neurology* (C/A=32.8), *Journal of Immunology* (C/A=32.6) and *Neuroimage* (C/A=28.6). It should be noted that some less-productive journals may have a higher ratio, such as the *New England Journal of Medicine*, which published 22 papers (C/A=266.6) and *Proceedings of the National Academy of Sciences of the United States of America*, which published 38 papers (C/A=68.3).

The ratio of citations per article in *Multiple Sclerosis Journal* was 13.2. Among the 27 journals with more than 50 articles, 11 journals were in the first quartile of their subject category in JCR, and five were in the second quartile.

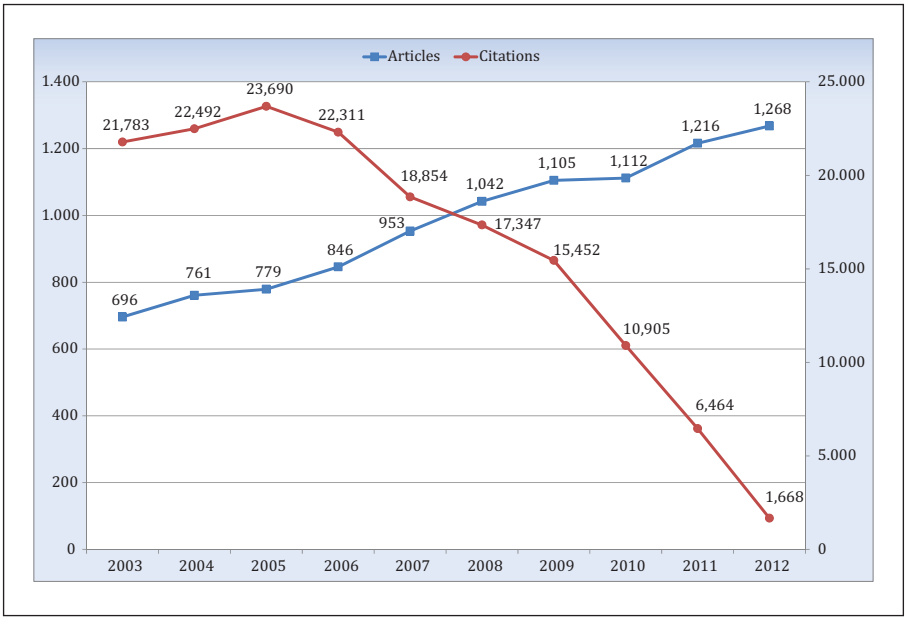

Figure 1. Evolution of the number of published papers and citations.

The impact factor of *Multiple Sclerosis Journal* has doubled since it was first included in JCR, from 2.154 in 1999 to 4.472 in 2012 (latest published edition of JCR). During these 14 years, it has also improved its ranking position in its category in JCR (clinical neurology) from 38th in 1999 (second quartile when the area included 132 journals) to 26th place in 2012 (first quartile when the area included 193 journals).

Subject areas

The articles were published in journals belonging to 135 subject areas. Table 2 shows the 26 most productive areas that included 50 or more papers. The subject category with the greatest number of papers was clinical neurology (n = 5447), followed by neurosciences (n = 2749), immunology (n = 932) and psychiatry (n = 668). The journals belonged mainly to the neurosciences (n = 151 journals) and clinical neurology (n = 137 journals) subject categories, but we highlight other areas, such as medicine, general and internal (n = 97 journals), pharmacology and pharmacy (n = 85 journals), biochemistry and molecular biology (n = 64 journals), immunology (n = 59 journals) and psychiatry (n = 59 journals). The area that received the greatest number of citations was clinical neurology (n = 90,978), followed by neurosciences (n = 51,616) and immunology (n = 17,550). The highest rate of citations per article corresponds to the subject area medicine general and internal (C/A=37.5), followed by genetics and heredity (C/A=27.1) and pathology (C/A=25.4).

Countries

The published papers involved institutions from 86 different countries. The 23 participating countries with the greatest number of papers are presented in Table 3. The countries with the greatest numbers of published papers were the US (n = 2786), followed by Italy (n = 1263), the United Kingdom (n = 1147) and Germany (n = 1018). Other countries that exceeded 500 works were Canada (n = 705), Spain (n = 575), the Netherlands (n = 555) and France (n = 527). The US also garnered the highest number of citations (n = 68,241), followed by the United Kingdom (n = 31,462) and Italy (n = 24,807). The highest rate of citations per article corresponds to Switzerland (C/A=33.4), followed by Canada (C/A=30.7) and Austria (C/A=30.4).

Most-cited papers (hot papers)

The papers that received more than 300 citations are presented in Table 4. The two works that received the most citations were both published by Polman et al. The first article, published in *Annals of Neurology* in 2005, has received 1690 citations, and the second, published in the *New England Journal of Medicine* in 2006, has received 861 citations. The number of papers without citations was 1454, which represents 14.88% of the total.

Scientific collaboration

The collaboration index for the decade was 6.35 authors per paper. This index increased at one point

Table 1. More productive journals, citations, impact factor (IF) and Web of Science (WoS) categories (+ 50 papers) and quartile.

Journal	Papers	Citations WoS	Citations per paper	IF 2012	WoS categories	Quartile	Category ranking
Multiple Sclerosis Journal	1511	19,888	13.2	4.472	Clinical neurology	Q1	25/190
Journal of Neuroimmunology	419	6667	15.9	3.033	Immunology; neurosciences	Q2	63/134; 116/251
Journal of the Neurological Sciences	381	5024	13.2	2.243	Clinical neurology; neurosciences	Q2; Q3	88/190; 162/251
Neurology	309	10,143	32.8	8.249	Clinical neurology	Q1	8/190
Journal of Neurology	304	4712	15.5	3.578	Clinical neurology	Q1	36/190
European Journal of Neurology	178	2480	13.9	4.162	Clinical neurology; Neurosciences	Q1; Q2	31/190; 65/251
Journal of Neurology Neurosurgery and Psychiatry	172	4325	25.1	4.924	Clinical neurology; psychiatry; surgery	Q1	17/190; 17/135; 4/195
Neurological Sciences	167	1063	6.4	1.412	Clinical neurology; neurosciences	Q3; Q4	133/190; 203/251
Annals of Neurology	143	8889	62.2	11.193	Clinical neurology; neurosciences	Q1	4/190; 9/251
PLoS One	142	1168	8.2	3.730	Multidisciplinary sciences	Q1	7/56
Zhurnal Nevrologii I Psikhiatrii Imeni S S Korsakova	103	44	0.4	0.062	Clinical neurology; psychiatry	Q4	189/190; 135/135
Clinical Neurology and Neurosurgery	90	796	8.8	1.234	Clinical neurology; surgery	Q4; Q3	147/190; 111/195
Revue Neurologique	88	235	2.7	0.510	Clinical neurology	Q4	174/190
Arquivos de neuro-psiquiatria	82	233	2.8	0.827	Neurosciences; psychiatry	Q4	226/251; 109/135
Disability and Rehabilitation	80	774	9.7	1.541	Rehabilitation	Q2	25/63
Neuroimage	80	2285	28.6	6.252	Neurosciences; neuroimaging; radiology, nuclear medicine and medical imaging	Q1	26/251; 2/14; 3/119
Journal of Immunology	79	2573	32.6	5.520	Immunology	Q1	24/134
European Neurology	76	575	7.6	1.500	Clinical neurology; neurosciences	Q3; Q4	128/190; 197/251
American Journal of Neuroradiology	73	1531	21.0	3.167	Clinical neurology; neuroimaging; radiology, nuclear medicine and medical imaging	Q2; Q2; Q1	52/190; 4/14; 24/119
Neuroepidemiology	69	700	10.1	2.370	Public, environmental and occupational health; clinical neurology	Q2	43/157; 83/190
BMC Neurology	64	443	6.9	2.564	Clinical neurology	Q2	76/190
Genes and Immunity	62	1067	17.2	3.675	Genetics and heredity; immunology	Q2	48/161; 43/134
Current Opinion in Neurology	54	1410	26.1	5.416	Clinical neurology; neurosciences	Q1	15/190; 38/251
Journal of Neuroimaging	52	962	18.5	1.409	Clinical neurology; neuroimaging; radiology, nuclear medicine and medical imaging	Q3	136/190; 9/14; 70/120
Nervenarzt	52	200	3.8	0.804	Clinical neurology; psychiatry	Q4	110/135
Nervenarzt	52	200	3.8	0.804	Clinical neurology; psychiatry	Q4	164/190
Revista de neurología	52	173	3.3	1.179	Clinical neurology	Q4	153/190

during the period, from 5.89 authors per work in 2003 to 6.99 in 2012 (Figure 2). Institutional collaboration presented the following characteristics: 76.6% of the articles were published in collaborations between institutions in the same country (domestic collaboration), 20.4% included international collaborations and

Table 2. Subject categories of journals (+ 50 papers).

Web of Science (WoS) categories	Papers	Citations WoS	Citations per paper	Different journals
Clinical neurology	5,447	90,978	16.7	137
Neurosciences	2,749	51,616	18.8	151
Immunology	932	17,550	18.8	59
Psychiatry	668	6,632	9.9	59
Radiology, nuclear medicine and medical imaging	466	8,054	17.3	45
Rehabilitation	438	3808	8.7	49
Surgery	345	5418	15.7	26
Medicine, general and internal	319	11,957	37.5	97
Pharmacology and pharmacy	278	2049	7.4	85
Neuroimaging	271	5495	20.3	12
Medicine, research and experimental	233	5749	24.7	56
Multidisciplinary sciences	220	5475	24.9	8
Biochemistry and molecular biology	212	4643	21.9	64
Genetics and heredity	207	5612	27.1	40
Public, environmental and occupational health	204	1784	8.7	49
Pathology	188	4768	25.4	26
Sport sciences	149	1374	9.2	26
Cell biology	144	2757	19.1	44
Psychology, clinical	143	1539	10.8	25
Psychology	137	1747	12.8	19
Ophthalmology	112	943	8.4	31
Health care sciences and services	101	813	8.0	23
Endocrinology and metabolism	72	726	10.1	22
Nursing	66	409	6.2	20
Urology and nephrology	58	368	6.3	19
Pediatrics	55	414	7.5	23

19.8% included a single institution, i.e. no collaboration (Figure 3). The total percentage exceeds 100% because some papers may receive the cooperation both of domestic and foreign institutions. The annual trend is increasing for papers with domestic and international collaboration and is stationary for papers without institutional collaboration. Collaboration between countries can be observed in Figure 4, which shows the dense network spread across the US, the United Kingdom, Germany, Italy, France, Canada, Spain and the Netherlands.

Discussion

This work has demonstrated several features of MS research: the progressive growth of publications worldwide; the publication of articles in a wide variety of journals in numerous subject areas; and the research leadership of Western countries, most notably European countries, the US and Canada. To analyse the research on MS, the WoS database, which is commonly used in studies examining scientific activity, was chosen. This database has several advantages over others, as it provides data on both scientific productivity and impact through the citation count and includes all institutions participating in the work and their country of origin information, which is not included in Medline, allowing for the quantification of collaboration between countries that publish these works.

The continued growth in the number of published papers has been observed in other studies. In a study published in 2002 in *Multiple Sclerosis*, Lana-Peixoto et al.[8] found that during the 1991–2000 period, 2098 papers came from countries on the American continent, 2511 came from Europe and 310 came from Asia, Australia and New Zealand. In the decade analysed in our work, the US published 2786 articles and the European Union published 5652 articles. The growth in the articles on MS must be considered in the context of the growth of biomedical research that occurred in the last decade. For instance, PubMed included 581,815 records in 2003 and 926,063 in 2012, thus the growth rate in the decade 2003–2012 was 59.17%. A search for articles in the WoS with the term ‘rheumatoid arthritis’ in the title in the same

Table 3. Countries of origin of papers (+100 papers).

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Papers	Citations	Citations per paper
United States	194	234	247	240	238	291	301	323	378	340	2786	68,241	24.5
Italy	94	98	113	100	124	136	140	155	149	154	1263	24,807	19.6
United Kingdom	112	83	92	99	112	117	127	135	124	146	1147	31,462	27.4
Germany	58	75	99	86	101	107	123	100	128	141	1018	21,296	20.9
Canada	45	52	58	50	78	77	86	86	85	88	705	21,637	30.7
Spain	36	40	43	47	49	69	65	63	84	79	575	9498	16.5
Netherlands	41	37	45	57	41	59	68	70	64	73	555	16,254	29.3
France	36	38	35	46	68	49	61	54	66	74	527	11,209	21.3
Switzerland	15	21	18	18	26	34	40	40	55	67	334	11,144	33.4
Australia	20	16	29	30	25	38	50	36	31	47	322	5859	18.2
Sweden	35	23	22	24	34	36	39	36	32	38	319	7868	24.7
Turkey	13	13	10	19	24	18	28	33	44	44	246	1492	6.1
Denmark	13	21	21	19	21	20	23	26	32	45	241	5459	22.7
Austria	18	22	25	13	20	26	23	18	31	24	220	6691	30.4
Japan	18	21	23	20	27	23	22	21	22	23	220	4555	20.7
Norway	11	10	16	11	20	22	29	23	21	31	194	4276	22.0
Iran	3	3	3	11	15	12	21	34	40	42	184	875	4.8
Russia	17	7	9	29	28	13	25	18	10	28	184	795	4.3
Israel	15	19	11	26	13	17	19	20	19	18	177	3223	18.2
Poland	9	14	9	9	14	21	13	25	20	20	154	3776	24.5
Brazil	4	6	10	14	17	14	24	20	17	22	148	755	5.1
Belgium	13	11	13	14	10	17	16	18	9	25	146	3266	22.4
Greece	4	10	10	12	9	16	11	21	18	8	119	1200	10.1
Czech Republic	8	5	10	8	10	14	15	10	11	26	117	2460	21.0
People's Republic of China	2	4	1	9	7	14	15	14	27	24	117	1180	10.1
Finland	8	14	10	10	11	13	9	14	10	11	110	2385	21.7

period retrieved 10,136 documents, with a growth rate of 75.16%, while the result of a search with the term 'diabetes' was 41,365 documents, with a growth rate of 129.98%. In short, it can be concluded that the growth of MS publications is higher than in general biomedical sciences and some diseases such as rheumatoid arthritis, but less than others, such as diabetes.

The *Multiple Sclerosis Journal*, formerly *Multiple Sclerosis*, has published the greatest number of articles, which is logical because it is specific for the disease. It has also increased its international recognition, as measured by citations and impact. As observed, the articles were published both in neurological and non-neurological subject areas, including medicine, general and internal, psychology and psychiatry, biochemistry and molecular biology journals, which reveals the participation and collaboration of numerous specialists from different areas. This is logical and necessary in a disease such as MS, which requires an integrated, multidisciplinary approach among various biomedical specialties.

Although the papers from domestic collaborations predominated, a growth in international collaboration was evident. International collaboration is needed to address priorities and fund research, with the ultimate goal of accelerating the development of disease-modifying treatments to alleviate the symptoms of MS. The heterogeneity of MS requires that these issues are addressed through international efforts to support the full range of research projects related to the diagnosis and prevention of MS and to permit the effective translation of research into treatments.[10,11] Moreover, collaborative research allows scientists to participate in multicentre clinical trials, a type of research necessary for the development of new treatments for this disease.

Table 4. Most cited papers (hot papers).

Authors	Title	Reference	Citations
Polman CH, Reingold SC, Edan G, et al.	Diagnostic criteria for multiple sclerosis: 2005 Revisions to the "McDonald Criteria"	*Ann Neurology* 2005; 58: 840–846	1690
Polman CH, O'Connor PW, Havrdova E, et al.	A randomized, placebo-controlled trial of natalizumab for relapsing multiple sclerosis	*N Engl J Med* 2006; 354: 899–910	861
Viglietta V, Baecher-Allan C, Weiner HL, et al.	Loss of functional suppression by CD4(+)CD25(+) regulatory T cells in patients with multiple sclerosis	*J Exp Med* 2004; 199: 971–999	804
Lennon VA, Wingerchuk DM, Kryzer TJ, et al.	A serum autoantibody marker of neuromyelitis optica: Distinction from multiple sclerosis	*Lancet* 2004; 364: 2106–2112	781
Hafler DA, Compston A, Sawcer S, et al.	Risk alleles for multiple sclerosis identified by a genomewide study	*N Engl J Med* 2007; 357: 851–862.	685
Lennon VA, Kryzer TJ, Pittock SJ, et al.	IgG marker of optic-spinal multiple sclerosis binds to the aquaporin-4 water channel	*J Exp Med* 2005; 202: 473–477	641
Miller DH, Khan OA, Sheremata WA, et al.	A controlled trial of natalizumab for relapsing multiple sclerosis.	*N Engl J Med* 2003; 348: 15–23	626
Pluchino S, Quattrini A, Brambilla E, et al.	Injection of adult neurospheres induces recovery in a chronic model of multiple sclerosis	*Nature* 2003; 422: 688–694	579
Hauser SL, Waubant E, Arnold DL, et al.	B-cell depletion with rituximab in relapsing–remitting multiple sclerosis	*N Engl J Med* 2008; 358: 676–688	534
Munger KL, Levin LI, Hollis BW, et al.	Serum 25-hydroxyvitamin D levels and risk of multiple sclerosis	*JAMA* 2006; 296: 2832–2838	530
Kleinschmidt-DeMasters BK and Tyler KL	(Brief report) Progressive multifocal leukoencephalopathy complicating treatment with natalizumab and interferon beta-1a for multiple sclerosis	*N Engl J Med* 2005; 353: 374–483	483
Kutzelnigg A, Lucchinetti CF, Stadelmann C, et al.	Cortical demyelination and diffuse white matter injury in multiple sclerosis	*Brain* 2005; 128: 2705–2712	481
Rudick RA, Stuart WH, Calabresi PA, et al.	Natalizumab plus interferon beta-1a for relapsing multiple sclerosis	*N Engl J Med* 2006; 354: 911–923	427
Kappos L, Antel J, Comi G, et al.	Oral fingolimod (FTY720) for relapsing multiple sclerosis	*N Engl J Med* 2006; 355: 1124–1140	417
Munger KL, Zhang SM, O'Reilly E, et al.	Vitamin D intake and incidence of multiple sclerosis	*Neurology* 2004; 62: 60–65	380
Kappos L, Radue EW, O'Connor P, et al.	A Placebo-controlled trial of oral fingolimod in relapsing multiple sclerosis	*N Engl J Med* 2010; 362: 387–401	378
Barnett MH and Prineas JW	Relapsing and remitting multiple sclerosis: Pathology of the newly forming lesion	*Ann Neurol* 2004; 55: 458–468	375
Cohen JA, Barkhof F, Comi G, et al.	Oral fingolimod or intramuscular interferon for relapsing multiple sclerosis	*N Engl J Med* 2010; 362: 402–415	366
Greter M, Heppner FL, Lemos MP, et al.	Dendritic cells permit immune invasion of the CNS in an animal model of multiple sclerosis	*Nat Med* 2005; 11: 328–325	325

Collaboration allows the exchange of knowledge and experiences and facilitates access to scientific facilities for different research groups.[12] Developing countries can benefit from the research conducted in the most scientifically advanced countries and can also benefit from their funding sources.

One research instrument that encourages collaboration is the MS registries, which allow researchers to share valuable data about the disease. However, a need for national registries and international collaborative research has been highlighted in previous studies.[13–15]

Today, the Internet provides an excellent opportunity for international collaborative studies on MS.[16] The potential of online platforms for research in MS has been described in a recent paper;[17] this paper confirmed the utility of this online platform by demonstrating its potential to provide a venue for MS investigations with unique strengths (frequent data collection, large sample sizes).

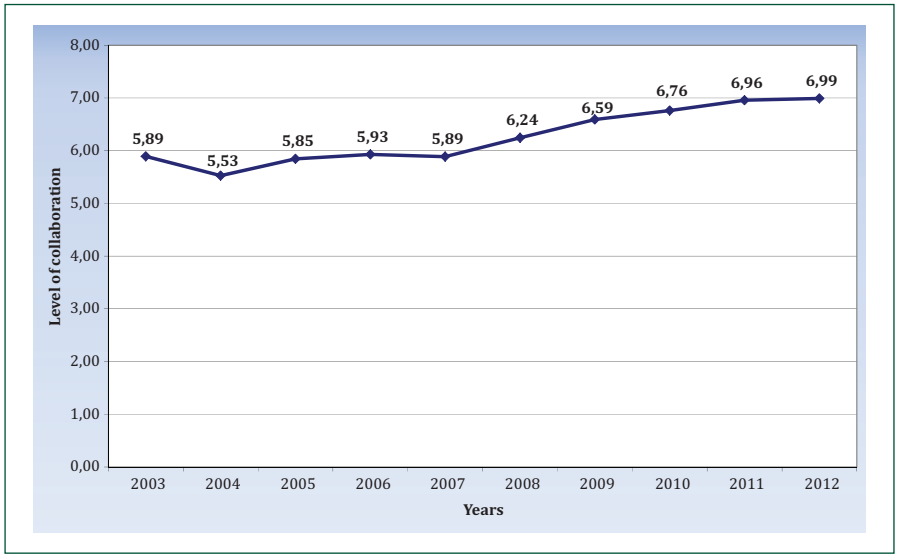

Figure 2. Evolution of the collaboration index.

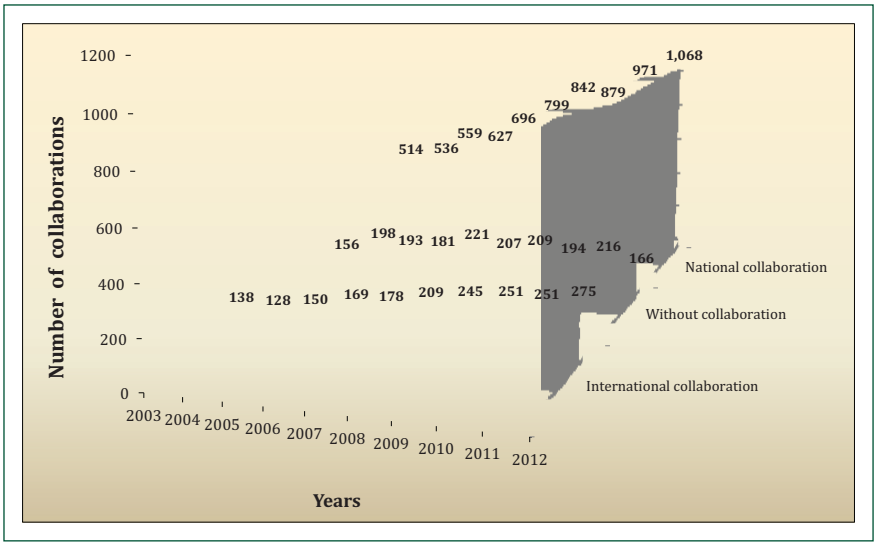

Figure 3. Evolution of scientific collaboration.

Other opportunities for MS studies are offered by scientific societies. For example, in the US, the National MS Society[18] (http://www.nationalmssociety.org/research/index.aspx) supports and funds research activities spanning all stages of research, including early discovery research, translational research that brings promising ideas forward into actual therapeutic solutions for testing, and clinical trials by offering special funding for collaborative teams. In this context should be mentioned the collaboration between the Multiple Sclerosis International Federation (MSIF) and the World Health Organisation, which has led to the creation of the Atlas of MS Database,[19,20] which provides information on the epidemiology of the disease and the resources available to their patients. The MSIF currently has the participation of 124 countries.

The social health importance of this disease reflects the number of institutional and private initiatives that have arisen in recent years. The Multiple Sclerosis International Federation has identified 92 MS organisations from Europe (38), Latin America (18), Middle East and North Africa (18), North America (three), Pan-Asia (11) and sub-Saharan Africa (four), in addition to a set of local organisations spread all over the world.[21] In addition, some social media initiatives, such as MS Connection (https://www.msconnection.

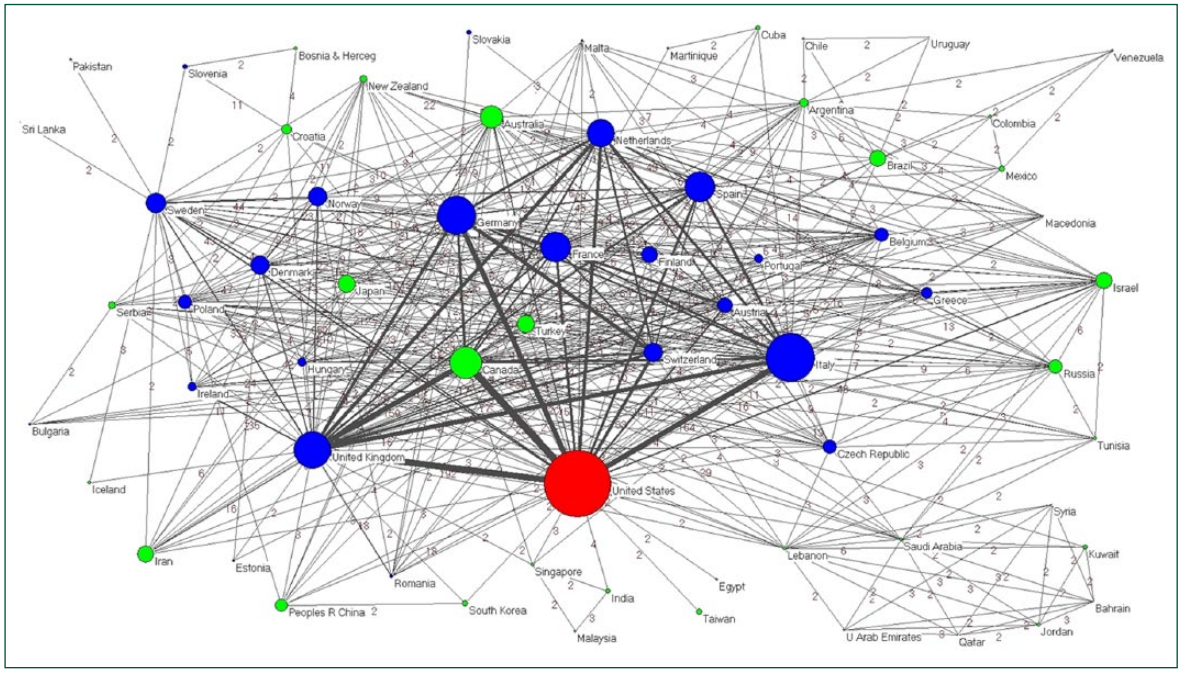

Figure 4. Network of collaboration between countries.
Peoples R China: People's Republic of China; Bosnia & Herceg: Bosnia and Herzegovina.

org/), created by the National Multiple Sclerosis Society to compile and share experiences from people living with MS, as well as the MS Blogger Community Online (http://www.msbloggers.com/) with 338 members, have emerged in recent years as a response to the social concern provoked by MS. A study by Bogosian et al. found six charities that fund research on MS (MS Society Canada, MS Trust (UK), MS Society New Zealand, MS Society Australia, National MS Society (US) and MS Society UK), which reflects the presence of private funding.[22]

Regarding the impact of papers, in our study the number of papers without citations represents 14.88% of the total. The percentage of uncited papers found in the literature varies widely. A study in the journal *Science* in 1991 found a total of 28% uncited papers,[23] similar to those found in general journals of chemistry (27%).[24] In 2004, a study reported that in cardiovascular research, 34.3% of papers remain uncited.[25] A more recent study published in 2010 found a percentage of 30.5% in several journals.[26] However, we have to keep in mind that the share of uncited papers changes in time because of the delay of several years of the citation of previous papers. Concerning hot papers, the article with more citations is a revision of diagnostic criteria for MS. In scientific literature, articles publishing consensus and agreements, as well as review articles, tend to receive more citations than others. In our study, the paper with the highest number of citations is on MS criteria, while the second most-cited article is a randomised controlled trial. Moreover, it is noteworthy that most of the hot papers have been published in high-impact journals of general purpose, such as *New England Journal of Medicine, Lancet, JAMA* and *Nature*. Obviously the number of citations of published papers is higher in the early years of the period, as they are available longer to be cited.

There are some limitations to this study that should be considered. Some articles have been published in journals that are not included in the WoS. However, the advantages of WoS should not be forgotten; this database includes journals with greater international impact and provides information on the number of citations, the impact factor of the journals and the institutional affiliations of all authors. Another limitation is due to the loss of relevant documents not including the term 'multiple sclerosis' in the title. However, searches in the field 'topic' that include the search in title, abstract, keywords and KeyWord plus would have retrieved non-relevant articles, so finally we chose the accuracy related to searches in the title instead of the exhaustiveness of the searches in the field topic. The inclusion of all articles of *Multiple Sclerosis* and *Multiple Sclerosis Journal* regardless of whether that term appeared in the title, is a bias in favour of this journal. However, we think it is logical to include all of them, since all articles published in the journal address MS. The limitations

of the impact factor of the journals as an indicator of the quality of the papers are widely known and have been published in other studies; however, thus far, no alternative indicators have been consolidated.[27]

The most important conclusions of this work are: 1) There has been a progressive increase in the number of articles published during the study period, confirming the importance of global research on MS; 2) papers have been published in a wide range of journals belonging to numerous subject areas, most notably *Multiple Sclerosis Journal*; and 3) Western countries are leading the research on this disease and scientific collaborations. Future work should test these trends in future periods, and it is necessary to encourage and support research on MS in other areas of the world.

Conflict of interest

None declared.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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