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The Evolution of Publications in the Field of Scoliosis: A Detailed Investigation of Global Scientific Output Using Bibliometric Approaches

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ABSTRACT

AIM: To carry out an in-depth bibliometric analysis of scoliosis literature.

MATERIAL and METHODS: This study used the Web of Science database to identify relevant articles for analysis. The literature search used the keyword "scolio*" and focused on the period between 1980-2019. Bibliometric network visualizations and mapping of specific results were done using VOSviewer software.

RESULTS: The literature search yielded 9706 publications on scoliosis between 1980 and 2019. Of these, 6975 (71.9%) journal articles were included in the bibliometric summary. Orthopedics was the most common area of research (4581 articles, 65.67%), and the United States of America (USA) exhibited the highest publication productivity (2327 articles, 33.36%). Nanjing University in China had the highest number of publications among institutions (n=219, 3.13% of the total literature), and there were a total of 60130 citations in 6975 articles. Fifty-five articles had a minimum of 100 citations, and the journal with the highest number of publications was 'Spine' (number of article: 1628, 23.3%).

CONCLUSION: This bibliometric analysis may be regarded as a summary and evaluation of global scientific output on scoliosis and can, therefore, be used a guide for researchers, clinicians and students. Furthermore, the keyword analysis can aid professionals in the field when planning new studies.

KEYWORDS: Scoliosis, Bibliometric analysis, Citation analysis, VOSwiever, Most cited

ABBREVATIONS: WoS: Web of science, **GDP:** Gross domestic product, **HDI:** Human development index, **USA:** United States of America, **UK:** United Kingdom

INTRODUCTION

Scoliosis, a common deformity of the spine, is well-recognized and continues to attract high scientific interest aimed at understanding the complex mechanisms behind it (48). However, despite the increasing number of publications and numerous paradigm shifts in this field of research, several gaps in the knowledge base still exist (17,22,49).

Bibliometric analysis methods such as citation analysis represent a valuable tool often used to examine the trends and academic impact of scientific literature in various fields of research (33,41) and also determine the strength of publications (11). They typically use various statistical methods to analyze citations and compare differences between countries, institutions, authors, and time points (25). Recently, there has been a rapid increase in the number of bibliometric studies examining medical literature, with the aim of summarizing scholarly publications, identifying high-impact studies and contemporary trends in research, recognizing active journals, and investigating collaborations between countries (7-10,13,21,23,26).

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However, despite the large number of studies focusing on scoliosis, bibliometric analyses in this field are few and limited in the range of literature included (33,35,50). Therefore, the aim of this study was to provide a summary of global research output in the field of scoliosis by carrying out a bibliometric analysis of all relevant journal articles published since 1980 and exploring articles and journals with the highest academic impact, collaborations between countries, factors affecting publication productivity, and trends in research topics.

MATERIAL and METHODS

All data on articles focusing on scoliosis and published between 1980 and 2019 were extracted from Web of Science (WoS; Web of Science by Clarivate Analytics) on the 2nd of January 2020 and analyzed using bibliometric techniques. Ethical approval was not required for this study as the search was conducted using public databases. The title keyword used for the literature search was "scolio*" [Title: (scolio*) *Refined by: Document Types: (ARTICLE) Timespan: 1980-2019. Indexes: SCI-Expanded, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI)*], and a built-in function of WoS allowed us to explore the trends in publications and their distribution across countries, research areas, active organizations, active journals, active authors, trend topics, and number of citations. GunnMap2 (http://lert.co.nz/map/) was used to illustrate a world map, and bibliometric network and density visualizations and mapping were carried out using the VOSviewer software, version 1.6.13 (Van Eck and Waltman, Leiden University, Leiden, The Netherlands) (40). Outcomes were represented using labels, circles, and lines on the network visualization map, with larger circles representing greater contributions by that item and thick lines positioned close together indicating strong relationships. Elements on the density visualization map were assigned colors on a density scale increasing from blue to red, with a higher number of items around a point and greater weight of the neighboring items representing the red end of the scale.

Statistical analyses were carried out using SPSS (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) Kolmogorov-Smirnov tests were used to explore data distributions, and correlations between the number of publications in a country and their gross domestic product (GDP), GDP per capita (purchasing power parity), and human development index (HDI) were analyzed using the Spearman's correlation coefficient. Linear regression was used to estimate the number of future publications (2019-2029), and a p value < 0.05 was considered statistically significant.

RESULTS

Total Number of Publications and Types of Documents

The literature search yielded 9706 publications, of which 6975 (71.9%) were journal articles, 808 (8.3%) were proceedings papers, 774 (7.9%) were meeting abstracts, 411 (4.2%) were editorial material, 364 (3.8%) were reviews and 360 (3.7%) were letters and others. This study included only journal articles, and the most common languages of publication were English (n=6538; 93.7%), German (n=202), French (n=154), Russian (n=26), Spanish (n=15), Italian (n=12), Turkish (n=9), Portugese (n=6), Czech (n=5), Slovenian (n=3), Afrikaans (n=1), Hungarian (n=1), Persian (n=1), Polish (n=1), and Serbo Croatian (n=1). The total number of citations for journal articles was 130678, of which 69829 were self-citations and were excluded. The mean number of citations per article was 18.74, and the total h-index for all included journal articles was 118.

Active Research Areas

The most common area of research was orthopedics with 4581 (65.67%) published articles, followed by clinical neurology (2975, 42.6%); surgery (1041, 14.9%); pediatrics (744, 10.6%); general internal medicine (297, 4.2%); rehabilitation (242, 3.4%); biomedical engineering (215, 3.0%); radiology, nuclear medicine, and medical imaging (165, 2.3%); experimental research in medicine (137, 1.9%); anesthesiology (135, 1.9%); sports sciences (123, 1.7%); hereditary genetics (116, 1.6%); neurosciences (112, 1.6%); multidisciplinary sciences (98, 1.4%); and rheumatology (82, 1.1%).

Development of Publications

The distribution of publication years has been shown in Figure 1. Regression analysis estimated that 563 journal articles [95% confidence interval (CI): 510-615] would be published in 2020 and this would increase to 941 (95 CI%: 678-1204) in 2029. Other estimations have also been shown in Figure 1.

Active and Productive Countries

The United States of America ranked first in terms of productivity (measured using number of published articles) with 2327 publications, followed by China (925), Canada (578), Japan (442), UK (435), France (422), Germany (357), South Korea (209), Turkey (198), Italy (191), Sweden (186), Australia (113), Poland (112), Netherlands (110), Spain (104), India (96), Switzerland (78), Finland (75), Greece (70), Brazil (68), Taiwan (68), Israel (57), Iran (53), Denmark (50), and Austria (49) (Figure 2).

Published articles originated from a total of 90 countries, and international collaboration networks between countries that published a minimum of 5 articles together have been shown in Figure 3.

Factors Associated with the Numbers of Publications

A statistically significant correlation ($p<0.001$) between the number of publications on 'scoliosis' and GDP ($r=0.709$), GDP per capita ($r=0.650$), and HDI was observed ($r=0.631$).

Active Authors and Organizations

The ten most active authors were Qiu Y (212), Labelle H (170), Zhu ZZ (164), Lenke LG (142), Cheng JCH (128), Aubin CE (102), Bridwell KH (100), Newton PO (100), Betz RR (97) and Liu Z (85). The most active organizations in scoliosis research have been listed in Table I.

Active Journals

There were a total of 986 journals that published articles on scoliosis, of which 30 journals had published a minimum of 30

Table I: Active Organization and Organizations-Enhanced on Scoliosis

Organizations	RC	Organizations-Enhanced	RC
Nanjing University	219	University of Montreal	293
Washington University	202	Nanjing University	225
Shriners Hospital Children	167	Washington University WUSTL	216
Montreal University	144	University of California System	210
Chinese University Hong Kong	143	Polytechnique Montreal	147
Ecole Polytech	106	Chinese University of Hong Kong	145
University Hong Kong	104	Shriners Hospitals Children Philadelphia	138
Texas Scottish Rite Hospital Children	103	Assistance Publique Hopitaux Paris APHP	137
University Calif San Francisco	95	Harvard University	132
Hop ST Justine	85	Texas Scottish Rite Hospital for Children	130
Hospital Special Surgery	84	University of Hong Kong	109
Second Mil Med University	84	Chinese Academy of Medical Sciences Peking Union Medical College	108
Chinese Acad Med Sci	80	Peking Union Medical College Hospital	108
Minnesota University	80	Nemours Alfred I Dupont Hospital for Children	102
Alberta University	73	Johns Hopkins University	101
Childrens Hospital Philadelphia	72	Boston Childrens Hospital	100
Virginia University	72	University of Pennsylvania	98
Johns Hopkins University	71	PLA Second Military Medical University	97
University Calif San Diego	68	University of California San Francisco	95
Keio University	67	Rady Childrens Hospital San Diego	93
NYU	64	University of London	88
Rady Childrens Hospital	54	Hospital Special Surgery	84
Columbia University	53	New York University	84
Hong Kong Polytech University	52	University of Minnesota System	82
		University of Minnesota Twin Cities	82

RC: *Record count.*

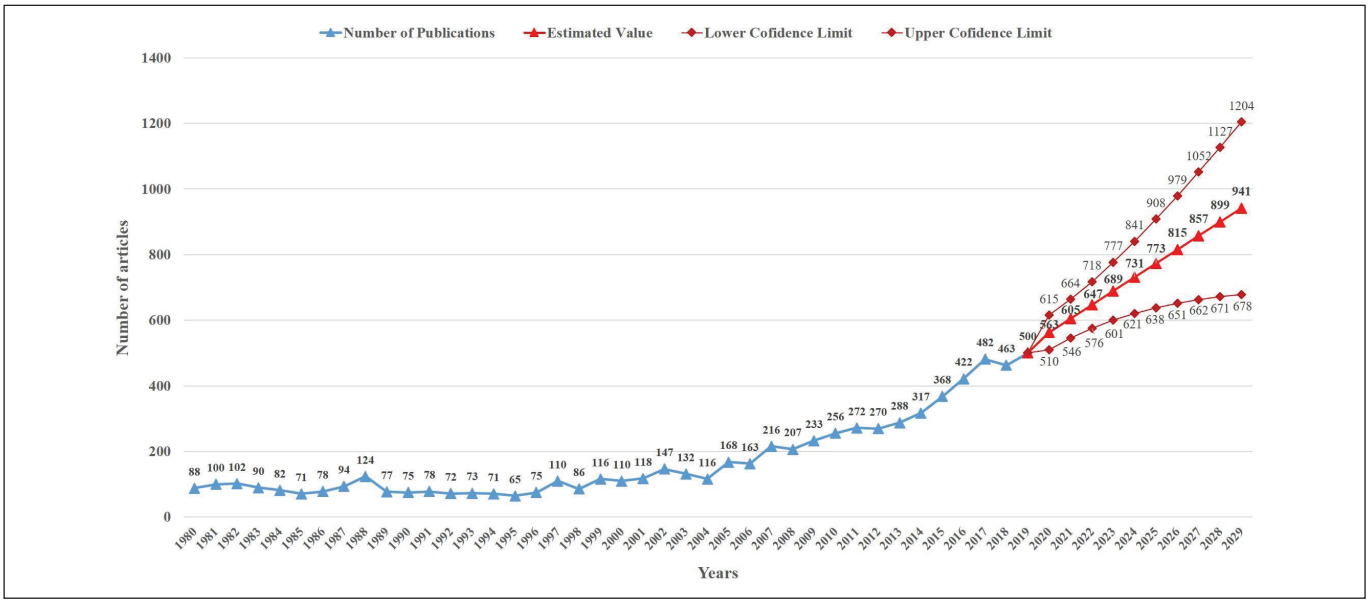

Figure 1: Number of publications on the topic of scoliosis by year.

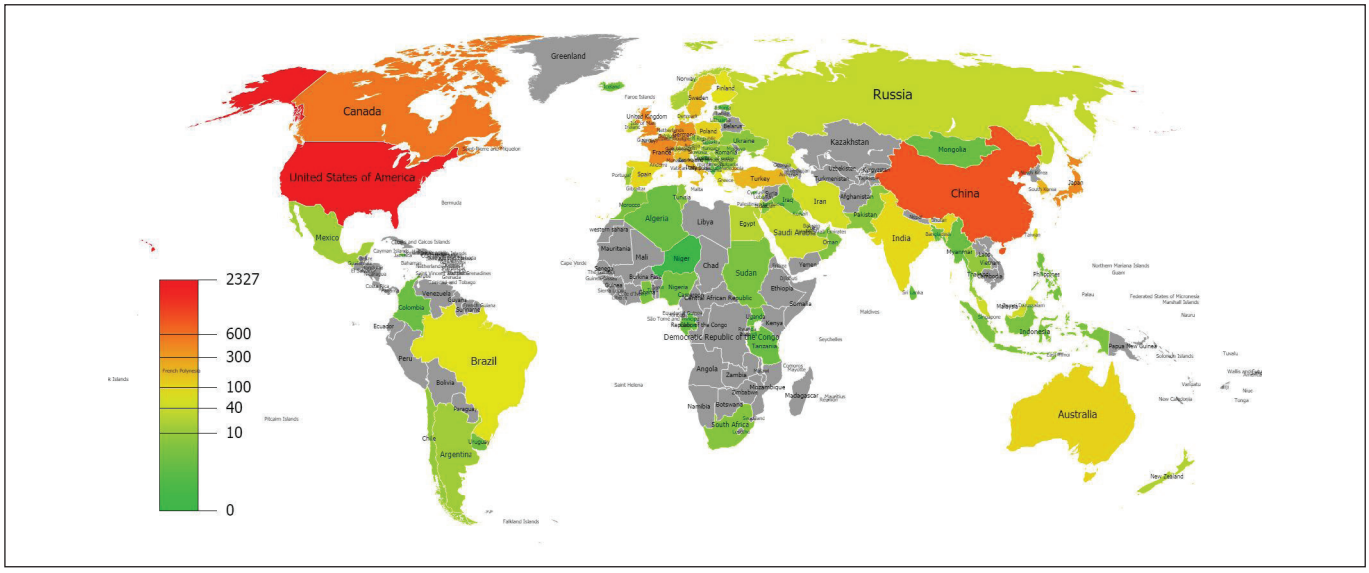

Figure 2: World map showing publication productivity in the field of scoliosis by country. [Productivity is represented on a scale ranging from green (low) to red (high)].

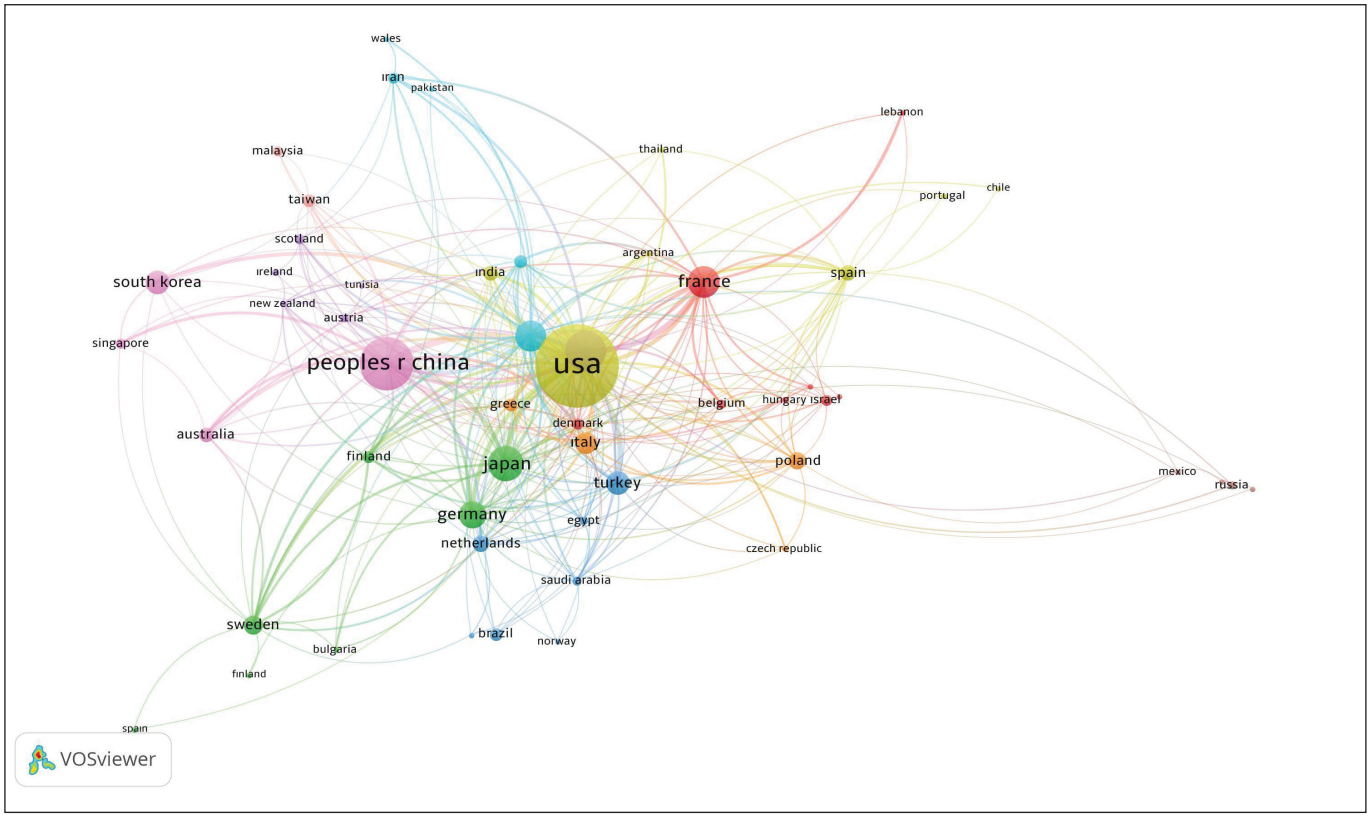

Figure 3: Network visualization map for international collaborations on scoliosis.
(The sizes of the circles represent the number of publications, the colors indicate clusters of collaborations, and the thickness of the lines indicates strength of collaborations).

articles (Table II). The total number of citations and number of citations per article have been shown in Table II, while Figure 4 presents a citation network visualization map of these journals.

Citation Analysis

The twenty most cited articles have been listed in Table III along with the mean number of citations per year.

Co-Citation Analysis

There were 60130 citations for 6975 articles, with 55 articles having a minimum of 100 citations (co-citation density map shown in Figure 5). Moreover, 9 studies had been cited in over 200 articles (articles with highest number of co-citations) and these were as follows: Lenke et al. published in 2001 and cited 607 times (27); Cobb JR published in 1948 and cited 559 times (6); King et al. published in 1983 and cited 384 times (24); Lonstein and Carlson published in 1984 and cited 315 times (29); Weinstein et al. published in 2008 and cited 283 times (43); Nachemson and Peterson published in 1995 and cited 223 times (31); Harrington published in 1962 and cited 215 times (20); Nash and Moe published in 1969 and cited 213 times (32); and Suk et al. published in 1995 and cited 213 times (39).

Trending Topics

There were a total of 8466 keywords used in 6975 articles, and the 95 keywords used in at least 25 different articles have been listed in Table IV. Figures 6-8 show cluster network visualization maps for these keywords, trend analysis using network visualization maps for keywords, and network visualization map of keywords from articles with the most number of citations, respectively.

DISCUSSION

This study found an increasing trend in the number of published articles on scoliosis since 2008. Between 1980 and 2006, the number of published articles ranged from 65 to 168, and this increased to 216 by 2007. Between 2007 and 2015, the number of published articles remained between 207 and 368, after which it increased to 400 in 2016 and 500 in 2019. Linear regression analysis confirmed this increase and estimated that a similar increasing trend would persist.

Countries with stronger economies such as USA, China, Canada, Japan, UK, France, Germany, South Korea and Italy appeared to be more productive. However, developing countries also had significant contributions in this field of research, with Turkey, India, Brazil, Taiwan, Israel and Iran

Table II: Active Journals on Scoliosis

Journals	RC	C	AC	Journals	RC	C	AC
Spine	1628	56381	34.6	Clinical Spine Surgery	54	160	3.0
European Spine Journal	576	8849	15.4	Journal of Neurosurgery Spine	54	651	12.1
Journal of Pediatric Orthopaedics	339	7050	20.8	International Orthopaedics	51	50	1.0
Journal of Bone and Joint Surgery American Volume	209	13457	64.4	World Neurosurgery	51	746	14.6
Spine Journal	137	1226	8.9	Clinical Biomechanics	47	541	11.5
Clinical Orthopaedics and Related Research	129	2561	19.9	Plos One	46	369	8.0
Journal of Spinal Disorders Techniques	117	1708	14.6	Acta Orthopaedica Scandinavica	43	823	19.1
Journal of Pediatric Orthopaedics Part B	93	761	8.2	Orthopedic Clinics of North America	43	992	23.1
Zeitschrift Fur Orthopadie und İhre Grenzgebiete	93	468	5.0	Orthopedics	41	449	11.0
Scoliosis and Spinal Disorders	90	357	4.0	Archives of Orthopaedic and Trauma Surgery	39	287	7.4
Journal of Bone and Joint Surgery British Volume	88	3640	41.4	Journal of Orthopaedic Science	38	250	6.6
Bmc Musculoskeletal Disorders	71	467	6.6	Journal of Spinal Disorders	38	812	21.4
Medicine	64	181	2.8	Journal of Neurosurgery Pediatrics	37	281	7.6
Revue de Chirurgie Orthopedique et Reparatrice de L'Appareil Moteur	57	274	4.8	Journal of Orthopaedic Research	37	856	23.1
Orthopade	55	270	4.9	Asian Spine Journal	30	39	1.3

***RC:** Record count, **C:** Number of citation, **AC:** Average citation per document.*

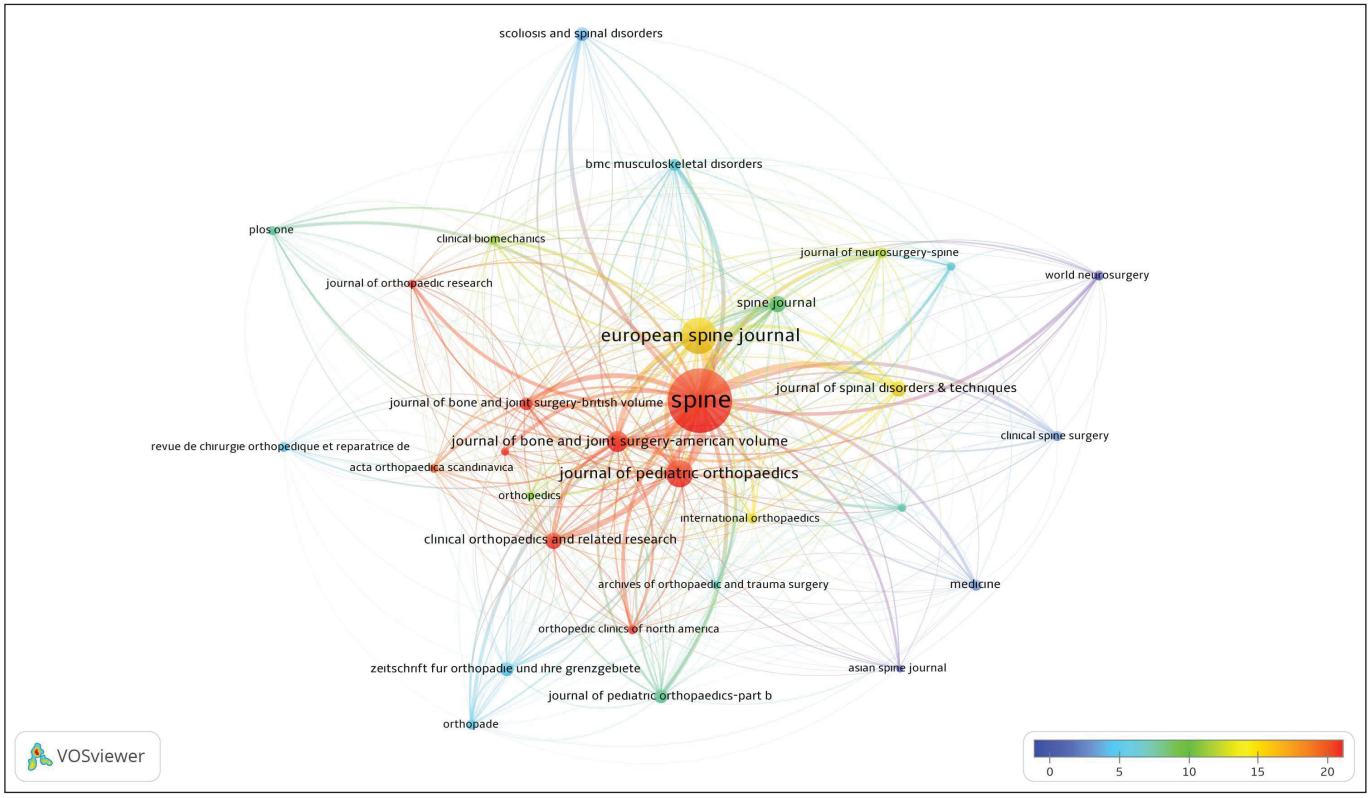

Figure 4: Network visualization map showing citation analysis of most active journals in the field of scoliosis.
[The mean number of citations increases from blue to red (blue-green-yellow-red). The sizes of the circles represent the number of publications, and the thickness of the lines indicates strength of citation collaborations].

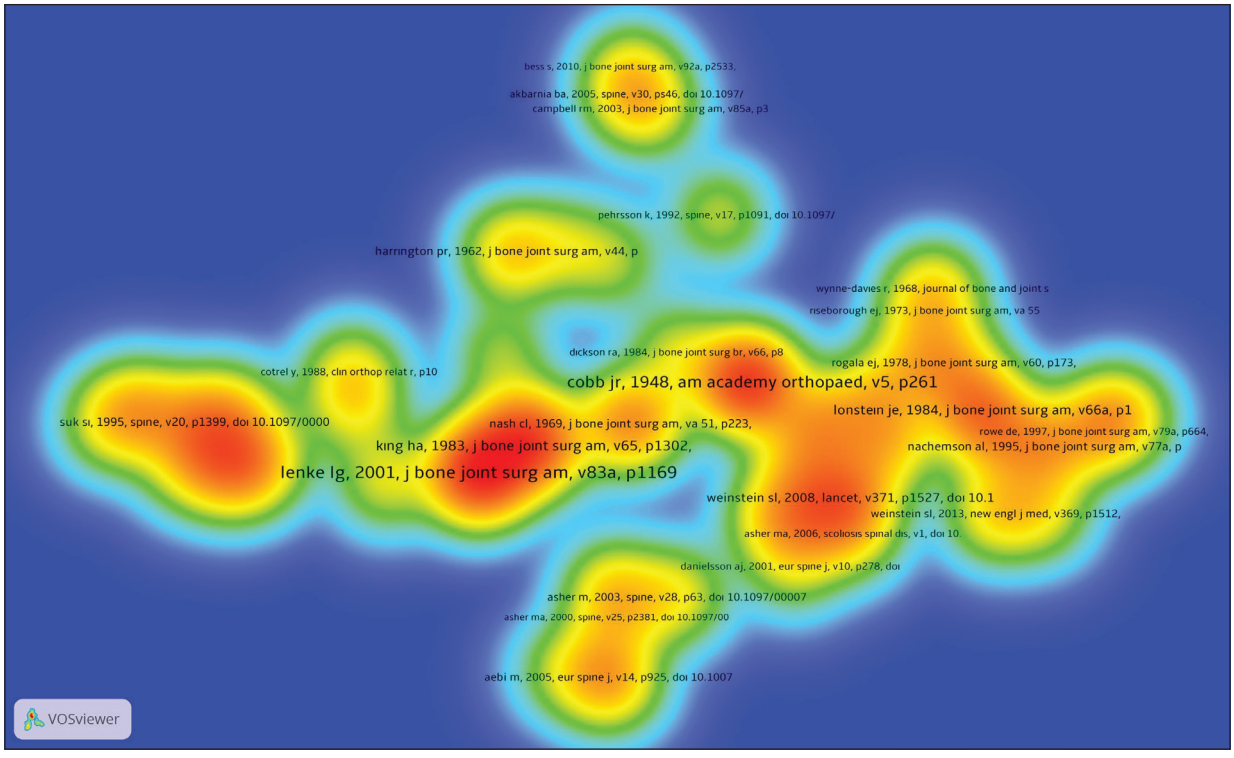

Figure 5: Density visualization map showing co-citation analysis in the field of scoliosis. [Number of citations are represented on a scale ranging from blue (low) to red (high)].

Table III: The 20 Most Cited Manuscripts on Scoliosis

No	Article	Author	Journal	PY	TC	AC
1	Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis	Lenke et al., (27)	Journal of Bone and Joint Surgery-American Volume	2001	850	42.5
2	The selection of fusion levels in thoracic idiopathic scoliosis	King et al., (24)	Journal of Bone and Joint Surgery-American Volume	1983	574	15.11
3	The prediction of curve progression in untreated idiopathic scoliosis during growth	Lonstein and Carlson, (29)	Journal of Bone and Joint Surgery-American Volume	1984	505	13.65
4	Correlation of radiographic parameters and clinical symptoms in adult scoliosis	Glassman et al., (19)	Spine	2005	497	31.06
5	Segmental pedicle screw fixation in the treatment of thoracic idiopathic scoliosis	Suk et al., (39)	Spine	1995	395	15.19
6	Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis - a prospective, controlled-study based on data from the brace study of the scoliosis-research-society	Nachemson and Peterson, (31)	Journal of Bone and Joint Surgery-American Volume	1995	384	14.77
7	Somatosensory-evoked potential spinal-cord monitoring reduces neurologic deficits after scoliosis surgery - results of a large multicenter survey	Nuwer et al., (34)	Evoked Potentials-Electroencephalography and Clinical Neurophysiology	1995	376	14.46
8	Measurement of the cobb angle on radiographs of patients who have scoliosis - evaluation of intrinsic error	Morrissy et al., (30)	Journal of Bone and Joint Surgery-American Volume	1990	349	11.26
9	Scoliosis research society-schwab adult spinal deformity classification a validation study	Schwab et al. (36)	Spine	2012	343	38.11
10	Effects of bracing in adolescents with idiopathic scoliosis	Weinstein et al., (45)	New England Journal of Medicine	2013	320	40
11	Breast cancer mortality after diagnostic radiography - findings from the us scoliosis cohort study	Doody et al., (16)	Spine	2000	307	14.62
12	3-dimensional terminology of spinal deformity - a report presented to the scoliosis research society by the scoliosis research society working group on 3-d terminology of spinal deformity	Stokes, (38)	Spine	1994	298	11.04
13	Measurement of scoliosis and kyphosis radiographs - intraobserver and interobserver variation	Carman et al., (5)	Journal of Bone and Joint Surgery-American Volume	1990	298	9.61
14	Pedicle screw instrumentation of the thoracic spine in idiopathic scoliosis	Liljenqvist et al., (28)	Spine	1997	294	12.25
15	Curve progression in idiopathic scoliosis	Weinstein and Ponseti, (46)	Journal of Bone and Joint Surgery-American Volume	1983	290	7.63
16	Dual growing rod technique for the treatment of progressive early-onset scoliosis - a multicenter study	Akbarnia et al., (1)	Spine	2005	285	17.81
17	The characteristics of thoracic insufficiency syndrome associated with fused ribs and congenital scoliosis	Campbell et al., (4)	Journal of Bone and Joint Surgery-American Volume	2003	281	15.61
18	Health and function of patients with untreated idiopathic scoliosis - a 50-year natural history study	Weinstein et al., (44)	Jama-Journal of the American Medical Association	2003	279	15.5
19	The reliability and concurrent validity of the scoliosis research society-22 patient questionnaire for idiopathic scoliosis	Asher et al., (2)	Spine	2003	279	15.5
20	Scoliosis and fractures in young ballet dancers - relation to delayed menarche and secondary amenorrhea	Warren et al., (42)	New England Journal of Medicine	1986	277	7.91

PY: *Publication year,* ***TC:*** *Total citation,* ***AC:*** *Average citations per year.*

Table IV: The Top 95 Trend Keywords most Frequently Used in Articles on Scoliosis

Keyword	O	Keyword	O	Keyword	O	Keyword	O	Keyword	O
scoliosis	1672	brace	70	aıs	45	blood loss	35	etiology	28
adolescent idiopathic scoliosis	1090	pulmonary function	69	sagittal alignment	45	outcome	35	growth modulation	28
idiopathic scoliosis	412	scoliosis surgery	65	curve progression	44	correction	34	neuromuscular	28
spine	223	degenerative lumbar scoliosis	61	surgical treatment	44	growing rods	34	spinal surgery	28
surgery	182	kyphosis	61	complication	43	rehabilitation	34	bone mineral density	27
spinal fusion	147	biomechanics	60	mrı	43	adolescents	33	polymorphism	27
congenital scoliosis	139	children	58	pedicle screws	41	pelvic obliquity	33	posterior instrumentation	27
posterior spinal fusion	136	degenerative scoliosis	58	risk factors	41	treatment	33	back pain	26
adolescent	118	bracing	56	classification	40	proximal junctional kyphosis	32	growth	26
cobb angle	117	computed tomography	56	instrumentation	40	adult spinal deformity	30	long-term follow-up	26
complications	113	early onset scoliosis	56	growing rod	38	conservative treatment	30	low back pain	26
neuromuscular scoliosis	111	outcomes	55	pain	38	flexibility	30	selective thoracic fusion	26
pedicle screw	87	syringomyelia	54	posture	38	melatonin	30	srs-22	26
deformity	85	reliability	53	prevalence	38	spine deformity	30	anterior instrumentation	25
spinal deformity	84	thoracic kyphosis	53	anterior spinal fusion	37	vertebral rotation	30	progression	25
early-onset scoliosis	80	brace treatment	50	health-related quality of life	37	posterior fusion	29	veptr	25
quality of life	78	fusion	48	pediatric	37	shoulder balance	29		
cerebral palsy	77	magnetic resonance imaging	48	spine surgery	37	adolescent idiopathic scoliosis (ais)	28		
adult scoliosis	71	sagittal balance	47	spinal instrumentation	36	adult	28		

O: *Number of occurrences.*

appearing in the list of 25 countries with the most publications. Previous literature has shown that economic power and development indices are factors affecting publication productivity (11,12,14,15,25), and this was supported by the correlation observed between some indicators of economy and development in the current study. Furthermore, the correlation between productivity and GDP and GDP per capita was stronger than that between productivity and HDI, implying that economic size had a stronger influence on publication productivity than level of development. Analysis of co-authorship between countries showed that geographic region was the primary factor for collaboration on scoliosis, and this was in agreement with previous evidence (11,12).

Most active journals that published 100 or more articles were of 7 journals, published with the 3135 (44.94%) articles. The most productive journal was Spine with 1628 (23.34%)

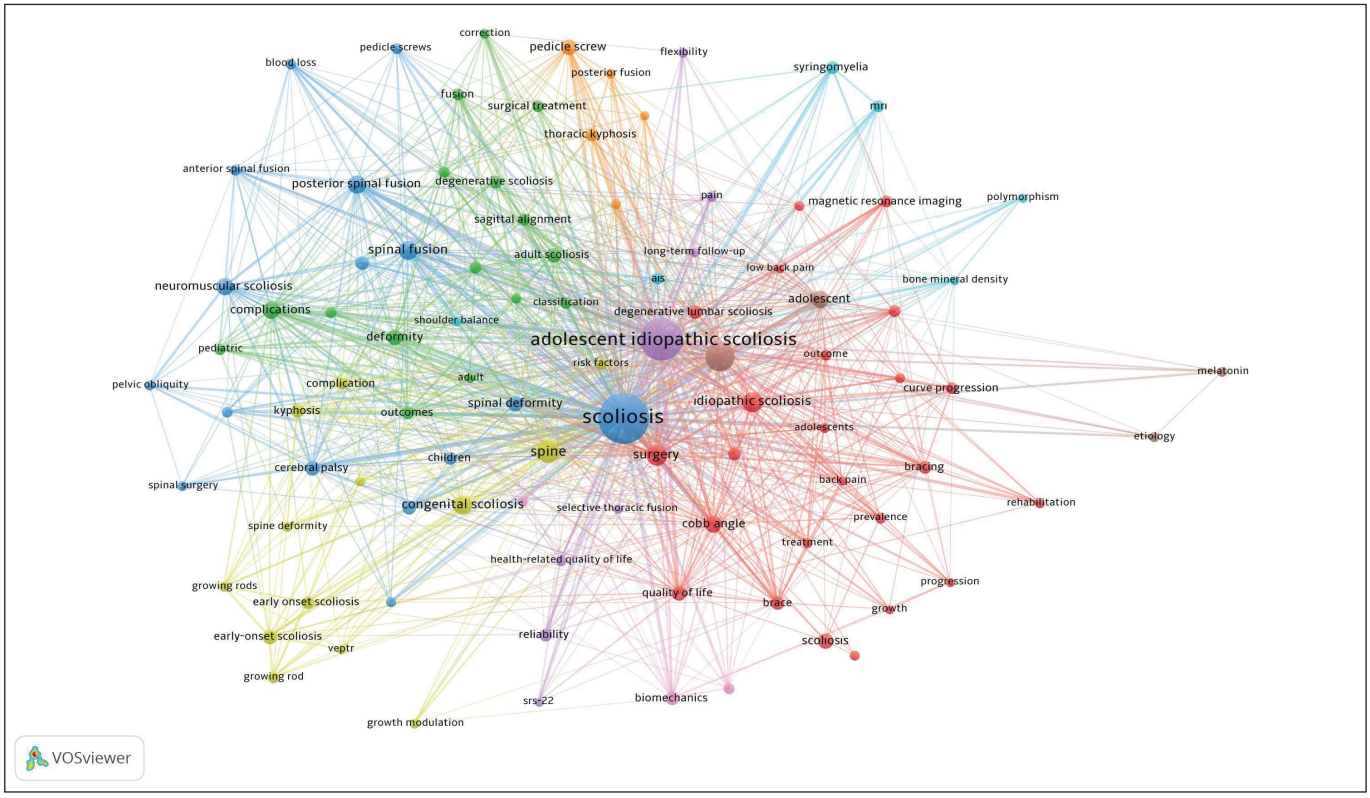

Figure 6: Network visualization cluster map showing keyword analysis in the field of scoliosis.
(Clustering between keywords shown using 6 different colors. The sizes of the circles represent frequencies of keywords, while the thickness of the lines indicate strength of relationship).

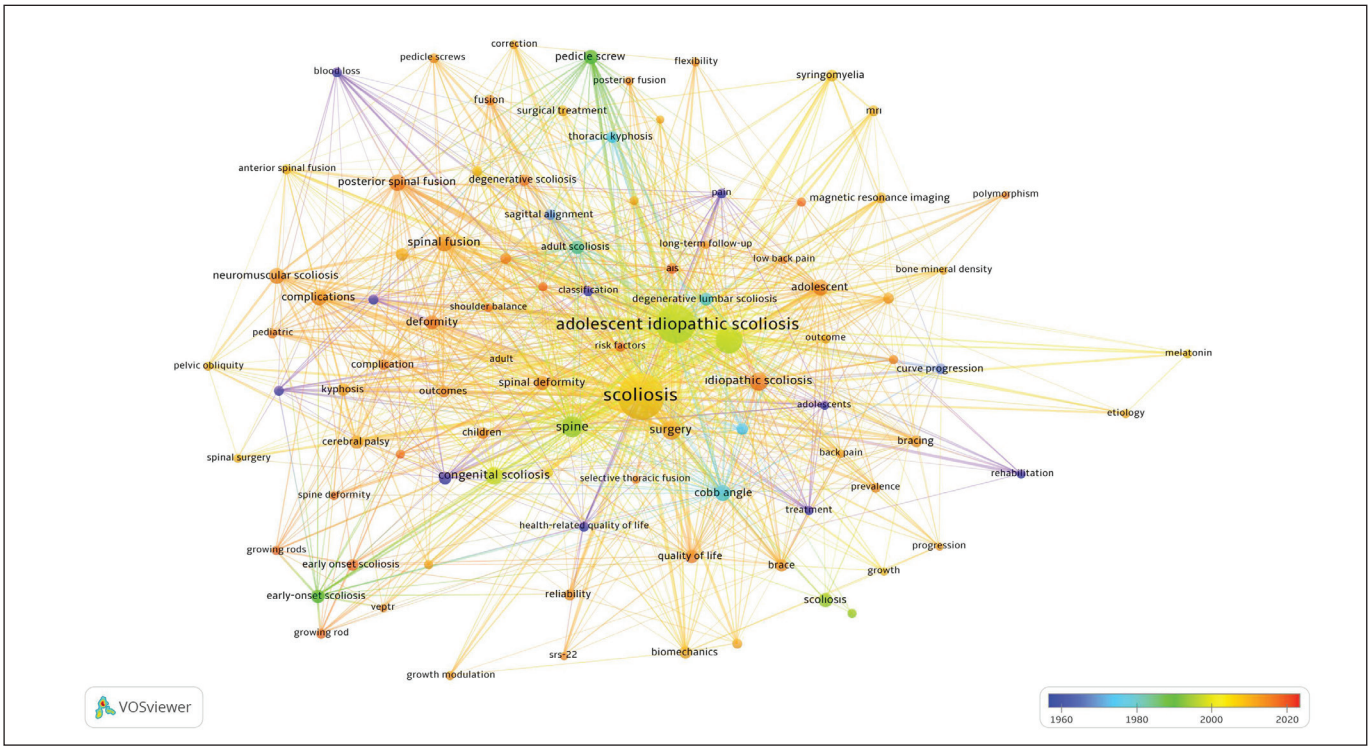

Figure 7: Network visualization map showing trends based on keyword analysis in the field of scoliosis. [The frequencies of keywords are shown on a color scale from blue (low) to red (high). The sizes of the circles represent frequencies of keywords, while the thickness of the lines indicates strength of relationship].

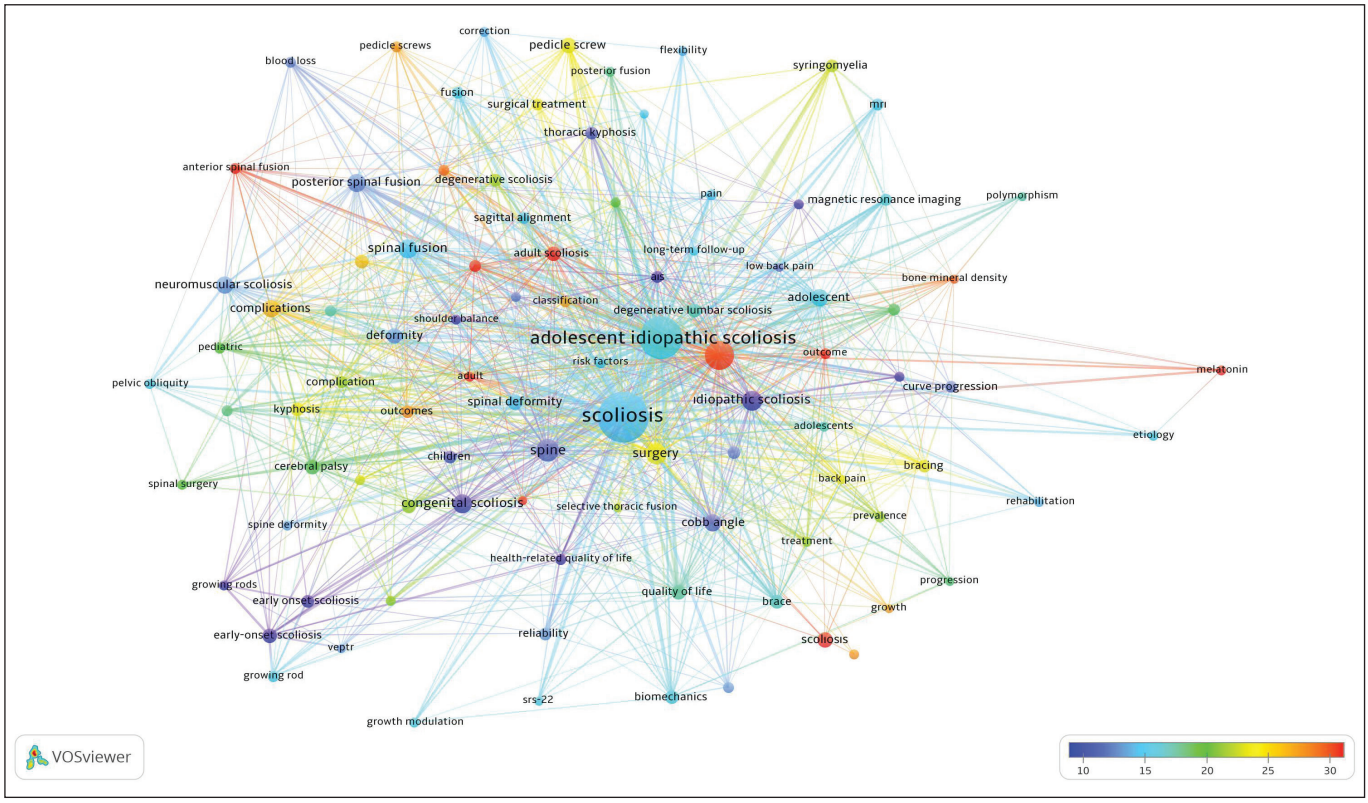

Figure 8: Network visualization map showing the most cited keywords in publications in the field of scoliosis.
[The number of citations received by keywords have been shown on a color scale from blue (low) to red (high). The sizes of the circles represent frequencies of keywords, while the thickness of the lines indicates strength of relationship].

publications, followed by the European Spine Journal (n=576, 8.25%). Journals having the highest average citations per article (more than 10 citations per article) were published with the 8 Journals. The Journal of Bone and Joint Surgery-American Volume had the highest mean number of citations per article (64.4), followed by the Journal of Bone and Joint Surgery-British Volume which had 41.4 citations per article. Based on these results, submission of articles to these journals is recommended. Moreover, researchers may also choose to primarily follow these commonly cited journals.

The article with the greatest impact (measured using mean of total citations) was "Adolescent idiopathic scoliosis: a new classification to determine extent of spinal arthrodesis" published by Lenke et al., in the Journal of Bone and Joint Surgery-American Volume in 2001 (27). The second most cited article was "The selection of fusion levels in thoracic idiopathic scoliosis" published by King et al., in the Journal of Bone and Joint Surgery-American Volume in 1983 (24), while the third most cited article was "The prediction of curve progression in untreated idiopathic scoliosis during growth" published by Lonstein and Carlson in the Journal of Bone and Joint Surgery-American Volume in 1984 (29). It is interesting to note that the 3 most commonly cited articles were all published in the same journal. Moreover, a majority of the 20 articles with highest impact originated from the USA. However, despite ranking second in terms of productivity, no articles originating from China were among the top 20 most cited articles. As older articles typically have higher number of total citations, assessing average citations per year is essential when estimating the impact of an article. In the current study, Lenke et al had the highest number of mean citations per year (27), followed by the article titled "Effects of bracing in adolescents with idiopathic scoliosis" published by Weinstein et al. in the New England Journal of Medicine in 2013 (45). The third and fourth highest mean number of citations per year were shown by "Scoliosis research society adult spinal deformity classification a validation study" published by Schwab et al. in Spine in 2012 and "Correlation of radiographic parameters and clinical symptoms in adult scoliosis" published by Glassmann et al. in Spine in 2005, respectively (19,36). The most commonly co-cited articles were those published by Lenke et al. in 2001 and Cobb in 1948 (6,27). Finally, the fifth and sixth ranking articles were "Complications of growing-rod treatment for early-onset scoliosis: Analysis of one hundred and forty patients" published by Bess et al. in the J Bone Joint Surg Am in 2010 (not included in Table, total citation: 215, average citation per year: 19.55), and "Rates of infection after spine surgery based on 108,419 procedures: a report from the Scoliosis Research Society Morbidity and Mortality Committee" published by Smith et al. in Spine in 2011 (not included in Table, total citation: 193, average citation per year: 19.3), respectively (3,37). Therefore, the articles listed in this paragraph may be considered as cornerstone research on scoliosis.

Cluster analysis of keywords used in articles on scoliosis revealed 9 key clusters, while trend analysis showed that "pulmonary function", "health-related quality of life", "treatment", "adolescent", "rehabilitation", "pain", "curve progression", "classification", "blood loss", "spinal instrumentation", and "spine surgery" had greater popularity in earlier studies while "cobb angles", "degenerative lumbar scoliosis", "thoracic kyphosis", "pedicle screw", "adult scoliosis", "early-onset scoliosis", "adolescent idiopathic scoliosis" gained popularity and replaced earlier keywords over time. Contemporary studies focused on "syringomyelia", "brace", "neuromuscular scoliosis", "posterior spinal fusion", "quality of life", "cerebral palsy", "deformity", "complications", "kyphosis", "adolescent", "prevalence", and "sagittal balance". Keywords used in articles with the highest number of citations were "idiopathic scoliosis", "melatonin", "anterior spinal fusion", "outcome", "adult scoliosis", "sagittal balance", "instrumentation", "bone mineral density", "anterior instrumentation" and "pedicle screws".

To the best of our knowledge, only four other bibliometric analyses of scoliosis literature have been carried out so far (18,33,35,50). The first such analysis, published by O'Neill et al. in 2014, used the Science Citation Index (SCI) database to carry out bibliometric analysis and investigate the 100 most cited papers in the field of spinal deformity surgery. However, in addition to the keyword 'scoliosis', the study also included other keywords such as 'spinal deformity' 'kyphoscoliosis' 'kyphosis', 'lordosis', 'sagittal plane deformity', 'sagittal imbalance', 'coronal plane deformity', coronal imbalance' and 'spondylolisthesis' (35). Zhou et al. also examined the 100 most cited articles in the field of scoliosis surgery since the beginning of the 20th century (50), while Gambín-Botella et al. limited their analysis of the 100 most cited articles by using the keyword "idiopathic scoliosis" (18). The most recent bibliometric analysis, published by Neyman et al. in 2020, included the 100 most cited articles containing the keyword "adolescent idiopathic scoliosis" and published in the field of orthopedics between 1992 and 2017 (33). In contrast, the current study included all articles published between 1980 and 2019 and spanning all research topics under scoliosis, thus granting it wider coverage. Additionally, citations, co-citations, international collaborations, and trend keyword analyses using network visualization maps were also included. The present study is also the first to estimate the number of yearly publications in the field of scoliosis.

This study also had several limitations. Firstly, it only used a single database (WoS database, reaching back to 1980), selected because of its reliability with regard to identification of publications and citations and its popularity in contemporary bibliometric studies, and exclusion of additional databases such as Index Medicus, Index Copernicus, Google Scholar, or Scopus may have affected the number of documents and journals identified for inclusion in this analysis. However, by focusing on a single database, inclusion of duplicate studies in the analysis which could have decreased its reliability was avoided (23,25,47). Secondly, the cross-sectional study design may have affected the findings of the study as the number of citations may have been influenced by the point in time the literature search was carried out. Therefore, more recently published studies may change the rankings of the articles, necessitating an update of the results presented here.

CONCLUSION

The findings of this study showed a considerable increase in publications in the field of scoliosis. Productivity was seen to be highest in countries with larger economies such as USA, Canada, China and Japan, and the highest number of articles was published by the journal "Spine". This bibliometric analysis may be regarded as a summary and evaluation of global scientific output on scoliosis and can, therefore, be used as a guide for researchers, clinicians and students. Furthermore, the keyword analysis can aid professionals in the field when planning new studies.

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