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# "Carpal tunnel syndrome:" A bibliometric study of 35 years of research

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## Abstract:

Carpal tunnel syndrome (CTS) is a disease caused by compression of the median nerve passing through the wrist. Patients suffer from severe pain and paresthesia in the median nerve. Compression of the median nerve occurs, with prolonged working on keyboards (computer or laptop or music players) being one of the reasons along with others such as diabetes or rheumatoid arthritis. CTS research holds great promise for the patients as well as doctors for better medical treatment. The study has been carried out with an objective to analyze research progress based on the literature published on CTS during the last 35 years. The retrospective study has been carried out from the data indexed in SCOPUS multidisciplinary database from 1983 to 2017 (35 years). The study involves analysis of publication trends in terms of total articles, productive countries, institutions, journals, productive authors, most cited articles along with impact in terms of citation and *h*-Index. The SCOPUS database yielded 13187 articles during the study period. These articles were analyzed further for interpreting results. In the last 35 years, the number of scientific publications on CTS has been increasing with an annual growth rate of 9.86% per year. USA has been the most productive country. Literature pertaining to females is more than clinical studies involving males.

## Key Words:

Bibliometric analysis, carpal tunnel syndrome, citation analysis, hand disease, research impact

## Key Message:

A literature analysis through bibliometric investigation of articles on carpal tunnel syndrome (CTS) was carried out for a period of 35 years. India ranked 18<sup>th</sup> with 1.44% of the global publication share. A large population around the globe working on computer or keyboards have been reported having CTS.

Publications form a central part of the research process. The published research in the form of articles must be evaluated in terms of its impact. Bibliometrics methods are widely being used as a tool to measure the research progress in a field through literature analysis. The field of bibliometrics is used to assess the research potential of a specific field, and for benchmarking activities for the organization or individuals under the 'publish or perish' principle.<sup>[1-3]</sup> This study was carried out to analyze the search progress and impact in the area of carpal tunnel syndrome (CTS). The major cause of CTS is the compression of the median nerve passing through the wrist. The CTS cases are increasing day by day in a large population, with prolonged working on keyboards (computer or laptop or music players) being one of the reasons.<sup>[4]</sup> Other reasons for CTS include diabetes, thyroid dysfunction, and autoimmune disease (such as rheumatoid arthritis), etc. Levine *et al.*,<sup>[5]</sup>

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presented a self-administered questionnaire for the assessment of severity of symptoms and functional status in CTS and reported the cause, complications, patient-oriented measures, and treatment of CTS in a group of people in the USA. As such, there are no bibliometric studies related to the CTS that have been reported. However, some bibliometric studies related to arthritis and rheumatism have been reported.<sup>[6-8]</sup> Some studies were concerned with the analysis of journals,<sup>[9]</sup> most cited papers on Dupuytren's contracture (Joyce *et al.*<sup>[10]</sup>), and other studies used bibliometric methods to determine the depth of research based on geographic factors for wrist arthroscopy.<sup>[11]</sup> A few other bibliometric studies were related to the bibliometric analysis of orthopedics patients, demonstrating the growth of research activities in related areas.<sup>[12,13]</sup> In recent years, due to the prolonged use of computers, cases of certain hand diseases have increased considerably.<sup>[14,15]</sup> These cases have been related to the field of orthopedics. Several bibliometric analyses of applications relating to

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orthopedic surgery concerning different parts of the human body have been reported in orthopedic journals,<sup>[16]</sup> as well as hand and surgery journals,<sup>[17]</sup> classic papers on hand surgery,<sup>[18]</sup> country-specific orthopedic research progress,<sup>[19,20]</sup> and hand and wrist surgery journals.<sup>[21]</sup> Some other studies related to neuromuscular disorders and stem cell analysis highlighted the research potential of the field.<sup>[22-24]</sup>

This research is concerned with the CTS literature published from 1983 to 2017 obtained from SCOPUS, and studied to identify the trends in research publication in terms of various document types, annual growth, share of publication, citation growth, average citation per paper, most productive country, authors, journals, institutions, highly cited articles, total citations, as well as *h*-index.<sup>[25]</sup> These factors were identified and compared for their research impact over a period of 35 years.

### Materials and Methods

Data for this study were obtained from the SCOPUS multidisciplinary database for the period from 1983 to 2017. The database was searched for the keywords “Carpal Tunnel Syndrome” in the title, abstract, and keywords fields. The impact factor (IF) of a journal was based on the Journal Citation Report 2017 (IF2017). The affiliated institution was taken from the corresponding address for each author. Collaboration among the authors was established based on the addresses of the authors. Collaborative research by the author or country was classified as either a 'single country' collaboration where all the authors' addresses were from the same country; or an 'international' collaboration where the authors' addresses were from more than one country. The citation count was taken as the number of citations scored by each article till December 2017. The *h*-Index was obtained from the SCOPUS database.

### Results and Discussion

There were 13187 documents during the period of study of 1983–2017. A total of 67.73% documents were published as journal articles followed by 14.22% as reviews, 7.36%

as letters, 3.36% as conference papers, 3.28% as notes, 1.48% as editorials, 1.14% as short surveys, and 1.06% as book chapters. Erratum, conference reviews, and books had a share of less than 1% each. About 0.95% documents were not classified in any of the document types.

Thirty-two languages were used for publishing 13187 documents on CTS; English was the most common mode of communication with 84.97% of the total articles published in the English language.

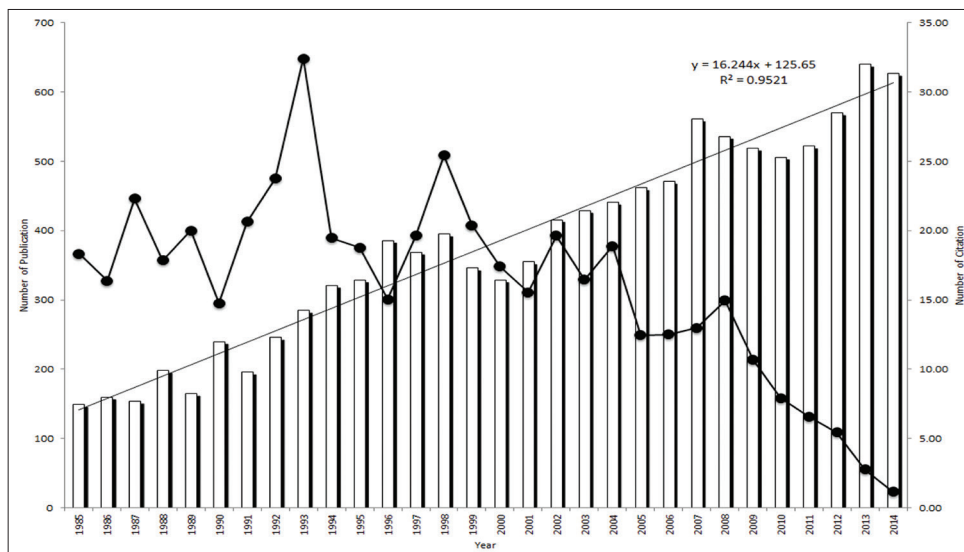
### Trends in carpal tunnel syndrome research publication

Figure 1 shows the growth of the research publications from 1983 to 2017. A total of 13187 articles showed a progressive increase in the number of articles published during the 35-year period. The correlation coefficient value was found to be 0.9253, which illustrates the continued growth of CTS literature. These 13187 articles accumulated a total of 2,06,266 citations till 2017. The articles published in 1998 scored the highest number of citations (11125 citations) with an Average Citation Per Paper (ACPP) of 100.23 citations. The articles published during 2003–2007 have the highest number of citations (42188 citations). The articles published between 1993 and 2009 had an average citation per paper of over 50. The overall ACPP was 15.64 during the study period.

**Table 1: Characteristics of CTS publication growth, 1985-2014**

Time Period	TP	APGR	TC	ACPP
1983-1987	687	-	15160	22.07
1988-1992	1054	5.34	23580	22.37
1993-1997	1701	6.14	38462	22.61
1998-2002	1829	0.75	41445	22.66
2003-2007	2360	2.90	42188	17.88
2008-2012	2685	1.38	35546	13.24
2013-2017	2871	0.69	9885	3.44
1983-2017	13187	9.86	206266	15.64

TP=Total publication; APGR=Annual publication growth rate; TC=Total citations; ACPP=Average citation per paper



**Figure 1: Carpal tunnel syndrome research publication trends from 1985 to 2017**

**Table 2: Top Productive countries with more than 100 articles on CTS Research**

Country	TP	%Share	SCP (R)	ICP (R)	TC	ACPP	R	h-Index
United States	4205	1 (37.14)	3535 (1)	670 (1)	101206 (1)	24.07 (5)	1	123 (1)
United Kingdom	997	2 (8.81)	620 (2)	377 (2)	20298 (2)	20.36 (8)	2	70 (2)
Turkey	576	3 (5.09)	305 (6)	271 (3)	14383 (3)	24.97 (3)	3	56 (3)
Italy	780	4 (6.89)	539 (4)	241 (5)	7463 (8)	9.57 (16)	7	41 (7)
Japan	510	5 (4.50)	268 (7)	242 (4)	9428 (4)	18.49 (9)	5	50 (5)
Germany	588	6 (5.19)	564 (3)	24 (19)	4703 (10)	8.00 (18)	9	36 (9)
France	584	7 (5.16)	526 (5)	58 (15)	8014 (6)	13.72 (13)	6	42 (6)
Canada	440	8 (3.89)	217 (8)	223 (6)	9207 (5)	20.93 (6)	4	51 (4)
Spain	320	9 (2.83)	188 (11)	132 (10)	4187 (13)	13.08 (14)	11	32 (11)
South Korea	204	10 (1.80)	77 (16)	127 (11)	4958 (9)	24.30 (4)	10	34 (10)
Iran	161	11 (1.42)	23 (20)	138 (9)	4187 (12)	26.01 (2)	12	32 (12)
Taiwan	182	12 (1.61)	29 (19)	153 (8)	7807 (7)	42.90 (1)	8	40 (8)
India	163	13 (1.44)	123 (13)	40 (18)	1734 (18)	10.64 (15)	18	20 (18)
Australia	241	14 (2.13)	71 (17)	170 (7)	4421 (11)	18.34 (10)	13	29 (13)
Sweden	234	15 (2.07)	194 (10)	40 (17)	1969 (17)	8.41 (17)	17	22 (17)
China	119	16 (1.05)	14 (21)	105 (14)	2060 (16)	17.31 (12)	16	25 (16)
Netherlands	229	17 (2.02)	208 (9)	21 (20)	716 (21)	3.13 (21)	21	12 (21)
Brazil	175	18 (1.55)	59 (18)	116 (13)	3574 (14)	20.42 (7)	15	26 (15)
Austria	163	19 (1.44)	150 (12)	13 (21)	1033 (19)	6.34 (20)	19	19 (19)
Switzerland	195	20 (1.72)	78 (14)	117 (12)	3503 (15)	17.96 (11)	14	29 (14)
Belgium	122	21 (1.08)	78 (15)	41 (16)	804 (20)	6.59 (19)	20	14 (20)
Total	11188	84.84			215655	19.28		

TP=Total publications; SCP=Single country publications; ICP=Internationally collaborated publications; TC=Total citations; ACPP=Average citation per paper; R=Rank

Table 1 gives the characteristics of the growth of the publications studied in a time span of five years each. The highest percent growth rate of the literature in CTS was 6.14% from 1993 to 1997, followed by 5.34% from 1988 to 1992. The lowest growth rate was reported from 2013 to 2017 (0.69%). The literature on CTS grew with an overall growth rate of 9.86% during the study period.

### Publication by country

Table 2 presents the contribution of the most productive countries that published more than 1% of total CTS articles. Seven indicators have been used to measure the research performance by a country. These include total publications, the share of publications and rank, independent single country publications (SCP) and rank, international collaboration publications (ICP) and rank, total citations (TC) and rank, average citation per paper (ACPP) and rank, and *h*-Index and rank. The top 21 countries contributing the most research were represented by two North American countries, ten European countries, and seven Asian countries, and one each from Australia and South America. USA ranked the first in terms of productive countries (4205 articles; 37.14% share), followed by UK (997 articles; 8.81%), and Turkey (576 articles; 5.09% share). The USA had the highest single country publications (3535 articles) followed by UK (377 articles) and Germany (564 articles). In terms of international collaborations, USA had the highest number of articles published as internationally collaborated studies (670 articles), followed by UK (377 articles), and Turkey (271 articles). Articles published in the USA had the highest citation count of 101206 with an ACPP of 24.07 citations (5<sup>th</sup> rank), followed by the UK with 20298 citations and an ACPP of 20.36 citations (8<sup>th</sup> rank) and Turkey with 14383 citations with an ACPP of 24.97 citations (3<sup>rd</sup> rank). However, papers published from Taiwan ranked 1<sup>st</sup> in terms

**Table 3: Most productive authors engaged in CTS research**

Author	TP	TC	ACPP	h-Index
P.C. Amadio	96	1583	16.49	26
L. Padua	90	768	8.53	26
M. Mondelli	53	457	8.62	20
A. Franzblau	50	224	4.48	12
K.N. An	51	500	9.80	18
P.A. Nathan	50	158	3.16	17

TP=Total publications; TC=Total citations; ACPP=Average citation per paper

of average citation per paper with 42.90 citations, and a paper published from Iran ranked 2<sup>nd</sup> with ACPP of 26.01 citations. The qualitative parameter *h*-Index reflects the academic and scientific quality of researchers. The USA had the highest *h*-Index value of 123 and ranked first, the UK ranked 2<sup>nd</sup> (*h*-Index = 70), and Turkey ranked 3<sup>rd</sup> (*h*-Index = 56).

India ranked 13<sup>th</sup> in terms of the total publication on CTS with 163 articles with a 1.44% global share. India ranked 13<sup>th</sup> in single country publications, 18<sup>th</sup> each in international collaboration publications, citation count, and *h*-index. One hundred and sixty-three papers from India accumulated a total of 1734 citations with an ACPP of 10.64 citations per paper.

### Author's productivity

The author's contribution and research impact were analyzed based on the total publication (TP), total citation (TC), average citation per paper (ACPP), and *h*-Index. The frequency of the top seven authors in terms of total publication is presented in Table 3 with more than 50 publications. Luca Podua has been found to be the most productive author with 103 articles, followed by P. C. Amadio (101 articles) and M.

**Table 4: Most frequently cited articles related to CTS**

Article Title	TC
Lawrence et al. (2008), Estimates of the prevalence of arthritis and other rheumatic conditions in the United States. Part II. Arthritis and Rheumatism, 58 (1)	1989
Levine et al. (1993), A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. Journal of Bone and Joint Surgery - Series A, 75 (11)	999
Dyck, P.J. (1993), The prevalence by staged severity of various types of diabetic neuropathy, retinopathy, and nephropathy in a population-based cohort: The Rochester diabetic neuropathy study. Neurology, 43 (4), 817-824	900
Atroshi et al. (1999), Prevalence of carpal tunnel syndrome in a general population, Journal of the American Medical Association, 282 (2)	809
Silverstein et al. (1987), Occupational factors and carpal tunnel syndrome. American Journal of Industrial Medicine, 11 (3)	626
Jablecki et al. (1993), Literature review of the usefulness of nerve conduction studies and electromyography for the evaluation of patients with carpal tunnel syndrome. Muscle and Nerve, 16 (12)	474
Stevens et al (1988), Carpal tunnel syndrome in Rochester, Minnesota, 1961 to 1980. Neurology, 38 (1)	336
de Krom MC et al. (1992), Carpal tunnel syndrome: Prevalence in the general population. Journal of Clinical Epidemiology, 45 (4)	331
Brown et al. (1993), Carpal tunnel release. A prospective, randomized assessment of open and endoscopic methods. Journal of Bone and Joint Surgery - Series A, 75 (9)	319
Jablecki CK et al. (2002), Practice parameter: Electrodiagnostic studies in carpal tunnel syndrome: Report of the American Association of Electrodiagnostic Medicine, American Academy of Neurology, and the American Academy of Physical Medicine and Rehabilitation, Neurology, 58 (11)	318

TC=Total citations

**Table 5: Most productive journals publishing CTS articles**

Journal	TP	%Share	SJR (2016)	IPP (2016)	SNIP (2016)	IF (2017)
Journal of Hand Surgery, American Volume	895	38.07	1.270	1.591	1.365	1.776
Muscle and Nerve	302	12.85	1.141	2.277	1.068	2.496
Journal of Hand Surgery, European Volume	203	8.63	1.252	1.615	1.301	2.648
Plastic and Reconstructive Surgery	171	7.27	1.986	2.677	1.707	3.621
Archives of Physical Medicine and Rehabilitation	161	6.85	1.427	2.925	1.427	3.077
Journal of Bone and Joint Surgery - American Volume	125	5.32	2.938	3.983	2.216	4.583
Handchirurgie Mikrochirurgie Plastische Chirurgie	119	5.06	0.348	0.671	0.520	0.513
American Journal of Industrial Medicine	112	4.76	0.993	1.738	1.048	1.729
Clinical Neurophysiology	107	4.55	1.581	2.884	1.323	3.614
Hand Clinics	106	4.51	0.996	1.745	1.346	1.171
Total	2301	20.32				

TP=Total publications; SJR=Scimago journal ranking; IPP=Impact per publication; SNIP=Source normalized impact per paper; IF

**Table 6: Most frequently used keywords for CTS research**

Year Range	CTS	Female	Male	Median Nerve	Neural Conduction	Wrist	Nerve Compression	Nerve Conduction
1983-1987	598	340	296	179	48	61	73	85
1988-1992	930	499	503	257	94	114	108	124
1993-1997	1542	787	726	442	216	152	195	150
1998-2002	1677	850	818	498	245	176	243	180
2003-2007	2170	1070	1002	594	315	252	275	220
2008-2012	2426	1342	1215	621	348	282	204	271
2013-2017	2557	1494	1384	724	378	313	186	211
1893-2017	11900	6382	5944	3315	1644	1350	1284	1241

Mondelli (58 articles). Regarding the parameter of citation impact, Peter C. Amada was more impactful with the highest number of citations (2643 citations) followed by Luca Podua (2522 citations) and David M. Rempel (2392 citations). David M. Rempel had higher average citations per paper of 41.96 citations compared to all other authors. Assessing the impact on the parameter of *h*-Index, Luca Podua had the highest *h*-Index of 29, followed by David M. Rempel (*h*-Index = 28) and Peter C Amadio (*h*-Index = 27).

One hundred and sixty-three papers published from India were contributed by 158 authors individually or in the collaboration.

Latha Venkatraya Prabhu from Kasturba Medical College, Manipal (5 articles, 27 citations) and Sujatha D'Costa, Kasturba Medical College Manipal (4 articles, 25 citations) were the leading authors.

#### Characteristics of most cited articles

The most cited articles published on CTS was analyzed based on the total number of citations scored by these articles till December 2017. Out of 13187 articles, 8365 (73.88%) articles have been cited at least one time. The top 10 most cited articles are given in Table 4.

Ram: Carpal tunnel syndrome

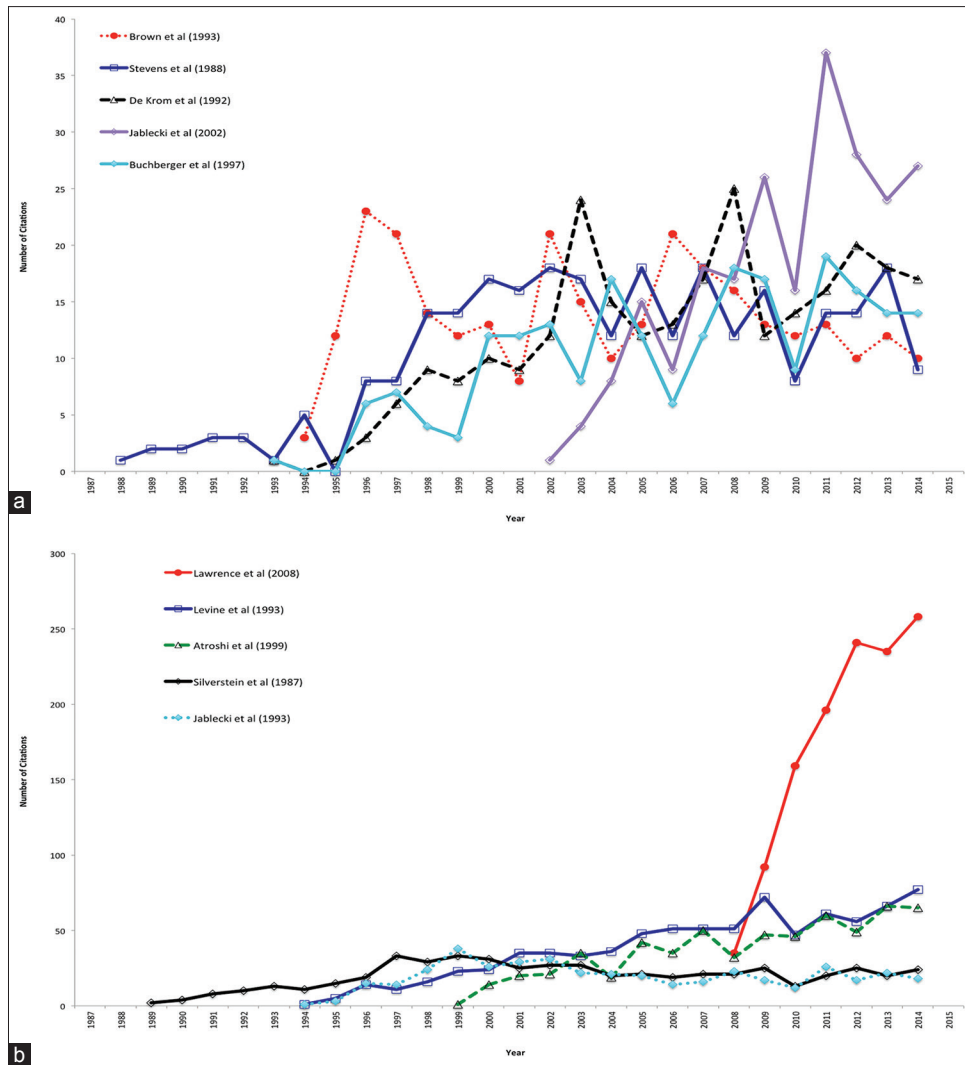


Figure 2: (a,b) Citation lives of top ten most frequently cited articles of CTS research

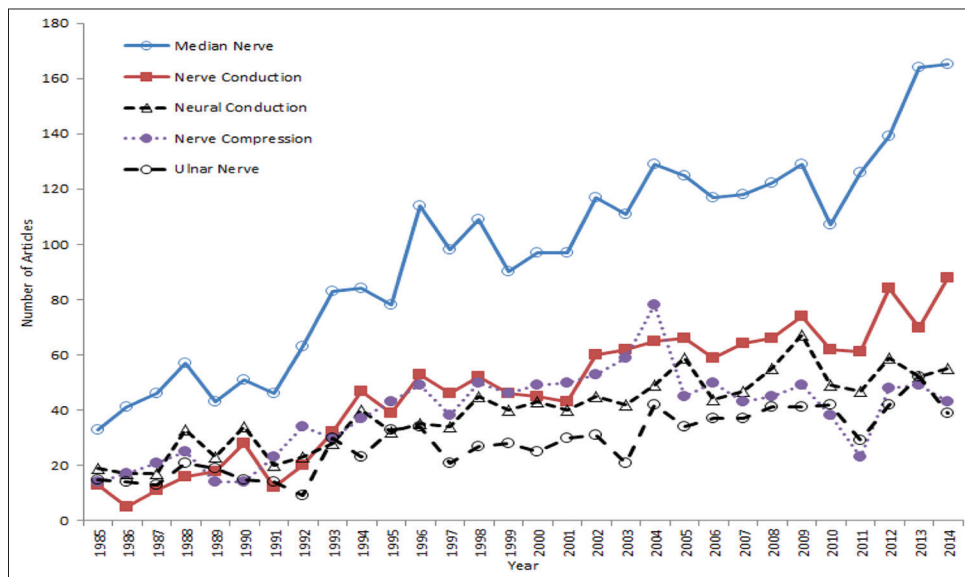


Figure 3: Distribution of most frequently used keywords by authors in CTS research

These 10 most cited articles are distributed throughout the study period starting from 1987 to 2008. The article by Lawrence *et al.*, scored the highest citations (1989 citations) published in "Arthritis and Rheumatism" (IF2017=8.955). The other article with second highest citations was a joint paper by Levine *et al.*, (1993) that was cited 999 times, published in "Journal of Bone and Joint Surgery – American Volume" (IF2017=4.583). The third highest paper by P. J. Dyck (1993) was published in "Neurology" (IF2017=8.055). None of the Indian publications finds a place in the top 10 cited papers [Figure 2a and b].

### Most productive journals publishing carpal tunnel syndrome research

Table 5 presents the 10 most productive journals publishing CTS research. These journals have shared a total of 18.31% (2073 articles) of the global output.

Of these most productive journals, the "Journal of Hand Surgery- American Volume" published 895 articles on CTS (38.07% share; IF2017=1.776). The other productive journals included "Muscle and Nerve" (302 articles; IF2017=2.496), "Journal of Hand Surgery European Volume" (166 articles; IF2017=2.648), "Plastic and Reconstructive Surgery" (137 articles; IF2017=3.621), "Archives of Physical Medicine and Rehabilitation" (114 articles; IF2017=3.077), "Journal of Bone and Joint Surgery – American Volume" (125 articles; IF2017=4.583) "Handchirurgie Mikrochirurgie Plastische Chirurgie" (119 articles; IF2017=0.513), "American Journal of Industrial Medicine" (112 articles; IF2017=1.729), "Clinical Neurophysiology" (107 articles; IF2017=3.614), and "Hand Clinics" (106 articles; IF2017=1.171). It is interesting to note that all these journals are related to Hand Surgery or Neurology, which is the prime focus of the CTS disease. Historically, CTS disease can be traced back to 1933, but since 1960, CTS has become the most frequently diagnosed of the various peripheral compression-induced neuropathies.<sup>[26]</sup>

Different methodologies are adopted to assess the value of the journals publishing research articles in a given field. The parameters included in the assessment by different database aggregators provide a platform where authors can assess the value of the journal and submit their research for probable publication. One such method given by Hank Moed is "Source Normalised Impact Per Paper (SNIP)" which is the contextual measure of the impact of the journal in similar subjects.<sup>[27]</sup> SCImago Journal Ranking (SJR) which measures the scientific influence of scholarly journals that accounts for both the number of citations received by a journal and the importance of the journals in that field.<sup>[28,29]</sup> The Journal of Bone and Joint Surgery Series A has an SJR ranking 2.938 followed by the Plastic and Reconstructive Surgery Clinical (1.986) and Neurophysiology (1.581). Impact Per Publication (IPP) measures the ratio of citations in a year to scholarly papers published in the 3 previous years divided by the number of scholarly papers published in the same year.<sup>[30]</sup> The IPP value for the Journal of Bone and Joint Surgery Series A is the highest among these journals.

### Research focus shift trends in carpal tunnel syndrome research

An expanding and shifting focus in recent CTS research has been witnessed which is analyzed based on the keywords

used by the author in the article title [Table 6]. The direction of research trends in a given field can be traced by statistical analysis of keywords and title-words used to represent the key theme in the paper.<sup>[31]</sup> Studies covering different subjects such as aerosol<sup>[32]</sup> and solid waste research<sup>[33]</sup> have exemplified this hypothesis.

To measure the research progression in the field of CTS, the keywords which have been used the maximum number of times are "Carpal Tunnel Syndrome" (11900 articles), which has represented the central theme of the subject. "Female" was used in 6382 and "Male" in 5944 articles. It infers that the females suffer more than males. This is in line with the epidemiology report mentioning that the ratio of females suffering from CTS is higher than males.<sup>[34-36]</sup> Middle-aged people are more affected than older-aged people. In the USA, workers aged 18–44 are more prone to CTS than those aged 45–64 or over.<sup>[37]</sup>

CTS is a neural disorder caused due to compression of the median nerve of the hand characterized by pain and numbness in the thumb, index finger, middle finger, and the thumb side of the ring finger.<sup>[38]</sup> The top keywords designating neural disorder includes "median nerve" (3315 articles), "neural conduction" (1644 articles), "wrist" (1350 articles), "nerve compression" (1284 articles), and "nerve conduction" (1241 articles). The progression of the use of these keywords is shown in Figure 3.

The clinical terms associated with CTS most frequently used were "clinical trials" (2224 articles), "electromyography" (1219 articles), "electrodiagnosis" (958 articles), "electrophysiology" (669 articles), "surgical decompression" (507 articles) and "echography" (582 articles). These key terms have been used to diagnose the disease and have been used in more than 500 articles.<sup>[39,40]</sup> The other most frequently used keywords during the entire period were "ulnar nerve," "hand," "occupational disease," "pathophysiology," and "peripheral neuropathy" with an increasing rate in the ranking of frequency, and can be identified as CTS research hotspots [Figure 3].

## Conclusion

A literature analysis through bibliometric investigation of articles on CTS was carried out for a period of 30 years. A total of 13187 articles were published that were indexed in the SCOPUS multidisciplinary database from 1982 to 2017. These articles were published in 11 different document types, where 67.31% were published as journal articles. These 13187 articles had accumulated 206266 citations till December 2017, wherein articles published in 1998 scored the highest number of citations. PC Amadio, from Mayo Clinic, was the most productive author with the highest citation and *h*-Index value. There were 10 articles which were most frequently cited. The USA was the most productive country with 37.14% of the global publication share. Papers published from the USA on CTS research accumulated the highest number of citations. India ranked 18<sup>th</sup> with 1.44% of the global publication share. "Journal of Hand Surgery American Volume" was the most productive journal which published 38.07% share of the total global publication on CTS. On the parameter of average citation per paper, articles published from Switzerland had the highest average measure. CTS is a neural disorder, so most of the keyword used by the authors, reflect the similar use of the

terminology in the title of the article. The keyword analysis also reveals that middle-aged population is more prone to the CTS. The analysis further reveals that females have a higher incidence of occurrence than males. CTS is an occupational disease, as a large population around the globe working on computer or keyboards have been reported to be having CTS. This study might be beneficial for stockholders to connect, collaborate and discover potential remedies for the CTS cure.

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Nil.

#### Conflicts of interest

There are no conflicts of interest.

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