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Trends in the growth of literature of telemedicine: A bibliometric analysis

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ABSTRACT

Over the past two decades, the use of telemedicine as a way to provide medical services has grown as communication technologies advance and patients seek more convenient ways to receive care. Because developments within this field are still rapidly evolving, identifying trends within telemedicine literature is an important task to help delineate future directions of telemedicine research. In this study, we analyzed 7960 telemedicine-related publication records found in the Science Citations Index – Expanded database between 1993 and 2012. Bibliometric analyses revealed that while the total growth in telemedicine literature has been significant in the last twenty years, the publication activity per country and over time has been variable. While the United States led the world in the cumulative number of telemedicine publications, Norway ranked highest when we ordered countries by publications per capita. We also saw that the growth in the number of publications per year has been inconsistent over the past two decades. Our results identified that neuroscience neurology and nursing as two fields of research in telemedicine that have seen considerable growth in interest in this field, and are poised to be the focus of research activity in the near future.

1. Introduction

Telemedicine is developed as a solution to provide health care to the underprivileged inaccessible regions, and aims to provide equal access to medical care irrespective of geographic location [1]. It has attracted increased interest in recent years. Health care organizations worldwide have increased interest in implementing telemedicine technology to improve care and services. The continued advancement of Internet-based

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audio and video communication technologies that enable more telemedicine applications, combined with the increased demands on the physician supply and the patients' desire for more convenient and efficient ways of receiving care, drive the growth of telemedicine. Over the past two decades, the functions of telemedicine have expanded significantly to include remote physician consultations, intensive care services, mental health monitoring, as well as chronic disease management, serving as a supplement or an alternative to traditional physician office visits [2]. This has proven particularly important to the improvement of rural health, as telemedicine effectively bridges the gap between inhabitants of rural areas and medical professionals located in city centers, providing specialist care, improving access, reducing long travels, and increasing the overall quality of care within these rural areas [3,4].

Since the field of telemedicine is still in a period of fast growth, keeping up-to-date of the latest developments and trends can be challenging; however, bibliometrics presents a useful quantitative tool to assess the large amount of literature within this field. Bibliometric methods have been effectively used to conduct citation analysis on an entire database of articles to identify the most influential journals and their publication characteristics [5]; within telemedicine, bibliometrics was most recently used to identify trends in key term usage within publications [6]. In this study, we focused on identifying telemedicine publication trends within the past two decades with regard to publication year, country, and language, as well as the relationship between these characteristics and factors such as population density, legislative influences, and the growth of specific research applications and areas.

2. Methods

2.1. Source of data

The Science Citation Index – Expanded (SCI-EXPANDED) was searched for articles relating to telemedicine using the Advanced Search feature of Web of Science (Thomson Reuters). This database was chosen since the journals within the index have been selected for inclusion based on high impact within their respective fields. Because the use and definition of the word "telemedicine" is not formally standardized within the literature, a query was developed to include variations in spelling as well as three other terms commonly used interchangeably with telemedicine [1]. "Telehealth", "e-health", and "telecare" were all searched in addition to "telemedicine" to ensure that the search results adequately reflects the literature in the field, following up on a recent bibliometric study that examined the usage of these terms [5]. By using these general search terms rather than terminology specific to any particular application, we hope to gain a cross-sectional perspective on the overall direction of development in the field of telemedicine. In the Web of Science, "Topic" (Tagged as 'TS') is one of the most common fields used for database searching and it searches for the entered term in Title, Abstract, Author keywords, and Keyword Plus fields of records in this database. The following query was used to search the "Topic" field of the Science Citation Index – Expanded for available articles:

TS = (telecare or "tele care" or tele-care) OR

TS = (telehealth or "tele health" or tele-health) OR

TS = (telemedicine or "tele medicine" or tele-medicine) OR

TS = (ehealth or "e health" or e-health).

The timeframe of the search was limited to 1993–2012 to analyze the characteristics of the publications within telemedicine for the most recent two decades. Articles published in 2013 were excluded to avoid incomplete results as this search was conducted in July 2013.

2.2. Analysis

Data analysis was conducted using the Results Analysis feature provided on Web of Science (Thomson Reuters) to first characterize the entire set of search results. Summary statistics regarding the publications, such as the publication year, countries of publication, and research areas were also gathered via this interface. Additional country information regarding population and land size were obtained from The World Bank: World Development Indicators [7], which includes current data from official sources, and used to obtain the population density by dividing a country's population by its land size. Countries were also ranked according to the total number of publications, publications per capita, and population density. Research areas, as classified and supplied by the Web of Science database based on the journal in which the article was published, were ranked by the total number of publications in each area during each of 4 sub-periods of 5 years over the past 20 years. These results were output to a text file and graphed using Excel (Microsoft, Redmond, USA) and map figures were drawn using the R 2.15.3 software [8] and the googleVis library [9].

3. Results

3.1. Results of query

A total of 7960 publications were located using the customized query in the Web of Science database, and the search results of each of the four terms searched individually as well as in conjunction are displayed in Table 1. We found that "telemedicine" (with its variants) was the most popular term with 6115 publications, followed by "telehealth" ($n = 1327$) and "e-health" ($n = 1246$). The term "telecare" returned the fewest, with only 392 results.

3.2. Publication languages, types, and by countries

Table 2 breaks down the 7960 publications by publication language, showing that the English language dominated with 7594 publications, which represented over 95% of total

Table 1 – Results by search query.

Search Query	Results
TS = (telemedicine OR "tele medicine" OR tele-medicine)	6115
TS = (telehealth OR "tele health" OR tele-health)	1327
TS = (ehealth OR "e health" OR e-health)	1246
TS = (telecare OR "tele care" OR tele-care)	392
TS = (telecare OR "tele care" OR tele-care) OR TS = (telehealth OR "tele health" OR tele-health) OR TS = (telemedicine OR "tele medicine" OR tele-medicine) OR TS = (ehealth OR "e health" OR e-health)	7960

publications. Analysis of the telemedicine publication types revealed that while articles make up the largest proportion of the publications with 5823 (73.16%) publications, a significant portion of the publications were proceedings papers and meeting abstracts (18.51%). Table 3 shows the 7067 (92%) publications that had associated country information broken down by country, for countries with over 100 total publications. We can see that the United States leads in the total number of publications with 2902 publications, or 36.45% of telemedicine publications, within the past two decades, reflecting trends previously identified in literature [10].

3.3. *Growth from 1993 to 2012*

Fig. 1 charts the growth of the total number of publications over the past two decades; we see the annual number of telemedicine publications has grown from 10 in 1993 to 996 in 2012. There was positive growth each year between 1993 and 2000, but the growth in publication rate slowed between 2000 and 2008. Despite this, growth of telemedicine publications has been maintained since 2009.

3.4. *Publications per capita*

To gain a more detailed understanding of the publication activity by country, the total number of telemedicine publications over the past two decades was divided by the size of the population in 2012, the last year of the analyzed data set. The United States led the world in terms of total number of telemedicine related publication within the last two decades, but it only ranked 9th on a publication per capita scale when the population of each country was taken into account, as shown in Table 3.

United States' volume of publications stood in contrast with Norway, which only produced 1.68% of the total publications over the past two decades, but ranked first when its small population size was considered in the per capita comparison. Table 3 indicates the publication rank per million populations for each country, and we see that Norway, the least populated country on the list, produced a disproportionately large volume of telemedicine literature for its size.

Table 2 – Publications by language and type.

Categorization	Publications	% of total
Languages		
English	7594	95.40
German	185	2.32
French	81	1.02
Spanish	64	0.80
Others	36	0.45
Types		
Article	5824	73.17
Proceedings paper, meeting abstract	1473	18.51
Editorial material	514	6.46
Review	476	5.98
News item	235	2.95
Letter	193	2.42
Other	34	0.43

3.5. *Population density*

Analyzing at the relationship between population density and publication activity within the telemedicine field, we also found that population density was inversely related to how much a country published about telemedicine per capita. Norway, Australia, and Canada ranked as the top 3 publishing countries and their population density ranked as the bottom 3 in the 18 countries presented in Table 3.

3.6. *Research areas*

The changing patterns of ranking of top 20 research areas between 1993 and 2012 are shown in Table 4, based on a time scale with 5-year period. While the top ranking categories, such as "Health Care Sciences Services", "Computer Science", and "Medical Informatics" experienced little change over the past two decades, specialty categories of neurosciences neurology and nursing saw consistent growth from one period to the next.

Neurosciences neurology and nursing ranked 6th and 9th respectively when only articles published within the past 5 years were considered. In 1993–1997, the first 5 years of the analysis, neurosciences neurology ranked 24th out of all categories then gradually climbed from 8th, to 7th and to 6th in the subsequent periods. No publications were listed for nursing for the first 5-year period; it was ranked 61st in the second period, then climbed rapidly to 10th and then 9th place by the final period.

4. Discussions

We conducted a blibiometric analysis of the telemedicine literatures published between 1993 and 2012 via the SCI-Expanded database, and the findings indicate the total growth of the telemedicine literature is apparently rapid in the last twenty years. Though this is not the largest scale of bibliometric researches concerning telemedicine [11], we revealed the changing patterns of top ranking research areas while others did not. Among those bibliometric researches in topics relevant to telemedicine [4,6,10–15], Armfield et al. conducted bibliometric analysis with 17,932 records from Medline base [11], Fatehi and Wootton used 11,664 documents from Scopus database [6], and the only one used SCI-Expanded database

Table 3 – Countries with >100 telemedicine-related publications.

Country	# of publications (1993–2012)	% of total	Population in 2012 (millions)[a]	# of publications (per million population)	Land area in 2011 (1000 km^2)[a]	Density (pop. per land area)	Rank (pub.)	Rank (pub. per million pop.)	Rank (pop. density)
United States	2902	36.46	313.9	9.2	9147.4	34.3	1	9	14
United Kingdom[b]	959	12.05	63.2	15.2	241.9	261.4	2	4	6
Canada	561	7.05	34.9	16.1	9093.5	3.8	3	3	17
Australia	531	6.67	22.7	23.4	7682.3	3.0	4	2	18
Germany	498	6.26	81.9	6.1	348.6	234.9	5	10	7
Italy	306	3.84	60.9	5.0	294.1	207.1	6	13	8
Spain	279	3.51	46.2	6.0	498.8	92.7	7	11	12
France	203	2.55	65.7	3.1	547.7	112.0	8	14	11
Netherlands	196	2.46	16.8	11.7	33.7	497.1	9	7	3
Japan	174	2.19	127.6	1.4	364.5	345.0	10	16	5
Greece	139	1.75	11.3	12.3	128.9	87.5	11	6	13
Norway	134	1.68	5.0	26.7	304.3	16.5	12	1	16
Taiwan	124	1.56	23.3[c]	5.3	36.2[c]	644.2	13	12	1
Switzerland	120	1.51	8.0	15.0	40.0	199.9	14	5	9
China	120	1.51	1350.7	0.1	9327.5	144.8	14	17	10
South Korea	106	1.33	50.0	2.1	97.1	515.0	16	15	2
India	105	1.32	1236.7	0.1	2973.2	416.0	17	18	4
Sweden	104	1.31	9.5	10.9	410.3	23.2	18	8	15

[a] The World Bank: World Development Indicators, accessed in July 2013.
[b] United Kingdom includes publications from England, Scotland, Wales, and Northern Ireland.
[c] Statistical Information Network of the Republic of China, accessed in July 2013s.

Table 4 – Ranking of top 20 research areas per 5-year period between 1993 and 2012. The periods are: 1993–1997 (I), 1998–2002 (II), 2003–2007 (III), 2008–2012 (IV). Nursing was ranked 61 in (II), not shown.

Research areas 1993–1997	Rank (I)	Rank (II)	Change (I–II)	Research areas 1998–2002	Rank (II)	Rank (III)	Change (II–III)	Research areas 2003–2007	Rank (III)	Rank (IV)	Change (III–IV)	Research areas 2008–2012
General Internal Medicine	1	4	−3	Health Care Sciences Services	1	1	0	Health Care Sciences Services	1	1	0	Health Care Sciences Services
Computer Science	2	2	0	Computer Science	2	2	0	Computer Science	2	3	−1	Medical Informatics
Medical Informatics	3	3	0	Medical Informatics	3	3	0	Medical Informatics	3	2	1	Computer Science
Radiology Nuclear Medicine Medical Imaging	4	9	−5	General Internal Medicine	4	4	0	General Internal Medicine	4	4	0	General Internal Medicine
Engineering	5	5	0	Engineering	5	6	−1	Cardiovascular System Cardiology	5	7	−2	Engineering
Information Science Library Science	6	7	−1	Surgery	6	9	−3	Engineering	6	5	1	Neurosciences Neurology
Surgery	7	6	1	Information Science Library Science	7	19	−12	Neurosciences Neurology	7	6	1	Cardiovascular System Cardiology
Telecommunications	8	19	−11	Neurosciences Neurology	8	7	1	Public Environmental Occupational Health	8	8	0	Public Environmental Occupational Health
Pathology	9	17	−8	Radiology Nuclear Medicine Medical Imaging	9	16	−7	Surgery	9	10	−1	Nursing
Public Environmental Occupational Health	10	13	−3	Ophthalmology	10	13	−3	Nursing	10	9	1	Surgery
Health Care Sciences Services	11	1	10	Cardiovascular System Cardiology	11	5	6	Endocrinology Metabolism	11	11	0	Endocrinology Metabolism
PSYCHIATRY	12	12	0	Psychiatry	12	12	0	Psychiatry	12	13	−1	Pediatrics
Cardiovascular System Cardiology	13	11	2	Public Environmental Occupational Health	13	8	5	Ophthalmology	13	15	−2	Psychiatry
Dermatology	14	16	−2	Pediatrics	14	15	−1	Mathematical Computational Biology	14	16	−2	Telecommunications
Emergency Medicine	15	23	−8	Mathematical Computational Biology	15	14	1	Pediatrics	15	12	3	Ophthalmology

Table 4 (Continued)

Research areas 1993–1997	Rank (I)	Rank (II)	Change (I–II)	Research areas 1998–2002	Rank (II)	Rank (III)	Change (II–III)	Research areas 2003–2007	Rank (III)	Rank (IV)	Change (III–IV)	Research areas 2008–2012
Ophthalmology	16	10	6	Dermatology	16	21	−5	Radiology Nuclear Medicine Medical Imaging	16	22	−6	Mathematical Computational Biology
Pediatrics	17	14	3	Pathology	17	32	−15	Oncology	17	18	−1	Dermatology
Oncology	18	22	−4	Endocrinology Metabolism	18	11	7	Telecommunications	18	14	4	Oncology
Medical Laboratory Technology	19	60	−41	Telecommunications	19	18	1	Information Science Library Science	19	35	−16	Rehabilitation
Obstetrics Gynecology	20	25	−5	Otorhinolaryngology	20	35	−15	Geriatrics Gerontology	20	24	−4	Respiratory System

analyzed highly cited articles published in two journals closely related to telemedicine [12]. To our best knowledge, this study is the largest one of bibliometric analysis (7960 publications) on telemedicine literatures using SCI-Expanded database. The novelties of our findings would be further discussed with regard to population density, legislative actions, and the research areas in telemedicine with most rapid development.

4.1. *Low population density effects*

Great interest in telemedicine in the less densely populated high-income countries of Norway, Australia, and Canada may be explained by the long time and distance required for rural community members to travel for medical care in the three countries. Because telemedicine enables remote connections from more rural areas to medical professionals in the urban centers, these countries may be particularly interested in how telemedicine technology can eliminate much of the barrier to access posed by a lack of medical facilities in outlying areas. Fig. 2 highlights the countries with the most number of publications per capita. It is worthwhile to note that several countries with very large areas and low population density, such as Russia and Greenland, do not have very high publication activity in telemedicine. Moser et al. found negative correlation was found between publications per million inhabitants and population density ($r = -0.12$) but it was not significant [15]. Further research is suggested for how severe the geographic barriers is in accessing medical care and how these countries overcome their geographic barriers.

4.2. *Legislative impact*

As mentioned above, telemedicine literature has not developed consistently over the past two decades as it shows both periods of rapid and slow growth. A similar work by Moser et al., but using Medline, also revealed the rapid growing period from 1988 to 1998 then slowed down from 2000 afterward [15]. These trends might be reflected by several factors, such as technical innovations [15], or other factors to be investigated. For instance, the trend of US literature shows several time points that ushered in periods of increased interest in telemedicine as denoted by shaded triangles in Fig. 3. While the overall growth may be more generally attributed to the improvement and development of technology and growing acceptance of this technology, these specific time points might correspond to major legislation in the United States that provided additional funding and attention for telemedicine. For example, the United States Congress passed and enacted the Telecommunications Act in 1996, which for the first time linked health care and communications explicitly [16]. In 2009, the American Recovery and Reinvestment allocated additional funding to build/support the infrastructure development and promotion of telemedicine [17]. In 2010, the Patient Protection and Affordable Care Act highlighted telehealth as a part of its many integrated proposals and presented opportunities for telehealth to develop under the healthcare reform environment [18]. With growing legislative attention being paid to telemedicine, such as the proposed Telemdicine Promotion Act of 2012, it is likely that the positive growth trend of

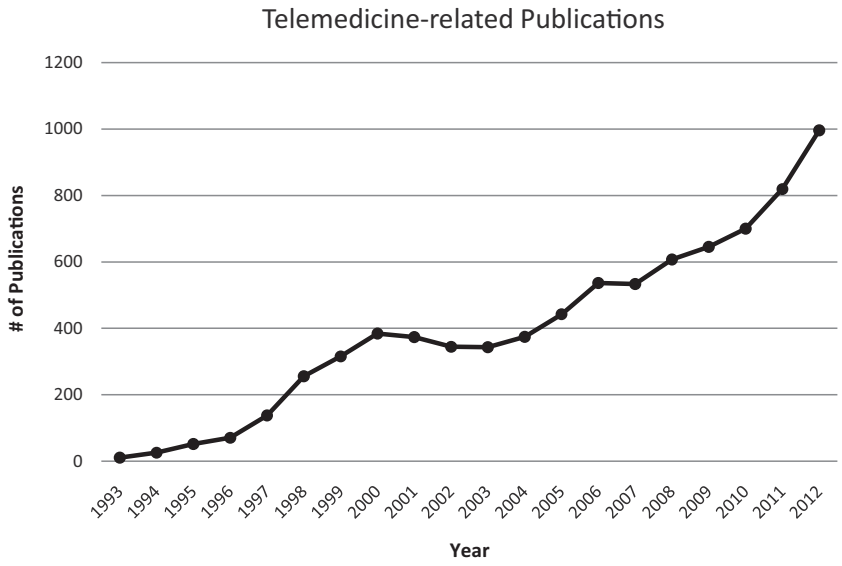

Fig. 1 – Telemedicine publications trend 1993–2012.

telemedicine publications will continue in the next few years within the United States.

4.3. *Growing interest in neurosciences neurology and nursing*

The growth in the research areas of neurosciences neurology and nursing reflect some of the advanced capabilities enabled by telemedicine. In particular, telemedicine technology allows primary care physicians to contact specialists remotely, as well as to transmit images and lab information electronically, which may explain the increased application of neurosciences neurology. In addition, remote monitoring technology, also a key feature of telemedicine, is likely to explain the growth in nursing applications as home telehealth can enable nursing professionals to monitor patients remotely [19,20]. Since these two areas are highly clinical-orientation, this findings coincided with a previous study disclosed a change focus from

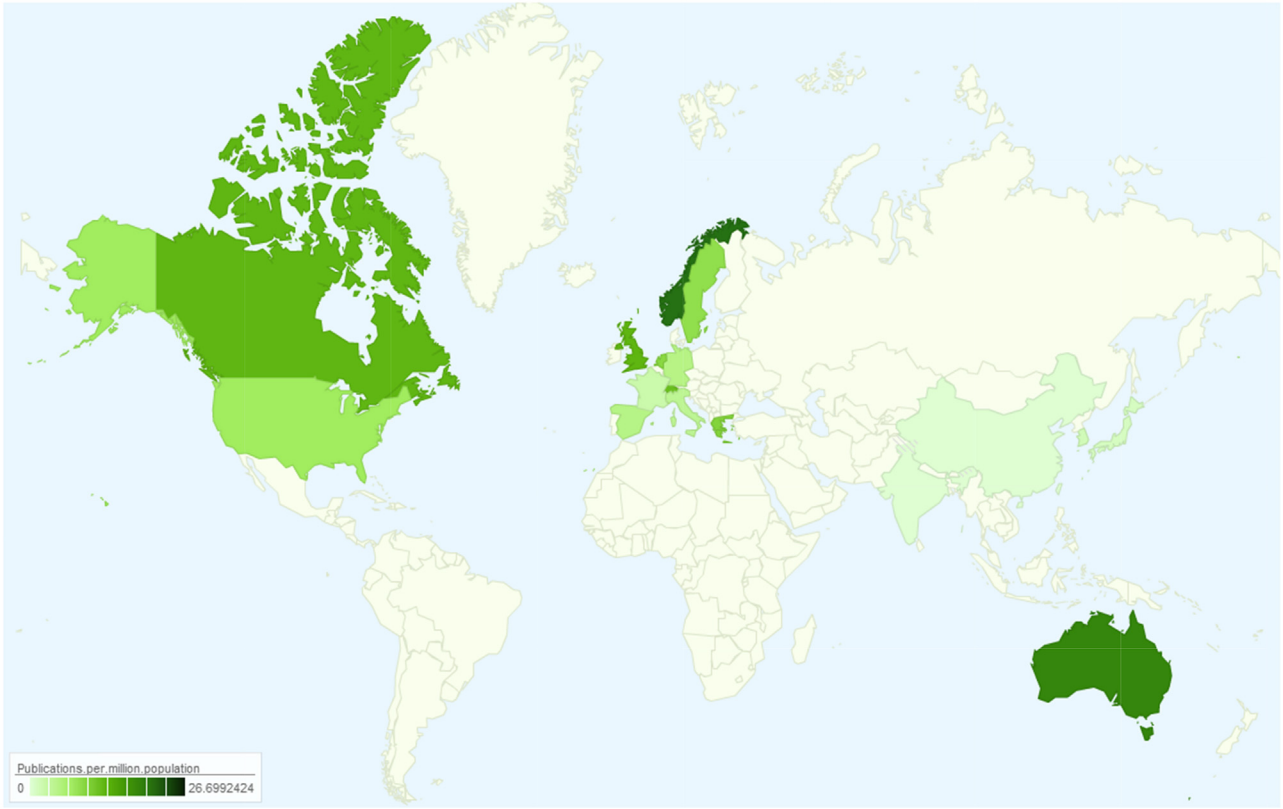

Fig. 2 – Publications by country (per million population).

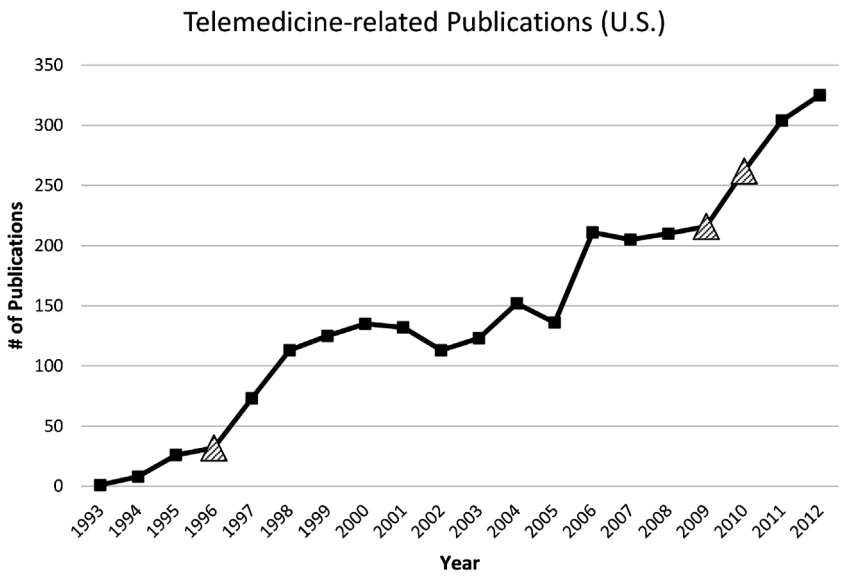

Fig. 3 – Telemedicine publications trend (U.S.) with years of major legislative action highlighted. The Telecommunications Act has been passed and enacted in 1996, the American Recovery and Reinvestment allocated additional funding in 2009, and the Patient Protection and Affordable Care Act have been passed in 2010.

the technical to the clinical between two epochs, 1970–1995 and 2009–2013, respectively [11]. The research interest in these two application areas for telemedicine represent the broadening of medical telemedicine applications in addition to pure technological improvements, a likely trend going forward.

5. Limitations

First of all, this study is limited that the literature search was relied on a single database. This indicates that our findings might be not necessarily representative of the totality of telemedicine literature, and the results should be explained with a cautious manner [21]. Such as non-English articles or those belongs to "gray literature", could not be easily accessed. The potential bias may occur when the analysis was stratified by geographic factors, such as county or population density. The relevant publications might be underestimated for those non-English-speaking countries. The results that English language dominated over 95% of total publications might be due to the limitation that only English terms were searched in the database. Besides, the scope of this study is limited by the exclusion of articles which did not utilize any variation of the broad search terms but still belong to the field of telemedicine, leading to an underestimate of the number of telemedicine-related publications available within the SCI-Expanded database. For example, articles published within a specialized field of nursing and dermatology may never refer to the field of telemedicine broadly, but only as "teledermatology" or "telenursing" in describing its specific application. Regarding these two fields we may miss in the bibliometric analysis, the number of publications since 1993–2012, were 484 and 64, for "teledermatology" and "telenursing", respectively. Since it is too difficult to exhaustively list each subspecialty, we chose to conduct the trend analysis at the most general level and propose this as an area of further research and analysis.

Other limitations in bibliometric methodology such as we only consider the country of both first author and corresponding author might cause some bias. For example, when a telemedicine project done in one country but have been written up by a researcher in another one, such situation could not be discovered via the current methodology we use. The research is also limited by the capabilities of the SCI-Expanded database itself, in that the analysis here depends on the database's categorization of articles into individual research areas. Short of conducting a hand-sorting of all articles, it would be difficult to clearly divide the articles into clinical and non-clinical applications of telemedicine, and thus remains another potential extension of this work.

6. Conclusion

Supported by the growth in the technological capabilities and enabled by legislation, telemedicine has developed from a relatively niche application of telecommunications to playing a vital part in improving healthcare delivery in terms of access, quality, and convenience over the past twenty years. Through this bibliometric analysis, we found that the number of publications within telemedicine in 2012 is almost 100 times the number of publications two decades ago in the 1993, with annual publication numbers growing by 35 times just over the last 10 years. We found that factors such as legislative changes and population density can help to explain the variation in research of telemedicine geographically and over time. These findings will be important to note for the expansion and increased adoption of telemedicine technology in countries where access to medical care is limited by geography, as effective legislative actions can help support the advancement of telemedicine by eliminating legal barriers and bringing increased public attention, thus ensuring convenient access to care. Lastly, we identified neurosciences

neurology and nursing as two emerging areas of research that have received increased interest from the research community and may present active areas of development in the future. Looking ahead, it is clear that telemedicine is now on a path of strong growth and integration into the changing health care environment.

Conflict of interest

The authors declare that there is no conflict of interest.

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