Information mining and visualization of highly cited papers on type-2 diabetes mellitus from ESI

Tong Zhai and Lizhi Di*

A bibliometric analysis based on 1845 highly cited papers extracted from the Essential Science Indicators database was carried out to provide insights into publication performances and research characteristics of type-2 diabetes mellitus. Indicators were applied to evaluate the influence of the most productive journals, countries/territories, organizations and authors. Social network analysis was performed to evaluate and visualize the interaction among productive countries/territories, organizations, authors and keywords using VOSviewer software. Results obtained from this study can provide valuable information for researchers to better identify present and future hotspots in type-2 diabetes-related fields.

Keywords: Bibliometric methods, type-2 diabetes mellitus, highly cited papers, social network analysis.

TYPE-2 diabetes mellitus is the most common form of diabetes. It is a long-term metabolic disorder that is characterized by high blood sugar, insulin resistance and relative lack of insulin[1,2]. Type-2 diabetes as a chronic disease is associated with a 10-year shorter life expectancy. This is partly due to a number of complications with which it is associated, viz. 2–4 times the risk of cardiovascular disease (including ischaemic heart disease and stroke), a 20-fold increase in lower limb amputations and increased rates of hospitalizations. Now, the prevalence of type-2 diabetes is increasing worldwide[3–5]. There are more researches involved with type-2 diabetes in order to improve human health. For example, Gerstein *et al.*[6] studied the effects of intensive glucose lowering in type-2 diabetes. They found that the use of intensive therapy to target normal glycated haemoglobin levels for 3.5 years increased mortality and did not significantly reduce major cardiovascular events. Neal *et al.*[7] studied canagliflozin, and cardiovascular and renal events in type-2 diabetes. Marso *et al.*[8] studied liraglutide and cardiovascular outcomes in type-2 diabetes.

The Essential Science Indicators (ESI) database (Clarivate Analytics) reveals emerging science trends as well as influential individuals, institutions, papers, journals and countries in a research field[9–11]. Article counts for ESI are derived from journals indexed in the Web of Science Core Collection (Science Citation Index Expanded (SCI) and Social Sciences Citation Index only) over a 10-year period. In ESI, papers are divided into 22 research fields and an article can be assigned to only one field. ESI highly cited paper (HCP) is one that belongs to the top 1% of papers in a research field published in a specified year. The HCPs help identify breakthrough research within a given field, and are used in the Web of Science (WoS) to identify and refine the most influential research papers. As for the field of type-2 diabetes, according to our search, there are more than 130,000 papers in SCI Expanded. It is difficult for a researcher to read all these papers, especially for those new to the field. Bibliometric technique is an efficient method for analysing the papers in a research field[12–14]. In this study, we employ the bibliometric method to analyse the ESI HCPs on type-2 diabetes. The characteristics and relationship networks of the HCPs are also presented.

Methodology

In this study, the publication data were obtained from the on-line version of Web of Science Core Collection database. All papers on type-2 diabetes were searched on the basis of topic (title, abstract, author keywords, keywords plus). As mentioned earlier, there were more than 130,000 papers on type-2 diabetes from 2007 to 2017 in SCI Expanded. Among these, 1845 papers were marked as ESI HCPs. The data of total 1845 HCPs were exported from the Web of Science Core Collection and analysed using VOSviewer, a software tool for constructing and visualizing bibliometric networks[15–20].

Results and discussion

Figure 1 shows the number of HCPs published each year. In 2007, there were 136 HCPs on type-2 diabetes. In

Tong Zhai is in the Tianjin University Library, Tianjin University, Tianjin 300072, PR China; Information Science Institute of Tianjin University, Tianjin University, Tianjin 300072, P.R. China; Lizhi Di is in the Tianjin Medical College, Tianjin 300222, PR China.
*For correspondence. (e-mail: zhaitong@tju.edu.cn)

2008, the number was reduced to 126. In the following six years, the number of HCPs increased steadily, and in 2014, it reached the highest value. The number of HCPs in 2015 and 2016 decreased slightly. Due to the hysteretic nature of the database, data in 2017 are not very representative. The 1845 HCPs on type-2 diabetes are distributed in 17 ESI research fields. Most of the papers are assigned to the 'clinical medicine' field, which accounts for 65% of the total. The next five research fields include biology and biochemistry (9.4%), agricultural sciences (6.2%), pharmacology and toxicology (5%), social sciences, general (4.7%), and molecular biology and genetics (4.6%) (Figure 2).

Open-access status is provided across the WoS platform. There are degrees of open access: OA (gold), OA (green published) and OA (green accepted). OA (gold) is identified as fully published articles available from the publisher without charge. OA (green published) is final published articles available without charge from a repository. OA (green accepted) is peer-reviewed accepted manuscripts available without charge from a repository. OA articles are available to anyone with a computer and an internet connection. This makes them have a broad audience, which helps improve their impact. For the 1845 HCPs, 66.4% is OA articles, specifically as follows: OA (gold) – 55.9%, OA (green accepted) – 9.2% and OA (green published) – 1.3% (Figure 3). There are 151 OA (gold) HCPs published by *Diabetes Care*, 22 OA (green accepted) HCPs by *Nature* and 4 OA (green published) HCPs published by the *Journal of Clinical Investigation*.

The HCPs on type-2 diabetes were published in 413 journals. Table 1 shows the number of HCPs and their citation indicators in the top 15 productive journals. *Diabetes Care* is the most productive journal which published 158 HCPs. The number of HCPs (PN) published by *Lancet* and *New England Journal of Medicine* ranks second (PN = 71) and third (PN = 67) in the top 15 productive journals respectively. For the top 15 journals, HCPs published by *New England Journal of Medicine* have the highest total citations (TC). They have been cited 43,217 times in total. However, HCPs published by *Circulation* have the highest average citations (AC), which reached 691 times. Figure 4 shows AC values and impact factor (IF) of each of the top 15 productive journals. For HCPs, variation trend of AC values is not consistent with that of journal IF. The most obvious one is *Circulation*. The IF of this journal ranks only sixth in the top 15 journals, however, its AC value ranks first.

The 1845 HCPs papers on type-2 diabetes are distributed in 82 countries/territories around the world. Among the 1845 selected publications, 855 papers (46.3% of the total studied papers) were published with international collaboration. Table 2 shows the top 15 most productive countries. They include 11 European countries/territories, two American countries, one Oceania country and one Asian country/territory, which are dominated by developed countries/territories, demonstrating the positive role of economic capabilities in promoting academic levels. USA is the most productive country with 1026 HCPs (55.6% of the total studied papers). TC of USA HCPs is also the highest in the top

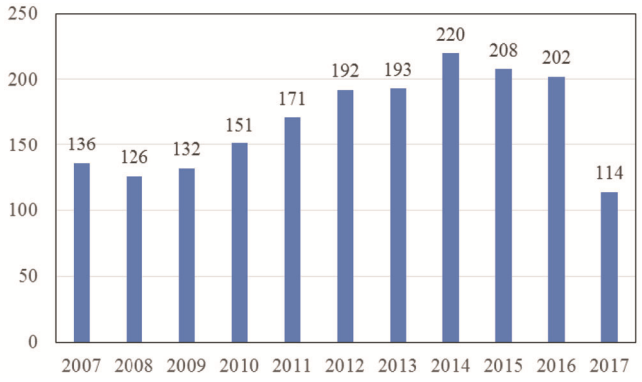


Figure 1. The number of highly cited papers published each year.

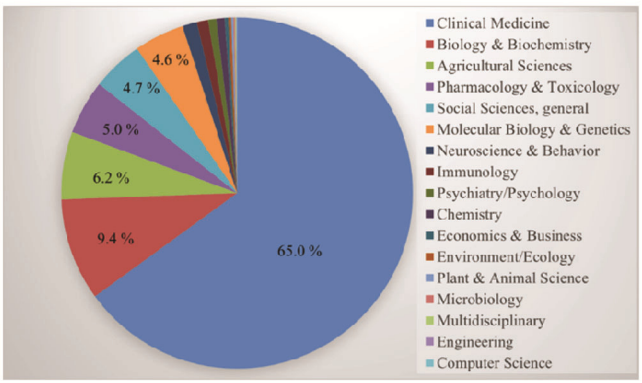


Figure 2. Distribution of 1845 highly cited papers in ESI research fields.

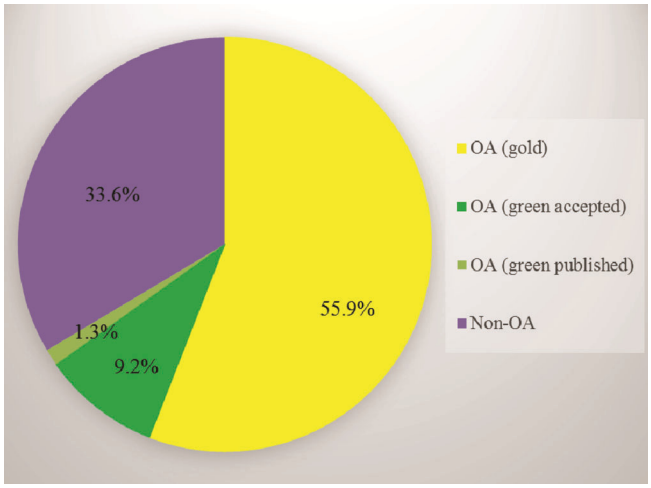


Figure 3. Open access status of the 1845 highly cited papers.

Table 1. The numbers of highly cited papers (HCPs) and their citation indicators in top 15 productive journals

Journal	PN	Total citations (TC)	Average citations (AC)
Diabetes Care	158	31,099	196.8
Lancet	71	26,052	366.9
New England Journal of Medicine	67	43,217	645.0
JAMA Journal of the American Medical Association	59	17,736	300.6
Diabetes	55	12,091	219.8
Diabetologia	51	9,622	188.7
Circulation	44	30,403	691.0
Diabetes Obesity Metabolism	41	5,238	127.8
Nature	41	21,731	530.0
Lancet Diabetes Endocrinology	33	2,466	74.7
Nature Reviews Endocrinology	33	4,237	128.4
Journal of Clinical Endocrinology Metabolism	33	6,844	207.4
Annals of Internal Medicine	32	5,617	175.5
Journal of Clinical Investigation	30	7,473	249.1
Journal of the American College of Cardiology	22	6,259	284.5

PN, Number of highly cited papers.

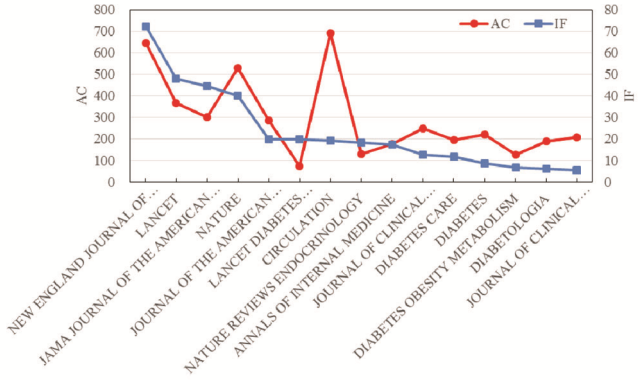


Figure 4. Highly cited papers average citations (HCP AC) values and impact factor of each of the top 15 productive journals.

15 countries/territories. For AC, Scotland (AC = 378.0) ranks first in the top 15 countries/territories. The HCP average growth rate per annum (AGRA) from 2007 to 2016 was calculated. The Agra of The Netherlands is the highest in the top 15 countries/territories and Switzerland experienced negative growth during 2007–2016. The Peoples' R China was the only developing country in the top 15 countries with 77 HCPs and ranked 15th. It presented a strong growth momentum during the past decade, with AGRA reaching 48.1%.

International collaborations of the top 15 countries/territories were studied (Table 2). The internationally collaborative papers of USA accounted for 54.3% of all HCPs in the country, which is the least (ICPC (the percentage of international collaboration publications in a country/territory) indicator) in the top 15 countries/territories. However, the internationally collaborative papers of USA accounted for 30.2% of all HCPs in the world, which is the highest (ICPW indicator) in the top 15 countries/territories. The ratio of collaborative to non-collaborative papers of USA is moderate. For the other 14 countries/territories, the ICPC values are very high (>77%). On the one hand, it shows that the 14 countries/territories have a high openness. On the other, it suggests that HCPs of these 14 countries/territories depend highly on other countries/territories, and that independent research ability is weak. Links is an indicator (VOSviewer) which is used to represent the number of connections of one factor (e.g. one country/territory) with other factors (e.g. the other 14 countries/territories). The links of all the 15 top countries/territories are 14, which indicates that all of the top 15 countries/territories collaborated with each other. Total link strength (TLS) is another indicator (VOSviewer), which is used to represent collaboration intensity of the selective factors (countries/territories). USA has the highest collaboration intensity (TLS = 1126) in the top 15 countries/territories. Figure 5 shows visualization of international collaborations and top 10 link strength combinations between the top 15 countries/territories. In network visualization, size of the circle of an item is determined by the weight of that item. The higher the weight of an item, larger is the circle of that item. The link strength between USA and England is maximum, with the number of USA–England collaboration HCPs being 163. Among the top 10 link strength combinations, the number of such combinations involving USA is 8. In the collaborations, USA is at the central position, which shows its research potential in the type-2 diabetes field. The colours in Figure 5 are used to distinguish between different clusters (a cluster is a set of closely related nodes). The clustering technique used by VOSviewer is discussed by Waltman and co-workers[21,22].

The first author of a paper is usually the person who has undertaken a major part of the research work. The corresponding author (CA) of a paper is the person to whom readers can address questions, request for materials, or even provide suggestions for further work, and is usually

Table 2. Top 15 most productive countries and related indicators

Country/territory	PN	TC	AC	AGRA (%)	ICPC (%)	ICPW (%)	TLS	Links
USA	1026	263,247	256.6	9.9	54.3	30.2	1126	14
England	378	97,135	257.0	30.1	78.3	16.0	868	14
Germany	220	49,092	223.1	42.4	83.6	10.0	655	14
Canada	195	63,625	326.3	19.2	77.9	8.2	473	14
Italy	190	51,952	273.4	33.9	86.8	8.9	618	14
Australia	173	48,755	281.8	34.7	82.1	7.7	473	14
The Netherlands	152	38,370	252.4	51.8	81.6	6.7	525	14
Denmark	151	43,703	289.4	26.0	80.1	6.6	483	14
France	150	48,858	325.7	21.1	88.0	7.2	530	14
Sweden	125	33,944	271.6	31.7	90.4	6.1	445	14
Switzerland	110	28,418	258.3	-5.0	88.2	5.3	320	14
Spain	89	21,349	239.9	58.7	82.0	4.0	343	14
Finland	88	28,576	324.7	0.0	87.5	4.2	329	14
Scotland	87	32,887	378.0	18.6	80.5	3.8	334	14
Peoples' R China	77	17,262	224.2	48.1	79.2	3.3	174	14

TC, Total citations; AC, Average citations; AGRA, Average growth rate per annum (2007–16); ICPC, Percentage of international collaboration publications in a country/territory; ICPW, Percentage of international collaboration publications in the world; TLS, Total link strength.

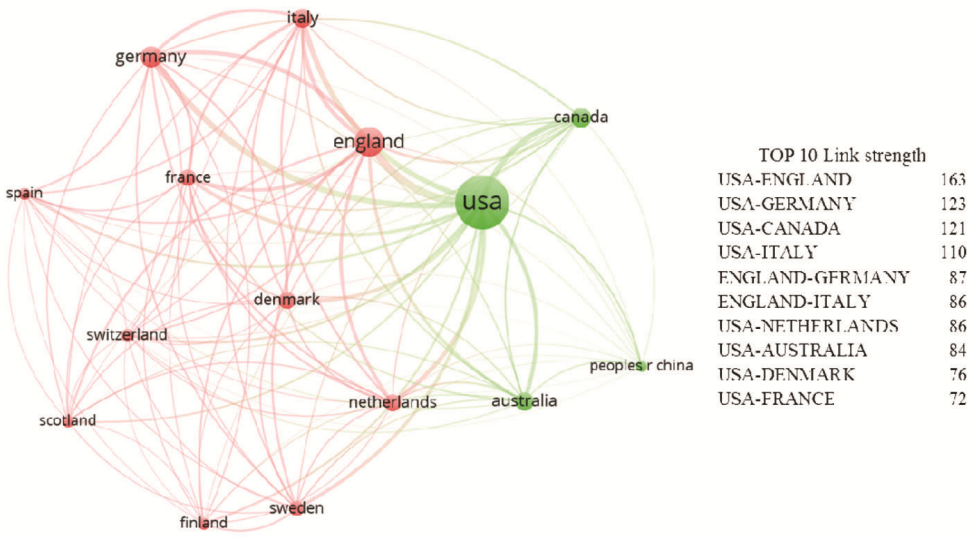


Figure 5. Visualization of international collaborations and top 10 link strength combinations between the top 15 countries/territories.

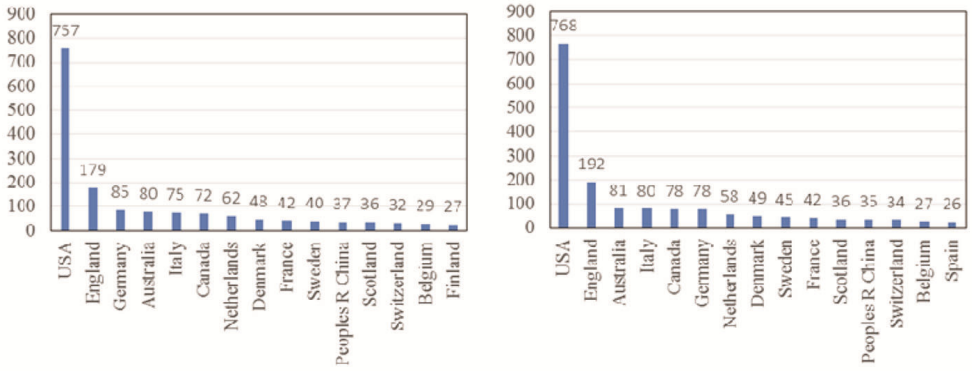


Figure 6. Top 15 productive countries/territories based on (***a***) first authored and (***b***) corresponding authored HCPs respectively.

Table 3. Top 16 most productive corresponding authors

Corresponding author (CA)	PN	Organization/institution	TC
F. B. Hu	16	Harvard Univ	3271
G. I. Shulman	13	Yale Univ	3104
R. A. DeFronzo	12	Univ Texas Hlth Sci Ctr San Antonio	3043
D. J. Drucker	11	Univ Toronto	4166
M. A. Nauck	10	Ruhr Univ Bochum; Diabet Zentrum Bad Lauterberg	1871
E. Ferrannini	9	Univ Pisa; CNR Inst Clin Physiol	1187
J. Rosenstock	8	Med City Dallas Hosp, Dallas Diabet and Endocrine Ctr	1093
J. B. Buse	7	Univ N Carolina	1714
P. D. Cani	7	Catholic Univ Louvain	1397
D. G. Hardie	7	Univ Dundee	2010
G. Targher	7	Univ Verona	2107
P. C. Butler	6	Univ Calif Los Angeles	1417
R. R. Holman	6	Churchill Hosp; Univ Oxford	4942
B. Neal	6	Univ Sydney; Royal Prince Alfred Hosp	375
J. M. Olefsky	6	Univ Calif San Diego	2831
Z. M. Younossi	6	Inova Fairfax Hosp; Inova Hlth Syst, Betty and Guy Beatty Ctr Integrated Res	1851

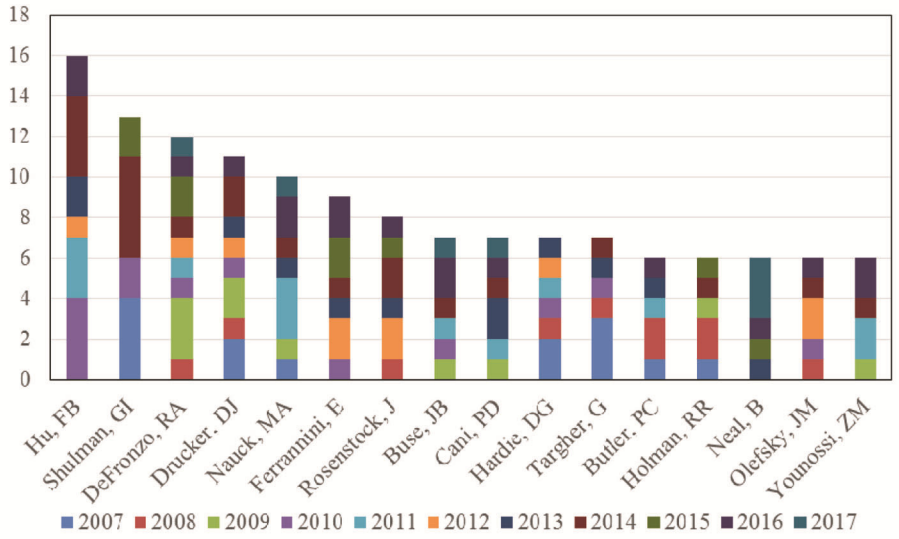


Figure 7. Time distribution of the top 16 most productive corresponding authors' HCPs.

the director of a research project. The distribution of the 1845 HCPs in the world based on first author and corresponding author was studied. As shown in Figure 6, the number of first-authored HCPs by the top 15 countries/territories is similar to that of corresponding-authored HCPs. USA and England are first and second productive countries/territories, based on both first author and corresponding author. USA has an obvious advantage compared with other countries/territories.

Table 3 shows the top 16 most productive corresponding authors. They come from different organizations and as corresponding authors have published 137 HCPs in total. F. B. Hu (Harvard University, USA) is the most productive corresponding author. As corresponding author, he has published 16 HCPs with a total citation of 3271. As shown in Figure 7, these publications were distributed as follows: 2010 – four HCPs, 2011 – three HCPs, 2012 – one HCP, 2013 – two HCPs, 2014 – four HCPs and 2016 – two HCPs. Hu has conducted detailed analyses of many dietary and lifestyle factors and risks of diabetes, including sugar-sweetened beverages, coffee, red meat, saturated and polyunsaturated fatty acids, iron and dietary patterns. These findings have contributed to current public health recommendations and policies for prevention of chronic diseases. For example, an important research finding of Hu is that higher consumption of sugar-sweetened beverages is associated with the development of metabolic syndrome and type-2 diabetes. Research data provide empirical evidence that intake of sugar-sweetened beverages should be limited to reduce obesity-related risk of chronic metabolic diseases[23].

R. R. Holman (Churchill Hospital and University of Oxford, UK) has the highest total citations (TC = 4942) among the top 16 corresponding authors. The six HCPs of

Table 4. Top 15 most productive organizations and related indicators

Organizations/institution	PN	TC	AC	TLS	Links
Harvard Univ (USA)	197	61,880	314.1	250	14
Brigham Womens HOSP (USA)	81	22,864	282.3	173	14
Univ Washington (USA)	75	25,380	338.4	142	14
Univ Oxford (England)	70	29,851	426.4	176	13
Univ N Carolina (USA)	70	32,839	469.1	163	14
Univ Copenhagen (Denmark)	67	17,310	258.4	77	14
Univ Toronto (Canada)	64	19,951	311.7	69	13
Univ Michigan (USA)	54	19,433	359.9	146	13
Univ Sydney (Australia)	54	15,446	286.0	32	10
Univ London Imperial Coll Sci Technol MED (England)	52	15,453	297.2	148	13
Yale Univ (USA)	50	17,832	356.6	42	11
Univ Helsinki (Finland)	48	17,115	356.6	121	13
Univ Cambridge (England)	47	14,237	302.9	122	12
Massachusetts Gen Hosp (USA)	46	20,436	444.3	167	14
Columbia Univ (USA)	45	18,877	419.5	36	10

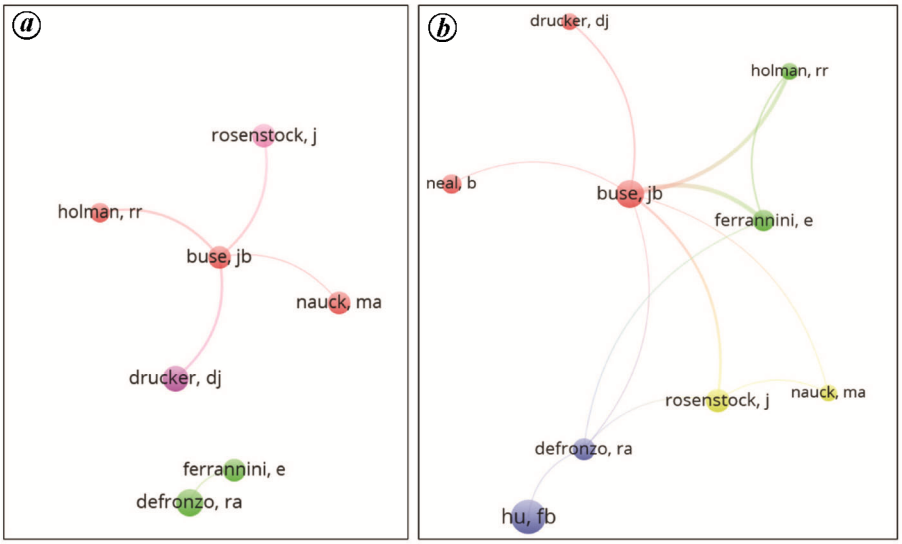


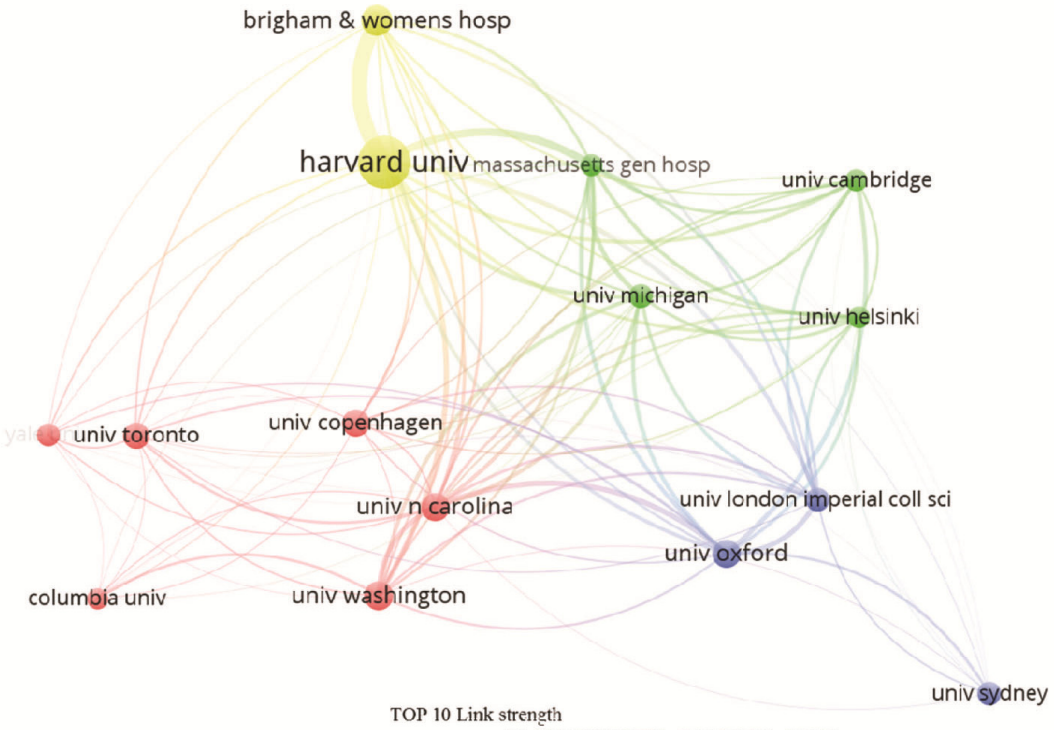
Figure 8. Collaborative relationships between the top 16 corresponding authors in (***a***) 137 HCPs and (***b***) total 1845 HCPs.

Holman were distributed as follows: 2007 – one HCP, 2008 – two HCPs, 2009 – one HCP, 2014 – one HCP and 2015 – one HCP. B. Neal has the least total citations (TC = 375). One of the main reasons is because the HCPs of Neal were published in recent years: 2013 – one HCP, 2015 – one HCP, 2016 – one HCP and 2017 – two HCPs. Holman directs the 10-year UK Prospective Diabetes Study post-trial monitoring programme and operates the 20-year UK Prospective Diabetes Study. He has designed and run many multicentre studies that focus primarily on the prevention, appropriate treatment and cardiovascular risk reduction in people with type-2 diabetes. For example, his research showed that a continued reduction in microvascular risk and emergent risk reductions for myocardial infarction and death from any cause were observed during 10 years of post-trial follow-up. A continued benefit after metformin therapy was evident among overweight patients[24].

Figure 8 *a* shows the collaborative relationships between the top 16 corresponding authors for the 137 HCPs. J. B. Buse has collaborative relationships with R. R. Holman, J. Rosenstock, M. A. Nauck and D. J. Drucker, E. Ferrannini has collaborative relationship with R. A. DeFronzo. There is no collaborative relationship between other corresponding authors in the 137 HCPs. Figure 8 *b* shows the collaborative relationship between the top 16 corresponding authors in total 1845 HCPs. Again J. B. Buse has the most collaborators: R. R. Holman, J. Rosenstock, M. A. Nauck, D. J. Drucker, E. Ferrannini, R. A. DeFronzo and B. Neal. R. A. DeFronzo has four collaborators: E. Ferrannini, F. B. Hu, J. Rosenstock and J. B. Buse. J. Rosenstock and E. Ferrannini both have three collaborators. J. B. Buse is an author with high openness. R. R. Holman and E. Ferrannini are the top two authors who have collaborated closely with J. B. Buse based on total 1845 HCPs.

Table 5. List of author keywords (occurrences ≥10) and their total link strength

Author keywords	Occurrences	Total link strength	Author keywords	Occurrences	Total link strength
Obesity	120	256	Diet	15	35
Type-2 diabetes	133	189	Nutrition	17	35
Diabetes	107	153	Cholesterol	16	34
Metabolic syndrome	69	151	Adipose tissue	15	33
Insulin resistance	71	147	Dyslipidemia	15	33
Cardiovascular disease	57	129	Exercise	16	33
Inflammation	65	121	Metformin	22	33
Meta-analysis	55	95	Oxidative stress	20	31
Diabetes mellitus	62	92	Prevention	12	28
Epidemiology	38	82	Glucose	11	27
Cancer	26	59	Blood pressure	14	26
Hypertension	28	57	Vitamin D	12	26
Type-2 diabetes mellitus	46	54	Non-alcoholic fatty liver disease	11	25
Insulin	24	50	Triglycerides	11	25
Review	26	50	Heart failure	14	24
Risk factors	19	45	Sglt2 inhibitor	18	24
Cardiovascular diseases	23	43	Stroke	11	24
AHA scientific statements	14	40	Nafld	12	23
Lipids	13	37	Cardiovascular risk	12	22
Metabolism	19	37	Aging	14	20
Mortality	20	37	Insulin sensitivity	13	19
Systematic review	24	37	Alzheimer's disease	11	18
Atherosclerosis	18	35	Physical activity	12	18



TOP 10 Link strength

HARVARD UNIV - BRIGHAM WOMENS HOSP	70	MASSACHUSETTS GEN HOSP - UNIV MICHIGAN	19
HARVARD UNIV - MASSACHUSETTS GEN HOSP	32	UNIV CAMBRIDGE - UNIV OXFORD	19
HARVARD UNIV - UNIV WASHINGTON	22	UNIV N CAROLINA - UNIV WASHINGTON	19
UNIV N CAROLINA - UNIV OXFORD	22	HARVARD UNIV - UNIV MICHIGAN	18
UNIV LONDON IMPERIAL COLL SCI TECHNOL MED - UNIV OXFORD	21	HARVARD UNIV - UNIV LONDON IMPERIAL COLL SCI TECHNOL MED	17

Figure 9. Visualization of collaborations and top 10 link strength combinations between the top-15 organizations.

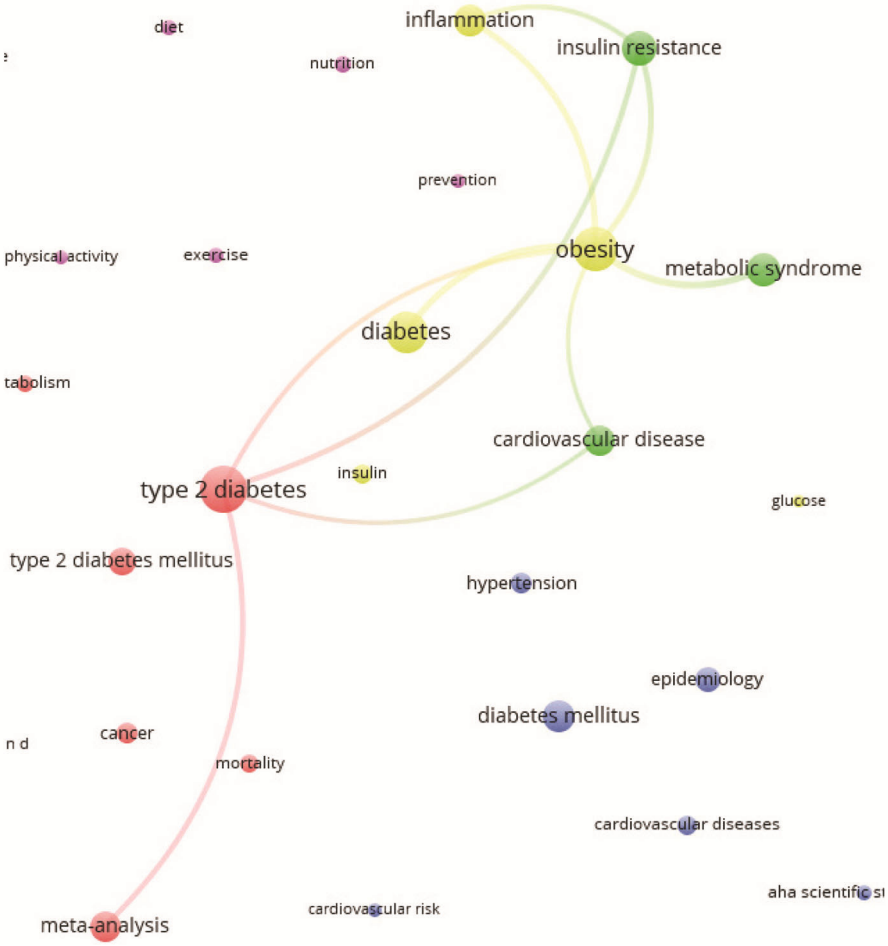


Figure 10. Top 10 closely connected groups of author keywords.

At the institution level, the 1845 HCPs on type-2 diabetes were from 3483 organizations around the world. Table 4 illustrates the primary performance of the top 15 most productive organizations. Among them, eight organizations are in USA, three in England, and one each in Denmark, Canada, Australia and Finland. Harvard University takes the leading position not only in total publications (PN = 197), but also in total citations (TC = 61880) and collaboration intensity (TLS = 250). As for average citations, University of North Carolina (AC = 469.1) ranks first in the top 15 organizations. The links of six organizations (Harvard University, Brigham and Women's Hospital, University Washington, University of North Carolina, University Copenhagen, Massachusetts General Hospital) are 14, which indicates that each of them collaborated with other 14 organizations. Figure 9 shows the visualization of collaborations and top 10 link strength combinations between the top 15 organizations. The link strength between Harvard University and Brigham and Women's Hospital is maximum, with number of collaborative HCPs being 70. The link strength between Harvard University and Massachusetts General Hospital ranks second. Brigham and Women's Hospital and Massachusetts General Hospital are both teaching hospitals of the Harvard Medical School. This could be the reason they collaborated closely with Harvard University. The colours in Figure 9 are used to distinguish between different clusters.

Table 5 shows the author keywords (occurrences ≥ 10) and their total link strength. Among the author keywords, 'diabetes' related words appeared the most, including 'type-2 diabetes', 'diabetes', 'diabetes mellitus' and 'type-2 diabetes mellitus'. 'Obesity' is the second-most common word that appears. In particular, it has the highest total link strength, which illustrates 'diabetes' as the keyword which is most closely connected with other keywords. The occurrences of 'insulin' related keywords (including 'insulin resistance', 'insulin' and 'insulin sensitivity') are also obvious. As can be seen from the listed author keywords, type 2 diabetes is associated with many other diseases, such as 'cardiovascular disease', 'inflammation', 'cancer', 'hypertension', 'atherosclerosis', 'dyslipidemia', 'non-alcoholic fatty liver disease', 'heart failure', 'stroke', 'nafld' and 'Alzheimer's disease'.

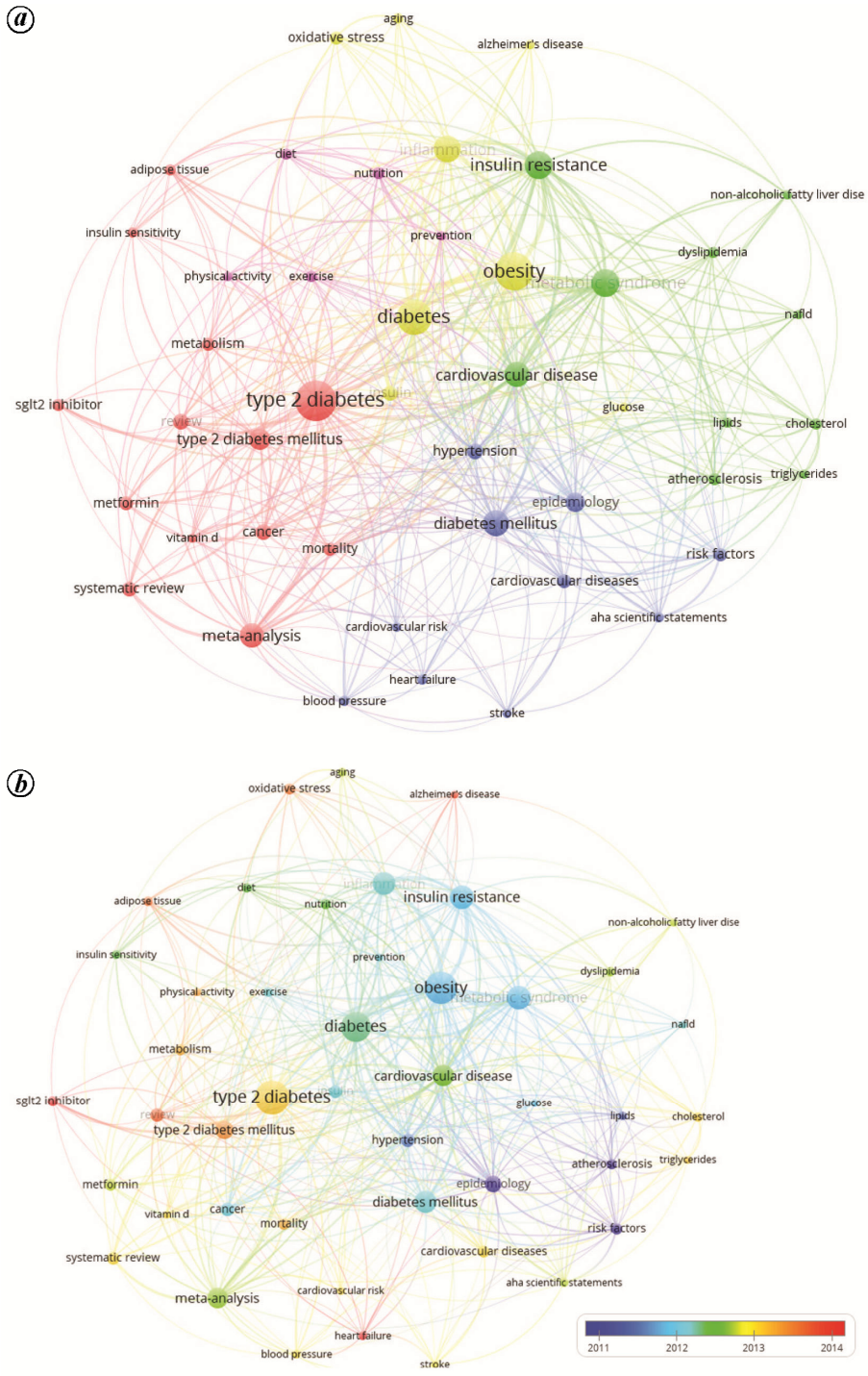


Figure 11. (***a***) network visualization and (***b***) overlay visualization of author keywords (occurrences ≥10).

Figure 10 shows the top 10 closely connected groups of author keywords. The link strength between 'obesity' and 'metabolic syndrome' is maximum, which indicates that they appeared at the same time in 31 HCPs. The second is the group of 'obesity' and 'diabetes' (link strength = 28), and the third is the group of 'obesity' and 'inflammation' (link strength = 24).

Figure 11 *a* shows the network visualization of author keywords (occurrences ≥ 10). The entire network of the 46 author keywords (occurrences ≥ 10) is presented. The 46 author keywords have been divided into five groups and each group presented with a certain colour. In network visualization, the colour of author keywords is determined by the cluster to which the item belongs, according to VOSviewer. Figure 11 *b* shows the overlay visualization of author keywords (occurrences ≥ 10). The author keywords in overlay visualization are coloured differently. The colour of an author keyword is determined by

the publication year (or average publication year) of the item. For example, for the 1845 HCPs, 'sglt2 inhibitor' and 'heart failure' occur frequently in recent years. However, 'epidemiology' and 'atherosclerosis' have occurred frequently in previous years.

Conclusion

In this study, we have employed the bibliometric method to analyse HCPs on type-2 diabetes mellitus from ESI. The influence of most productive journals, countries/territories, organizations and authors was evaluated. As for countries/territories, USA is the most productive country and has the highest total citations; Scotland has the highest average citations; The Netherlands has the highest AGRA values. At the institution level, Harvard University is the most productive organization and has the highest total citations; University of North Carolina has the highest average citations. F. B. Hu, (Harvard University) is the most productive corresponding author and R. R. Holman who ('Churchill Hospital' and 'University of Oxford') has the highest total citations. The interaction among productive countries/territories, organizations, authors and keywords was analysed. In international collaborations, USA is at the central position, which shows its research potential in type-2 diabetes mellitus field. For organizations, Harvard University has the highest collaboration intensity. For corresponding authors, J. B. Buse has the most collaborators. The relationship networks among productive countries/territories, organizations, authors and keywords were also visualized using VOSviewer.

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