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Pro-Metrics

ORIGINAL ARTICLE

Global research on type 1 diabetes: A bibliometric study during 2001-2022

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ABSTRACT

Objective. Type 1 diabetes (T1D) publications have increased over the past three decades. However, there is no study to address and identify gaps in this area and to plan future research. This study aims to analyze the global scientific production of T1D in terms of overall structure and hotspots.

Methodology. The research literature on T1D from 2001 to 2022 was obtained and examined from the Scopus database. We then performed bibliometric analysis and network visualization using MS Excel and VOSviewer software.

Results/Discussion. The global T1D research comprised 20473 publications, which witnessed 6.19% and 58.91% annual average and 10-year cumulative growth during 2001-2022. These together received 596950 citations, with an average Citation Per Paper (CPP) of 29.16. Of the total global publications, 6030 (29.45%) received external funding support from international agencies and 19553 citations (with an average CPP of 32.43). The global publications were sourced from more than 150 countries and were published in 2665 journals by 63747 authors from 24899 organizations. There is an uneven distribution of countries, organizations, and authors in T1D research, wherein 88.37%, 45.15%, and 20.66% of the global literature was contributed by the top 12 countries and top 30 organizations and authors each. The most productive countries were the USA and UK, with a global share of 30% and 11.1% respectively. The most impactful countries were Finland and the UK regarding CPP & Relative Citation Index (RCI). The Barbara Davis Center for Childhood Diabetes, USA, and the University of Colorado Anschutz Medical Campus, USA, were the most productive organizations, with 735 and 679 publications. Jaeb Center for Health Research, USA (77.03 and 2.64) and Harvard Medical School, USA (67.42 and 2.31) were the most impactful organizations regarding CPP & RCI. *Pediatric Diabetes* (n=1447) and *Diabetes Care* (n=1191) were the most productive journals, with 1447 and 1191 papers. *Diabetes and Diabetes Care* registered the highest CPP (81.54 and 73.88 CPP). The most significant and frequently appearing keywords were

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"diabetes mellitus, type 1") (92441), "insulin dependent diabetes mellitus" (95750), "metabolism" (24911), "genetics" (11229), "autoantibodies" (8942), "c peptide" (9931) and "pancreas islet beta cell" (7191). Only 5.54% (1134) of the global publications (considered highly-cited papers) received 100 to 4654 citations since their publications and registered a total of 220.28 CPP.

Conclusions. This bibliometric study indicated that most of the contributions came from developed countries and only a meager contribution from developing countries, especially South Asia, despite a significant disease burden. This analysis provides a comprehensive overview of the present status of T1D research. It enables a better understanding of T1D research over the years. It should give the researchers structured information and a comprehensive analysis to help identify gaps in the research and the hot spots in this area of research.

Keywords: child; diabetes mellitus type 1; incidence; epidemiology; insulin, bibliometric study.

1. INTRODUCTION

Type 1 diabetes (T1D) is also known as Juvenile diabetes since it mainly involves the pediatric population. It is an autoimmune disease, where the Beta-cells of the islet of Langerhans of the pancreas are affected, leading to Insulin hormone deficiency and, consequently, high blood sugar levels (NIDDK, 2017). The cause of T1D is not well known, and it is thought to be due to a combination of genetic and environmental factors (WHO, 2023). The exact number of global cases with T1D is not known. It is estimated that out of all the cases of diabetes, T1D accounts for 5-10% of them (Daneman, 2006). It is reported that around 80,000 children develop T1D per year (Chiang *et al.,* 2014). T1D begins in children and young adults (NIDDK, 2017), but its symptoms can appear at any age (Atkinson *et al.,* 2020).

The worldwide incidence of T1D has risen in the recent past. Although the exact causes of this phenomenon are not well understood, it is believed that it is multifactorial and could be due to prenatal and perinatal factors, early life infections, and diet composition that could trigger the immune system. Interestingly, a rapid increase in new T1D cases indicates that lifestyle factors (like unhealthy eating patterns and obesity) may also be responsible for it, similar to Type 2 Diabetes (T2D) (Ogrotis, Koufakis & Kotsa, 2023). The number of people with T1D is rising, doubling almost every decade. In 2022, there were 8.75 million (95.0% uncertainty interval: 8.4-9.1) with T1D globally, and around $1/5^{th}$ (1.9 million) of them lived in low-income and lower-middle-income countries (LMIC). In 2022, amongst all the global T1D cases, 17% were younger than 20 years, 64% were aged between 20 and 59, and ~20% were 60 years or older. In 2022, the total number of T1D cases of less than 20 years was higher than in 2021 (Ogle, Wang & Gregory, 2022).

The ten countries with the highest number of T1D prevalent cases at all ages were the United States of America (USA)(1447298), India (860423), Brazil (588800), China (448480), Germany (431313), the United Kingdom (UK) (413042), Russia (336,901), Canada (285324), Saudi Arabia (241348), and Spain (206944). Whereas, the number of children and adolescents (of less than 20 years of age) were slightly different in order, with India (282832) (highest), followed by the USA (170408), Brazil (112240), China (66040), Russia (58338), Saudi Arabia (49118), Algeria (46642), the UK (42048), Germany (40390), Morocco (37194), Canada (32211), Ukraine (32093) and Turkey (29000). This difference in the rankings of cases for all ages and those under 20 years points to the fact that there are substantially younger populations in the countries (with T1D), such as India, Algeria, Morocco, and Turkey, and also have a higher mortality in LMIC in younger age, resulting in lesser number of T1D cases in older population (Ogle, Wang & Gregory, 2022). It is estimated that there were 182000 deaths in 2022 due to T1D, among which the majority were from LMIC of Southeast Asia (~ 42000) and Africa (~38000). In contrast, in developed nations of Europe and North America, these deaths were lower at 34000 and 20000, respectively (Ogle, Wang & Gregory, 2022).

The T1D research has witnessed a significant increase over the past two decades. However, considerable progress and changes in our understanding of etiology, pathogenesis, and pharmacological treatment remain

limited and must be documented. No comprehensive review is available to address these gaps by analyzing trends, evaluating previous research, and providing insights for future investigations. The present study aims to analyze and explore the research activities in the area of T1D, including the overall structure and hotspots at the global level. We also aimed to identify the most productive and impactful authors, organizations, and countries. In addition, we sought to characterize the highly-cited papers (HCP) and identify the journals in which these were published.

Bibliometric analysis is a proper research method to assess and quantify the published research data, which can detect the important researchers, institutions, and countries and their collaboration. The global trends and research hotspots can be identified using keywords, references, and co-citation analysis (Zhang *et al.,* 2020). A few bibliometric studies on T1D have been published (Gupta & Dayal, 2020), examining the global research output in pediatric T1D from 2000 to 2019. In another study (Dayal, Gupta, & Gupta, 2021), an assessment of Indian research on pediatric T1D from 1990-2019 was done, and it reported that India's research contribution on T1D is lagging in quantity and quality, as compared to the developed countries, but is showing some improvement in the recent past. They suggested a need for collaborative research by the Indian researchers. Among other related literature, the bibliometric assessment was made on "Covid-19 and T1D" (Dayal *et al.,* 2021) and "Stem cell therapy for T1D" (Dayal *et al.,* 2022). The bibliometric studies can help identify current concerns and guide future research directions. Therefore, applying bibliometrics may have great significance in pediatric T1D research.

2. MATERIAL AND METHODS

We included this study's data from Scopus, which offers many unique features to help in the bibliometric analysis of any specific medical condition (Sweileh *et al.,* 2016), like T1D. Scopus includes 20,000+ journals that also have Medline coverage. Moreover, it is a better search engine than the others because it has 20% greater coverage than Web of Science (WoS) and offers more consistent and accurate results (Falagas *et al.,* 2008). The Scopus database was searched for all global publications related to pediatric T1D over the 22-year (2001-2022), using the following search strategy:

> (KEY (type 1 diabet* OR diabet*, AND type 1) AND KEY (child* OR infant OR kid OR paediat* OR pediat* OR juvi* OR adolescent)) AND PUBYEAR > 2000 AND PUBYEAR < 2023

The retrieval time range was from January 1, 2001, to 31st December 2022. The search was conducted using keywords related to "Type 1 diabetes" and "children" in the "keyword" tag in the advanced search option. The search was conducted on 4.8.2023. A total of 20473 documents were retrieved and obtained from the Scopus database. The main authors, institutions, countries, journal metrics, and documents were extracted. The details of publications in terms of their numbers, type, countries, institution, publishing journals, citation patterns, and funding agencies were analyzed using Microsoft Excel. We clustered the countries and authors based on their collaboration network using the VOSviewer software. Different nodes represent an institution or country, while the magnitude of the node circle represents productivity in the network map. The nodes in the collaboration network were countries, organizations, and authors, and the links represented co-authorship in the network map (Wang *et al.,* 2019). The links between them reflect the collaboration network, co-citation, or co-occurrence relationships, and a wider line represents a stronger association (Zheng *et al.,* 2020).

This study considered the HCP for those that registered 100 or more citations. The most productive authors and institutions published the maximum number of articles on T1D. The most impactful authors and institutions had the highest citation impact in terms of Citations per paper (CPP) and Relative citation index (RCI).

3. RESULTS

3.1. Overall picture

The global output on T1D resulted in 20,473 publications from a search in the Scopus

database from 2001 to 2022. The annual publications increased from 475 (in 2001) to 1456 (in 2022), registering a 6.19% average yearly growth rate. The cumulative 10-year publications increased from 7662 during 2001-2011 to 12811 during 2012-2022, registering 59.81% absolute growth. The 20,473 global publications received 596950 citations, averaging 29.16 CPP, which decreased from 43.83 CPP to 20.39 from 2001-2011 to 2012-2022. The decrease is mainly because publications from 2012 to 2022 did not accumulate sufficient years to accumulate citations compared to the previous period (Table 1).

Year	TP	TC	CPP	HCP	Year	TP	TC	CPP	HCP
2001	475	26928	56.69	46	2014	1015	38026	37.46	89
2002	539	29213	54.20	61	2015	1058	31507	29.78	52
2003	539	25379	47.09	72	2016	1063	26887	25.29	35
2004	634	24798	39.11	53	2017	1095	25580	23.36	32
2005	662	36712	55.46	75	2018	1179	25245	21.41	34
2006	714	30836	43.19	67	2019	1179	19021	16.13	15
2007	737	30001	40.71	58	2020	1375	16338	11.88	19
2008	813	33478	41.18	74	2021	1469	10401	7.08	8
2009	811	34784	42.89	88	2022	1456	4091	2.81	0
2010	859	31525	36.70	72	2001-11	7662	335726	43.82	723
2011	879	32072	36.49	57	2012-22	12811	261224	20.39	393
2012	933	32787	35.14	61	2001-22	20473	596950	29.16	1116
2013	989	31341	31.69	48					

(TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; HCP: Highly-cited papers).

Table 1. Growth of global publications on type 1 diabetes during 2001-2022.

Of the 20473 global publications, 29.45% (6030) received external funding support from national and international agencies and received 19553 citations, averaging 32.43 CPP. The significant agencies providing external funding support along with their publication output were: the National Institute of Diabetes and Digestive and Kidney Diseases (n=2318), National Institute of Health (n=1346), National Center for Advancing Translational Sciences (n=601), National Center for Research Resources (n=554), Juvenile Diabetes Research Foundation of USA (n=488), Eunice Kennedy Shriver National Institute of Child Health & Human Development (n=432), Juvenile Diabetes Research Foundation International (n=303), National Institute of Allergy & Infectious Diseases (n=303), Leona M & Harry B Helmsley Charitable Trust (n=300), Novo Nordisk (n=297), National Institute of Child Health & Human Development (n=259), Medical Research Council (n=196), etc.

Research articles (17350, 84.75%) constitute the largest share, followed by reviews (1606, 7.84%), letters (575, 2.81%), conference papers (354, 1.73%), notes (281. 1.37%), and other publication type less than 1.0%. The clinical studies (12677, 61.92%) constitute the largest publication share, followed by epidemiology (3802, 18.57%), risk factors (3373, 16.48%), pathophysiology (2858, 13.96%), complications (2501, 12.22%), genetics (1711, 8.36%), quality of life (1291, 6.31%). and prognosis (732, 3.58%). There is also an overlapping of publications under the above research type. On classifying the global publications by research design, controlled studies (9277, 45.31%) constitute the largest share, followed by clinical trials (1890, 9.24%), cross-sectional studies (1803, 8.81%), retrospective studies (1740, 8.50%), case-control studies (1492, 7.29%), randomized control trials (1450, 7.08%), prospective studies (1379, 6.74%), multicenter studies (1190, 5.81%), observational studies (705, 3.44%) and controlled clinical trials (647, 3.16%).

3.2. Geographical distribution of publications

3.2.1. Contribution of the top 12 countries

The participating authors were affiliated with more than 150 countries/regions. The top 12 countries collectively contributed 18092 papers

(88.73%) and received 709161 citations (Table 2). The average citation impact, measured by CPP and RCI, was 39.20 and 1.34, respectively. Eight countries have a citation impact exceeding the average: Finland (47.46 and 1.62), U.K. (46.68 and 1.60), USA (42.35 and 1.45), Denmark (41.81 and 1.43), Australia (41.75 and 1.43), Canada (41.18 and 1.41), Sweden (39.30 and 1.34) and Germany (39.23 and 1.34). The share of ICPs in these countries varied from 11.97% to 67.13%, averaging 41.32%. The share of externally funded papers in the top 12 countries varied from 12.49% to 57.56%, averaging 42.96%. The share of HCP of the top 12 countries varied from 2.24%% to 11.19%, with an average value of 8.60% (Table 2).

No.	Country	TP	TC	CPP	RCI	ICP	%ICP	FP	%FP	HCP	%HCP	Links within top 12 countries	Total link strength
1	USA	6244	264429	42.35	1.45	1922	30.78	3594	57.56	587	9.40	2213	3944
2	U.K.	2272	106048	46.68	1.60	1180	51.94	849	37.37	240	10.56	1673	2410
3	Germany	1511	59275	39.23	1.35	846	55.99	592	39.18	144	9.53	1400	2783
4	Italy	1357	43404	31.99	1.10	487	35.89	247	18.20	87	6.41	815	1601
5	Sweden	1167	45858	39.3	1.35	680	58.27	540	46.27	93	7.97	1270	2135
6	Australia	1106	46177	41.75	1.43	569	51.45	379	34.27	90	8.14	889	1174
7	Canada	897	36938	41.18	1.41	507	56.52	381	42.47	85	9.48	744	1237
8	Poland	849	12464	14.68	0.50	253	29.8	106	12.49	19	2.24	324	694
9	Finland	715	33934	47.46	1.63	480	67.13	387	54.13	80	11.19	731	1268
10	Denmark	685	28641	41.81	1.43	431	62.92	277	40.44	61	8.91	796	1589
11	China	666	11546	17.34	0.59	207	31.08	263	39.49	18	2.70	267	380
12	France	623	20447	32.82	1.13	304	48.8	158	25.36	52	8.35	615	1105
Total of top 12 countries		**18092**	**709161**	**39.20**	**1.34**	**7866**	**43.48**	**7773**	**42.96**	**1556**	**8.60**		
Total Global publications		**20473**	**596950**	**29.16**	**1.00**								
Share of top 12 countries		**88.37**											

TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; ICP: International collaborative papers; FP: Funded papers; HCP: Highly-cited papers.

Table 2. Profile of top 12 most productive countries in type 1 diabetes research.

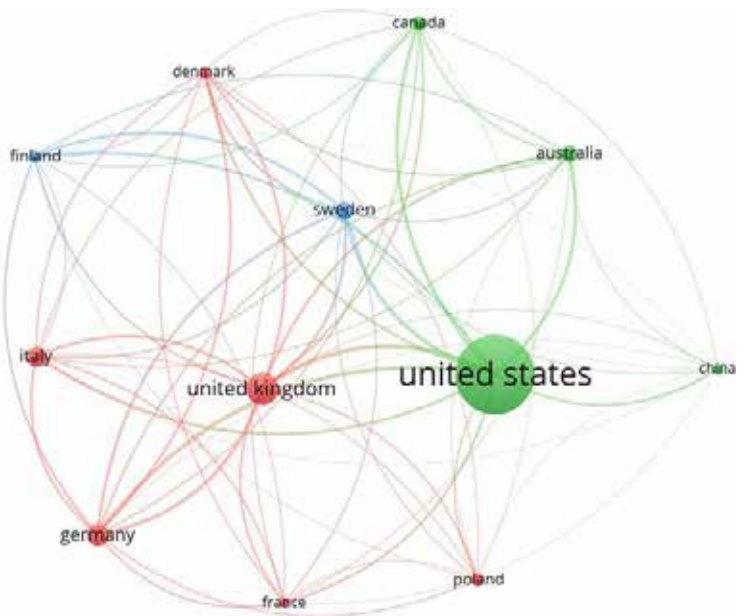

Figure 1. Collaboration network map among top 12 countries.

Figure 1 shows the collaboration network created by VOSviewer between the top 12 countries that contributed 623 or more documents. The network indicates 12 nodes, 132 links, and 12064, with a network density of 0.121. It produced three clusters: Cluster 1 (6 countries) includes the United Kingdom, Germany, Italy, Denmark, France, and Poland; Cluster 2 (4 countries) consists of the United States, Australia, Canada, and China; and Cluster 3 (2 countries) includes Sweden and Finland. The most prominent country depicting the highest Total Link Strength (TLS) was the USA (n=2370), followed by the U.K. (n=1705), Germany (n=1444), Sweden (n=1302), Finland (n=841), Italy (n=8340), Denmark (832), and Australia (n=829).

3.2.2. Contribution of the top 12 developing countries

The individual among the top 12 developing countries contributed 103 to 491 papers. These 12 developing countries collectively contributed 2968 papers and 59423 citations, representing 14.50% and 9.95% share, respectively, in global publications and citations. The average publication productivity by the top 12 developing countries was 247.33, and only four countries contributed more than average productivity: Brazil (491 papers), India (490 papers), Israel (326 papers), and Egypt (304 papers). The average citation impact, in terms of CPP and RCI, registered by the top 12 developing countries was 20.02 and 0.69, and 5 countries registered more than average citation impact: Israel (36.3 and 1.24), New Zealand (27.45 and 0.94), South Korea (35.3 and 0.87), Greece (23.28 and 0.80) and Mexico (20.46 and 0.70). The share of international collaborative papers of the top 12 developing countries varied from 17.73% to 45.05%, with an average of 28.81%. The share of externally funded papers of the top 12 developing countries varied from 2.27% to 33.20%, with an average value of 15.70%. The share of HCP in the top 12 developing countries varied from 0.00% to 6.44%, with an average value of 2.53% (Table 3).

No.	Country	TP	TC	CPP	RCI	ICP	%ICP	FP	%FP	HCP	%HCP
1	Brazil	491	8590	17.49	0.60	94	19.14	163	33.20	6	1.22
2	India	480	7908	16.48	0.56	121	25.21	55	11.46	12	2.50
3	Israel	326	11834	36.30	1.24	135	41.41	69	21.17	21	6.44
4	Egypt	304	3709	12.20	0.42	69	22.70	11	3.62	1	0.33
5	Saudi Arabia	225	3914	17.40	0.60	99	44.00	23	10.22	4	1.78
6	Iran	220	2548	11.58	0.40	39	17.73	5	2.27	1	0.45
7	Greece	216	5028	23.28	0.80	67	31.02	5	2.31	6	2.78
8	New Zealand	202	5544	27.45	0.94	91	45.05	35	17.33	10	4.95
9	Taiwan	146	2466	16.89	0.58	40	27.40	34	23.29	0	0.00
10	South Korea	137	3466	25.30	0.87	30	21.90	14	10.22	7	5.11
11	Chile	118	2309	19.57	0.67	38	32.20	28	23.73	2	1.69
12	Mexico	103	2107	20.46	0.70	32	31.07	24	23.30	5	4.85
Total of 12 countries		**2968**	**59423**	**20.02**	**0.69**	**855**	**28.81**	**466**	**15.70**	**75**	**2.53**
Total global publications		**20473**	**596950**	**29.16**	**1.00**						
Share of top 12 countries		**14.50**	**9.95**								

TP: Total papers; TC: Total citations; CPP: Citations per paper; RCI: Relative citation index; ICP: International collaborative papers; FP: Funded papers; HCP: Highly-cited papers.

Table 3. Profile of top 12 top developing countries in type 1 diabetes research.

3.3. Subject-wiser distribution of research output

The literature on T1D as classified by Scopus subject categories, *medicine* contributed the largest publication share (89.31% and 18285 publications), followed by *biochemistry, genetics and molecular biology* (28.77% and 5890 publications), *immunology and microbiology* (4.55%), *psychology* (3.04% and 622 publications), *pharmacology, toxicology* and *pharmaceutics* (1.71% and 350 papers), etc.

3.4. Significant keywords

Among the total keywords, the top 13 most common keywords were "diabetes mellitus, type 1" (92441), "insulin dependent diabetes mellitus" (95750), "metabolism" (24911), "genetics" (11229), "autoantibodies" (8942), "c peptide" (9931), "pancreas islet beta cell" (7191), "pregnancy" (6522), "genetic predisposition" (6050), "c-peptide" (4971), "autoimmune disease" (4257), "genetic association" (4191), "single nucleotide polymorphism" (4065) and "celiac disease" (3544). Figure 2 shows the co-occurrence network of 88 most important and frequent keywords. Keywords (along with their frequency of appearances) are clustered into four broad categories or clusters, as shown below. The same color presented keywords in the same cluster and clustered together because they often appeared together in the same article.

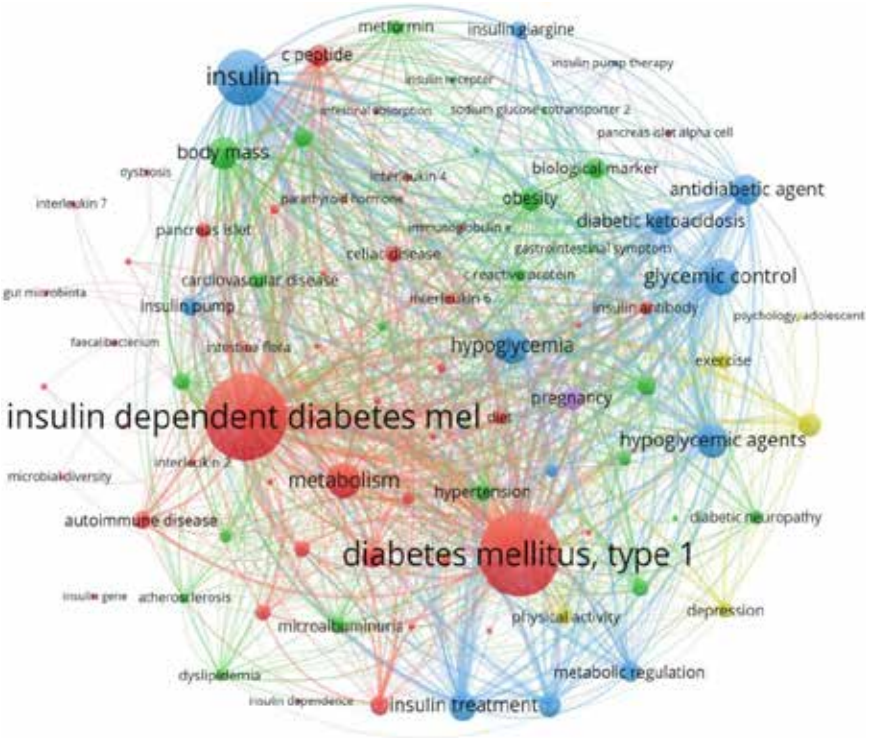

Figure 2. Keyword co-occurrence map of top 88 significant keywords.

3.4. Leading organizations

In terms of affiliations, 24,899 organizations participated in global pediatric T1D research. The top 30 organizations individually contributed 216 to 735 papers. Collectively, these 30 organizations contributed 9244 papers and 465617 citations, representing 45.15% and 78.0% share in global publications and citations. Of the top 30 organizations, 13 were located in the USA, followed by Finland (6), Sweden (4), Canada, Denmark, Germany (2 each) and Australia, and the U.K. (1 each). The average publication productivity by the top 30 organizations was 308.13. Table 4 presents the profile of the top 8 most productive and top 8 most impactful organizations.

The top 30 organizations' collaborative network map is shown in Figure 3, where all 30 organizations are depicted in the following three clusters. The organization collaboration analysis identified 30 nodes, 715 links, and 14496 TLS, with a network density of 0.011. The collaboration network is strong as all 30 authors are connected and divided into three clusters (Figure 3). The organizations in each column belong to the same collaborative group, and the connecting lines indicate their linkage. The node size is proportional to the quantum of publications from the organizations.

No.	Affiliation	Country	TP	TC	CPP	RCI	ICP	ICP
Top 8 Most Productive Organizations								
1	Barbara Davis Center for Childhood Diabetes	USA	735	41459	56.41	1.93	284	38.64
2	University of Colorado Anschutz Medical Campus	USA	679	37813	55.69	1.91	241	35.49
3	Helsingin Yliopisto	Finland	427	19496	45.66	1.57	206	48.24
4	University of Washington	USA	364	22148	60.85	2.09	156	42.86
5	Turun yliopisto	Finland	344	18112	52.65	1.81	196	56.98
6	Harvard Medical School	USA	343	23124	67.42	2.31	145	42.27
7	Universität Ulm	Germany	331	12224	36.93	1.27	221	66.77
8	Lunds Universitet	Sweden	325	12167	37.44	1.28	213	65.54
Top 8 Most Impactful Organizations								
1	Jaeb Center for Health Research	USA	228	17563	77.03	2.64	64	28.07
2	Harvard Medical School	USA	343	23124	67.42	2.31	145	42.27
3	Joslin Diabetes Center	USA	320	21164	66.14	2.27	92	28.75
4	Stanford University	USA	222	14442	65.05	2.23	69	31.08
5	University of Washington	USA	364	22148	60.85	2.09	156	42.86
6	University of Florida	USA	303	18247	60.22	2.07	135	44.55
7	Colorado School of Public Health	USA	238	13686	57.50	1.97	61	25.63
8	Barbara Davis Center for Childhood Diabetes	USA	735	41459	56.41	1.93	284	38.64

TP: Total papers; TC: Total citations; CPP: Citations per paper;
RCI: Relative citation index; ICP: International collaborative papers.

Table 4. Profile of top 8 most productive and impactful organizations in type 1 diabetes research.

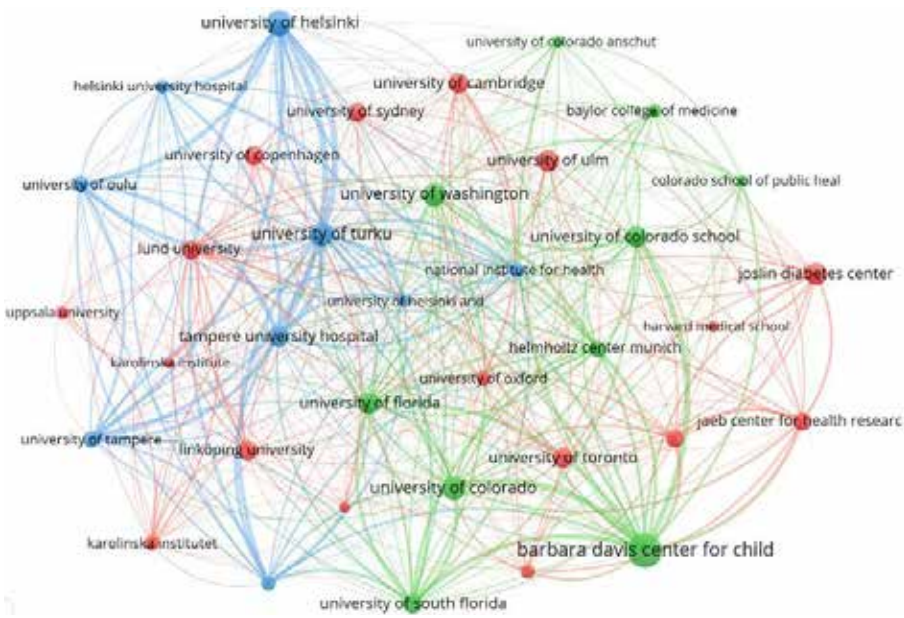

Figure 3. Network collaboration map of top 30 institutions.

3.5. Leading authors

A total of 63647 authors participated in global T1D research. The top 30 authors contributed 4229 papers and 214261 citations, representing 20.66% and 35.89% of global publications and citations, respectively. These top 30 authors' share of international collaborative papers varied from 13.68% to 80.37%, with an average of 45.85%. Table 5 presents a profile of the top 8 most productive and impactful organizations.

No.	Author	Affiliation	TP	TC	CPP	RCI	ICP	%ICP
		Top 8 Most Productive Authors						
1	R. W. Holl	Universitat Ulm, Germany	263	9910	37.68	1.29	166	63.12
2	J. Ilonen,	Turun yliopisto, Finland	246	12985	52.78	1.81	119	48.37
3	M. Knip	University Hospital of Tampere, Finland	242	14136	58.41	2.00	103	42.56
4	J. Ludvigsson.	Linköpings Universitet, Sweden	210	7106	33.84	1.16	87	41.43
5	A. G. Ziegler.	Helmholtz Center Munich, German Research Center for Environmental Health, Germany	194	11835	61.01	2.09	116	59.79
6	D. M. Maahs.	Barbara Davis Center for Childhood Diabetes, USA	166	9360	56.39	1.93	58	34.94
7	R. Veijola	Medical Research Center Oulu, Oulu, Finland	165	7487	45.38	1.56	78	47.27
8	A. Lernmark	Lund University Diabetes Centre, Malmo, Sweden	163	7666	47.03	1.61	131	80.37
		Top 8 Most Impactful Authors						
1	J. M. Lawrence.	National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), USA	99	10342	104.46	3.58	32	32.32
2	R.W. Beck	Jaeb Center for Health Research, Tampa, USA	129	13213	102.43	3.51	28	21.71
3	E. J. Mayer-Davis	The University of North Carolina, Chapel Hill, USA	117	8673	74.13	2.54	16	13.68
4	D. Dabelea	Colorado School of Public Heath, USA	156	11023	70.66	2.42	26	16.67
5	C. Pihoker	University of Washington, Seattle, USA	96	6768	70.50	2.42	21	21.88
6	M. Rewers.	Barbara Davis Center for Childhood Diabetes, USA	126	8354	66.30	2.27	100	79.37
7	J. P. Krischer.	University of South Florida, Tampa, USA	102	6409	62.83	2.15	81	79.41
8	A. G. Ziegler.	Helmholtz Center Munich, German Research Center for Environmental Health, Germany	194	11835	61.01	2.09	116	59.79

TP: Total papers; TC: Total citations; CPP: Citations per paper;
RCI: Relative citation index; ICP: International collaborative papers.

Table 5. Profile of top 8 most productive and impactful authors in type 1 diabetes research.

Of the 692 authors, 30 met the thresholds. The author's collaboration analysis identified 30 nodes, 378 links, and 6478 TLS, with a network density 0.001. The collaboration network is strong as all 30 authors are connected and divided into four clusters (Figure 4). The authors of the same collaborative group are represented in each column, and the connecting lines indicate their collaborative links. The number of authors' publications is proportional to the node size and color; e.g., the darker yellow node represents the closeness of the corresponding author to this field in recent years.

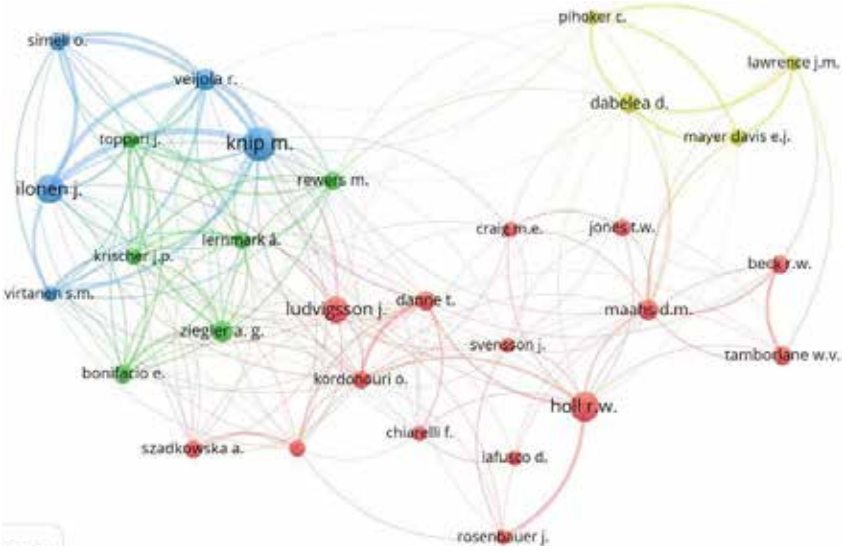

Figure 4. Network collaboration map of top 30 authors.

3.6. Publishing journals

Of the 20473 publications on T1D, 99.01% (20,271) were published in 2665 journals. Among top 30 most productive journals, *Pediatric Diabetes* published the highest (n=1447) number of articles with 5.88% share, followed by *Pediatric Diabetes* (n=1447), *Diabetes Care* (n=1191), *Diabetic Medicine* (n=765), *Diabetologia* (n=572), *Diabetes Technology and Therapeutics* (n=487) and *Diabetes Research and Clinical Practice* (n=435) and they together produced 4897 publications, constituting 24.16% share of total publications in journals by top 30 countries. Among the top 30 journals, the top six journals by total citations received were *Diabetes Care* (n=87987), followed by *Pediatric Diabetes* (n=36345), *Diabetologia* (n=33325), *Diabetes* (n=28294), *Diabetic Medicine* (n=26108), and *Diabetes Technology and Therapeutics* (n=16423). Together, they received 228482 citations, accounting for a 71.10% share in total citations received by the top 30 journals. *Diabetes* registered the highest (81.54) CPP among the top 30 most productive journals, followed by *Diabetes Care* (73.88 CPP), *Pediatrics* (73.19 CPP), *Diabetologia* (58.26), *Journal of Pediatric Psychology* (38.95), and *Journal of Clinical Endocrinology and Metabolism* (38.51 CPP). All six journals registered higher CPP than the average CPP (36.7) of all 30 journals.

The impact factor (IF) (2022) of the top 30 journals varied from 1.14 to 16.2. Among the top high-impact journals, *Diabetes Care* had the highest IF (16.2), followed by *Diabetes* (9.5), *Diabetes and Metabolism* (8.2), *Diabetologia* (8.2), *Diabetes Research and Clinical Practice* (8.2) and *Diabetes Metabolism Research and Reviews* (8).

3.7. Highly-cited papers

Among the 20473 global publications, 1134 (5.54%) registered 100 to 4654 citations and received 249799 citations, averaging 220.28 CPP. There was a skewed distribution of these HCPs: 1073 papers fell in the citation range of 100-500, 46 in the range of 503-978, and 15 in the range of 1013-4654. Table 6 provides a profile of the top 12 countries contributing to HCPs on T1D.

No.	Country	Total Papers	Total Citations	Citations Per Paper	% Total Papers
1	USA	600	137665	229.44	52.91
2	U.K.	250	59834	239.34	22.05
3	Germany	149	2864	19.22	13.14
4	Australia	96	24179	251.86	8.47
5	Italy	90	18120	201.33	7.94
6	Canada	89	18899	212.35	7.85
7	Sweden	94	22006	234.11	8.29
8	Finland	82	17979	219.26	7.23
9	Denmark	63	13391	212.56	5.56
10	France	55	10806	196.47	4.85
11	Netherlands	54	11638	215.52	4.76
12	Austria	44	8567	194.70	3.88
Total of 12 countries		**1666**	**345948**	**207.65**	
Total global publications		**1134**	**249799**	**220.28**	

Table 6. Profile of top 12 countries contributing to highly-cited papers in type 1 diabetes.

Among the top 20 organizations, the top 5 most productive organizations were: *Barbara Davis Center for Childhood Diabetes,* USA (n=106), *University of Colorado,* Anschutz (n=94), *Harvard Medical Scholl,* USA (n=68), *University of Florida,* USA and *Joslin Diabetes Center,* USA (n=54 each). The top organizations in terms of citation impact per paper were the *National Institute of Health and Welfare,* Finland (366.0 CPP); *University of North Carolina at Chapel Hill,* USA (311.35 CPP); *Stanford University,* USA (299.45 CPP); *University of Washington,* USA (259.66 CPP), and *Colorado School of Public Health,* USA (259.56 CPP) (Table 7).

No.	Organization	Total Papers	Total Citations	Citations Per Paper
1	Barbara Davis Center for Childhood Diabetes, USA	106	25003	235.88
2	University of Colorado, Anschutz Medical Campus, USA	94	23109	245.84
3	Harvard Medical School, USA	68	16308	239.82
4	University of Florida, USA	54	12142	224.85
5	Joslin Diabetes Center, USA	54	13736	254.37
6	University of Washington, USA	53	13762	259.66
7	Jaeb Center for Health Research, USA	49	12103	247.00
8	Helsinki University, Finland	47	9666	205.66
9	Tarun Yliopisto, Finland	45	10667	237.04
10	University of Cambridge, U.K.	41	8385	204.51
11	University of Toronto, Canada	38	8807	231.76
12	Cincinnati Children's Hospital, Medical Center, USA	36	8407	233.53
13	Yale University, USA	33	7527	228.09
14	University of Pittsburg, USA	33	8181	247.91
15	Stanford University, USA	33	9882	299.45
16	University of North Carolina at Chapel Hill, USA	31	9652	311.35
17	Tampere University, Finland	32	7742	241.94
18	Colorado School of Public Health, USA	32	8306	259.56
19	Universitat Ulm, Germany	31	5511	177.77
20	National Institute of Health and Welfare, Finland	27	9882	366.00
	Total of top 20 organizations	937	228778	244.16
	Total global publications	1134	249799	220.28
	Share of top 20 organizations	82.63	91.58	

Table 7. Profile of top 20 organizations contributing to highly-cited papers in type 1 diabetes.

Among the top 16 authors, the five most productive authors were R. W. Beck (USA) and M. Knip (Finland) (n=40 each), J. Ilonen (Finland) (n=34), D. Dabelia (USA) and M. Rewers (USA) (n=29 each). The top 5 authors in terms of citation impact per paper were J. M. Lawrence (354.79 CPP), D. M. Maahs (275.27 CPP), R. W. Beck (262.48 CPP), D. Dabelia (261.28 CPP) and A. G. Ziegler (251.61 CPP) (Table 8).

4. DISCUSSION

We analyzed bibliometrically 20473 publications on T1D. We noticed a healthy progression in various aspects of T1D-related research during the last 22 years (since 2001), where the number of articles on this topic has been increasing steadily, with 6.19% annual average growth and 59.81% 10-year cumulative publications growth. With the improvement in living standards and unhealthy behaviors such as physical inactivity, the incidence of T1D in young children (age <6 years) is rising (Streisand *et al.,* 2014). The booming literature on this topic reflects the growing awareness of the importance of detecting and treating T1D. The American Diabetes Association guidelines for managing T1D have thus emphasized the crucial role of caregivers to check the blood sugar levels of young children and monitor their diet and insulin therapy to maintain tight blood sugar control (Streisand *et al.,* 2014). The publications on T1D have received a reasonably good number of citations (n=596950), with an average CPP of 29.16.

It is of note that a substantial share (29.45%) of global research output on T1D received funding from international agencies and governments, mainly originating from developed countries, with more than 50% support from the USA alone. These funded research projects registered a higher CPP of 32.43 than the CPP of 29.16 of overall research output, signifying the importance of adequate funding for good research. However, global publications on TID were sourced from more than 150 countries. The developed nations contributed 88.37% of the total research, whereas the developing

No.	Author	Affiliation	Total Papers	Total Citations	Citations Per Paper
1	R. W. Beck	Barbara Davis Center for Childhood Diabetes, USA	40	10499	262.48
2	M. Knip	Helsingin Yliopisto, Finland	40	8163	204.08
3	J. Ilonen	Turun Yliopisto, Finland	34	7552	222.12
4	D. Dabelia	Colorado School of Public Health, USA	29	7577	261.28
5	M. Rewers	Barbara Davis Center for Childhood Diabetes, USA	29	7284	251.17
6	A. G. Ziegler	Helmholtz Center Munich Germany Research Center for Environmental Health, Germany	28	7045	251.61
7	R. W. Holl	Universitat Ulm, Germany	27	4672	173.04
8	E. Bonifacio	Helmholtz Center for Environmental Health, Germany	24	4285	178.54
9	J. M. Lawrence	National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), USA	24	8515	354.79
10	O. Simell	Turun Yliopisto, Finland	23	4206	182.87
11	D.M. Maahs	Barbara Davis Center for Childhood Diabetes, USA	22	6056	275.27
12	B. A. Buckingham	Barbara Davis Center for Childhood Diabetes, USA	21	3541	168.62
13	C. Pihoker	University of Washington, USA	20	5002	250.10
14	C. Kollman	Jaeb Center for Health Research, USA	20	4099	204.95
15	R. Veijola	Oulin Yiopisto, Finland	20	3679	183.95
16	T. Daan	Hannover Medical School, Germany	20	3230	161.50
		Total of 16 authors	**421**	**95405**	**226.62**
		Total global publications	**1134**	**249799**	**220.28**
		Share of top 16 authors	**37.13**	**38.19**	

Table 8. Profile of top 16 authors contributing to highly-cited papers in type 1 diabetes.

nations only had a share of 11.3%. The top 12 countries (all from the developed world), including the USA, UK, and Germany, contributed the most and accounted for approximately 50% share of global output.

On the contrary, the top 12 developing countries, including Brazil, India, and Israel, have a 14.5% share of the global research output. In addition, the publications from the developed countries received a much higher citation impact than the developing nations, with more than 100.0% and 9.95% citation share, respectively, in global publications and citations. There is little difference in the prevalence of T1D in developing and developed countries. Desai & Deshmukh (2020) reported an estimated 97700 children with T1D in India. In the T1D research, the contribution and citation impact of the developing countries is comparatively little, with no developing country listed among the top 15 countries. In addition, a vast difference was observed in the contribution and impact of developed and developing countries, which indicates the need for more active research in developing countries, with government and developed countries nationally prioritizing this research, leading to much larger funding support, more intense international collaboration within their own countries as well with developed countries and supporting creation of appropriate research infrastructure and training of scholars in this area.

Among developed countries, the USA (n=170408), China (n=66040), Russia (n=58338), U.K. (n=42048), Germany (n=40390), and Canada (n=32211) have a high prevalence rate of T1D and individually ranked from 2nd, 4th, 5th, 7th, 8th, to 10th position in global prevalence rates (Ogle, Wang & Gregory, 2022). Similarly, developing countries like India (n=282832), Brazil (n=112240), and Saudi Arabia (n=49118) have high prevalent rates. They are ranked 1st, 3rd, and 6th in global prevalence rates (Streisand *et al.,* 2014). Developing countries with a high prevalence of T1D should strengthen international research collaboration to improve the ability to diagnose, prevent, and treat TID more effectively.

The main reasons for the superiority of developed countries' research are multifactorial.

They ensure substantial R&D efforts and make significant investments, besides active institutional and author participation and involvement in much larger international collaboration across countries and among research players within their own countries. These countries are very resourceful and can make provision for research funding. In the USA, a research program for T1D has provided ~$2.5 billion for its prevention, cure, and treatment. Some meager other national and international organizations are committed to providing funding support in the quest of their T1D research missions. Such efforts by developed countries are vital for impactful publications, compared to the developing countries where T1D is still not given adequate importance in the national research plans (Sweileh *et al.,* 2016; Falagas *et al.,* 2008).

The HCPs create a significant impact on clinical practices through their research findings (Vaishya *et al.,* 2022; Vaishya *et al.,* 2023). In the present bibliometric analysis on T1D, we found 1134 of such papers (5.54%) that received 100 or more citations (100 to 4654) and together registered a high average CPP of 220.28 and the majority of HCPs were published by the authors from developed countries.

5. LIMITATIONS, STRENGTHS, AND FUTURE DIRECTIONS OF THE STUDY

This bibliometric study used data from only one SCOPUS database. Hence, we missed instrumental publications not listed in other databases like the Web of Science. However, SCOPUS is the largest medical database with the highest number of journals listed, so we chose it for our study (Falagas *et al.,* 2008). Moreover, it provides several metrics that are useful for bibliometric analysis. In addition, mixing the metrics of different databases may cause heterogenicity of the data and wrong interpretations.

This bibliometric study on T1D spans over two decades and has identified the trends and gaps in T1D publication, which should help direct future research. The study has also identified the core channels of communications and presented the characteristics of the HCP literature, besides identifying the core authors, institutions, and journals involved in highly cited research.

This study provides valuable information to help you understand and identify hotspots, present research status, and possible emerging trends to guide further studies. In addition, it offers a scientific perspective on this topic, providing helpful information for future researchers, funding agencies, and policymakers. Understanding the leading countries may help to understand the academic frontiers and allow opportunities for research collaboration.

Conflict of interests

The authors declare that there are no conflicts of interest.

Contribution statement

Raju Vaishya and Brij Mohan Gupta: Conceptualization, Literature search, Data analysis, Manuscript writing, editing, and final approval.

Yogendra Singh, Madhu Bansal, and Abhishek Vaish: Data extraction and analysis, Manuscript writing, editing, and final approval.

Statement of data consent

The data generated during the study have been included in the article. The raw data can also be requested from the corresponding author.

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