



# Global Research in Iron Deficiency Anemia during 1934–2019: A Bibliometrics and Visualization Study

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## Abstract

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**Introduction:** This analysis aimed to investigate the global research output in Iron Deficiency Anemia from a bibliometric perspective.

**Methods:** All 29,789 publications in Iron Deficiency Anemia indexed in Scopus from 1934-2019 were included. Using MeSH-assigned keyword search within title/abstract/keywords, this research analyzed and visualized the bibliometric data, including annual publication trends and languages and types of publications, as well as more active and influential authors, research institutes, countries, and journals. The scientific visualization was done by co-authorship, co-citation, and word co-occurrence techniques in VOSviewer.

**Results:** The trend in Iron Deficiency Anemia annual publication growth was increasing. Publications were in over 40 languages, with English as the predominant one. The majority of publications were original research. The highest scientific collaboration was between the USA and UK. Seven out of 13 top authors were from the USA. The top high influential journals were the Lancet, New England Journal of Medicine and Blood, respectively. Highly-frequent keywords were in two clusters: epidemiology and Iron Deficiency Anemia management, iron metabolism, and Iron Deficiency Anemia pathophysiology.

**Conclusion:** The increasing trend of publication growth in Iron Deficiency Anemia demonstrates the importance of research on it and being as an international concern. Iron Deficiency Anemia needs to be investigated from many perspectives, with the main contributions of developing countries where the disease has its causes and consequences. More prolific and highly-cited journals in Iron Deficiency Anemia are of prestigious and known journals that can potentially widen the reach of publications and increase their readability and citation rates. Research on Iron Deficiency Anemia has found its way, and many topics have been considered.

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## Introduction

As a common condition among elders worldwide and one of the significant factors of morbidity and mortality that affects life quality, anemia is manifested by an abnormally low hemoglobin level (1). Women and ones with chronic conditions are at the highest risk of anemia. Anemia affects roughly a third of the world's population; half the cases are due to iron deficiency. Iron Deficiency Anemia (IDA) is one of the most common kinds of anemia, especially among pregnant women and children (2). Many mental and

psychological problems among children may relate to IDA (3).

Bibliometrics is an interdisciplinary scientific field that uses statistical methods to analyze a body of research literature to reveal the historical development of subject fields and discover the patterns of authorship, publication, citation, use, and other related patterns (4). In order to manage research output and make effective scientific policies, bibliometrics or scientometric indicators have been widely applied for the evaluation of research performance in a wide range of scientific



fields, including health topics and medical subfields (5, 6).

Despite some bibliometric studies on hematology-related topics, e.g., Daneshmand et al. for hematological research in five Islamic countries (7), Vellaichamy and Jeyshankar for anemia research in India (8) and Gupta for global heredity blood disorder research in the top ten leading countries (9), few bibliometric studies have been done in the topic of IDA, only focusing the scientific output made by individual countries/regions, such as India (1). Therefore, it is necessary to evaluate and visualize researchers' contributions in this main subfield from a global bibliometric perspective by extracting data from major bibliometric databases for identifying highly productive and more influential agents, leading countries, emerging and hot topics. As the first bibliometric study in IDA from a global perspective, this study can help determine research direction, assign research grants and funds, and identify possible gaps in research on IDA.

## Methods

### Data

In this bibliometric and visualization study, all publications on IDA from the beginning (1934) to the end of 2019 Scopus-indexed publications were selected. With several functions facilitating reliable bibliometric analyses (such as having better coverage of scientific journals), Scopus is commonly used as a reference indexing and abstracting database for bibliometric studies of all kinds (10).

Data on the population size and Gross Domestic Product (GDP) of contributing countries as measures of standardizing research output were extracted from World Bank (11). Data on the quartiles and the Joint Supplier Registration System (JSRS) of publishing journals were extracted from Scimago Journal Rank (12), a publicly available portal that includes the journals and country scientific indicators developed from the information contained in the Scopus.

### Search strategy

The searched query for extracting data from Scopus was done with the use of specific keywords (including “Anemia, Iron Deficiency”, “Iron Deficiency Anemia” and “Anemias, Iron Deficiency”) and within title/abstract/keywords for publication year>2020 and without any limitation of publication language and/or type.

In line with other related studies, these keywords were selected from MeSH (Medical Subject Headings) as the

National Library of Medicine (NLM)'s controlled vocabulary and thesaurus for indexing papers. As Scopus is updated daily, data were extracted during a certain day (August 7, 2020) to avoid possible bias.

### Bibliometric and visualization indicators

In any bibliometric study, extracted data are analyzed to measure specific indicators at hand. The present study used the retrieved data to analyze annual publication trends in IDA and the languages and types of publications and identify more prolific authors, research institutes, countries, and journals. Such indicators have been used in similar global studies, especially in the health and medical fields (13-16). The publications of each contributing country were evaluated and compared based on their GDPs and population sizes. The total number of citations, the average number of citations per publication (CPP), and h-indices were calculated to assess the quality of research made by some entities, such as top authors and institutes. Quartile ranks and JSRs were extracted to identify top publishing journals.

The scientific visualization was done by co-authorship, co-citation, and co-occurrence techniques to determine international scientific collaboration, highly-cited authors, and highly-frequent keywords, respectively.

### Statistical analysis

This research used two software packages in this study: the Statistical Package for the Social Sciences (SPSS) 17.0 software for Windows (SPSS Inc., Chicago, IL, USA) for bibliometric analysis and VOSviewer (Version 1.6.13 for Windows) for visualization and mapping.

## Results

### Year-wise trend in publications

Search in Scopus resulted in 29,789 publications in IDA from the beginning to 2019. The first documents appeared in 1934. The first one, entitled “Iron-deficiency anemia in children: Its association with gastro-intestinal disease, achlorhydria, and haemorrhage,” was published in Archives of Disease in Childhood by Hawksley, Lightwood and Bailey (17). The second one, titled “The diagnosis and treatment of the iron-deficiency anemias,” was published in the Journal of the American Medical Association by Bethell et al. (18). Figure 1 shows the year-wise trend in publication growth within this time span.

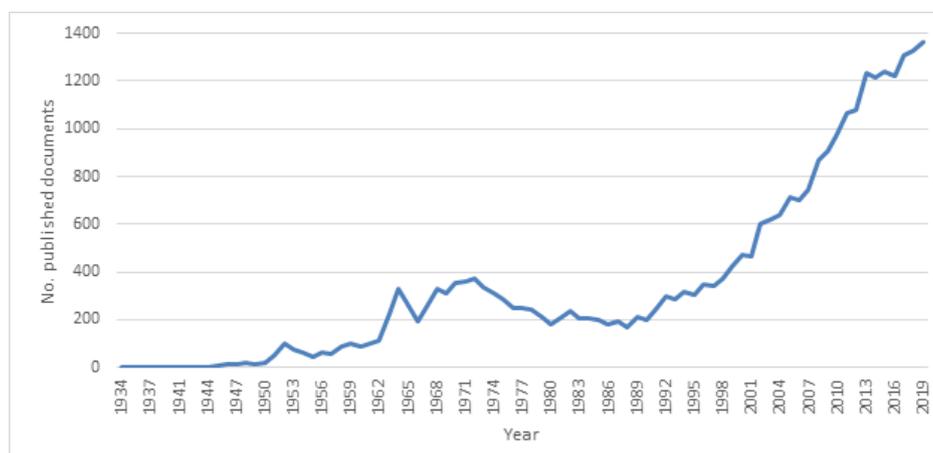


Figure 1. Number of publications per year on IDA (1934–2019)

The trend in IDA publication growth was gradual without any considerable ups and downs, with a fair growth from 1950 to 1972. The trend decreased during 1972-1988, with 371 publications in 1972 and 169 in 1988. Again, an increasing trend can be seen from 1988 to 2019, with 1363 publications in 2019. In total, the trend of publication growth was increasing in this period.

### Publication languages and types

Publications were in over 40 languages, with English predominantly covering about 80% of publications. Only 20% were in non-English languages, with German as a first-ranked non-English language (1160; 3.90%) publications, followed by Russian (854; 2.87%).

Analysis of the retrieved publications based on their types showed that the majority of them were original research articles (22,863; 76.73%), followed by reviews (3034; 10.18%) and letters (1733; 5.82%).

### More active publishing countries and collaboration networks

In total, 159 countries worldwide contributed to IDA publications during the studied time. Table 1 shows top countries, publishing about 59.01% of total documents (n=17,585). These countries included six European countries (United Kingdom (UK), Italy, Germany, Turkey, Spain, and France), three Asian (India, Japan, and China), and two Northern American countries (the USA and Canada).

The highest contribution belonged to authors from the USA (20.38%, n=6072), followed by those from the UK (2356; 7.91%) and India (1655; 5.55%). When productivity was standardized according to GDP, India ranked first followed by Turkey and the USA. When research output was proportioned by population size per 10 million inhabitants, the UK ranked first, followed by Canada and Italy. However, when the quality of publications (based on the average number of citations per publication or CCP) was regarded, the USA ranked first (CCP= 32.69), followed by Canada (CCP= 28.48) and the UK (CCP= 26.51).

Table 1. Top productive countries on IDA (1934–2019)

SCRa	Country	Number of publications (%)	Publications/GDP (R)	Publications/10 million inhabitants (R)	Citations/publication (R)
1st	United States	6072 (20.38)	93.01 (3)	184.99 (5)	32.69 (1)
2nd	United Kingdom	2356 (7.91)	55.70 (4)	352.51 (1)	26.51 (3)
3rd	India	1655 (5.55)	786.60 (1)	12.11 (10)	9.10 (11)
4th	Italy	1220 (4.09)	36.76 (5)	202.33 (3)	24.86 (4)
5th	Germany	1171 (3.93)	25.31 (7)	140.86 (6)	22.28 (5)
6th	Japan	952 (3.19)	23.65 (8)	75.40 (9)	13.80 (8)
7th	Turkey	895 (3.00)	98.98 (2)	107.28 (8)	10.77 (10)
8th	Spain	873 (2.93)	29.48 (6)	185.44 (4)	20.40 (7)
9th	France	803 (2.69)	19.83 (9)	119.74 (7)	20.47 (6)
9th	Canada	803 (2.69)	17.38 (10)	213.62 (2)	28.48 (2)
10th	China	785 (2.63)	9.33 (11)	5.62 (11)	13.79 (9)

SCR: Standard competition ranking; <sup>a</sup> Equal countries have the same ranking number; GDP: gross domestic product; R: Rank

Figure 2 visualizes the international scientific collaboration among countries in the field. Countries with at least 20 publications were included in the co-authorship network. The circle sizes in the map show the magnitude of each country in a number of publications. The thickness of the line between any two countries represents the strength of collaboration between the authors. The distance between each of the two countries reflects how much/the extent to which the two countries are scientifically related concerning to this field. For example, Chile and the Czech Republic are unrelated because there is no connecting line between them, and their distance is relatively long. However, Chile and India are related to each other as they are in close proximity to, with one connecting line between them (Chile has not been shown in the figure due to so-called “overlap”). The scientific collaboration between the USA and the UK was the strongest (link strength=310,456), followed by USA and Italy (link strength=177,716), and the

USA and Germany (link strength=165,997).

### Highly-productive and more influential research institutions

Table 2 shows top productive research institutes in IDA based on the number of their publications. The most productive institute was Harvard Medical school by publishing 212 documents, followed by University of Toronto (with 175 documents) and Universidade de Sao Paulo (with 168 documents), respectively. However, when top ten productive institutes were ranked based on the quality of their publications or their scientific influence calculated by the average number of citations per paper (CPP), University of Oxford in the UK ranked first (CCP=154.62) followed by VA Medical Center (CCP=124.50), and Harvard Medical School in the United States (CCP=116.06). In addition, 6 out of 13 top institutes were with USA origin, and others were in Canada, Brazil, France, India, Switzerland, Italy, and the UK.



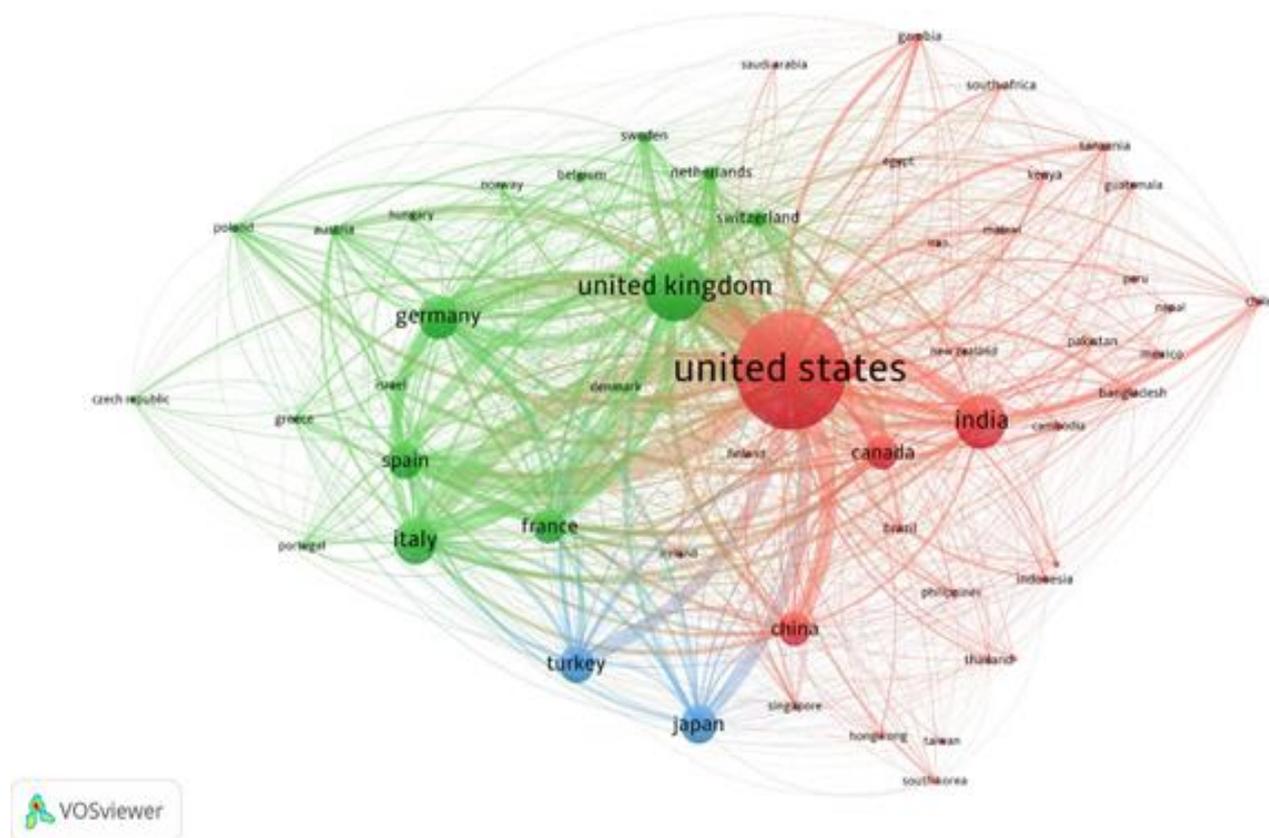


Figure 2. The co-authorship network of top countries collaborating in research on IDA (1934–2019)

Table 2. Top publishing institutes on IDA (1934–2019)

SCR <sup>a</sup>	Institution	Number of publications (%)	Total citation	Citations/publication (R)	h-index	Affiliation country
1st	Harvard Medical School	212 (0.71)	24605	116.06 (3)	53	United States
2nd	University of Toronto	175 (0.59)	14286	81.63 (9)	37	Canada
3rd	Universidade de Sao Paulo	168 (0.56)	12776	76.05 (10)	29	Brazil
4th	VA Medical Center	155 (0.52)	19297	124.50 (2)	43	United States
5th	Inserm	142 (0.48)	12990	91.48 (7)	35	France
5th	University of California, Davis	142 (0.48)	12578	88.58 (8)	44	United States
6th	All India Institute of Medical Sciences, New Delhi	138 (0.46)	15667	113.53 (4)	23	India
7th	Children's Hospital Boston	128 (0.43)	13941	108.91 (5)	45	United States
7th	ETH Zürich	128 (0.43)	6848	53.50 (12)	44	Switzerland
8th	Cornell University	127 (0.43)	5030	39.61 (13)	36	United States
9th	Università degli Studi di Roma La Sapienza	126 (0.42)	11559	91.74 (6)	29	Italy
9th	University of Michigan	126 (0.42)	8381	66.52 (11)	39	United States
10th	University of Oxford	123 (0.41)	19018	154.62 (1)	39	United Kingdom

SCR: Standard competition ranking; <sup>a</sup> Equal institutes have the same ranking number; R: Rank.

### More active authors and co-citation networks

Highly-productive researchers based on their publication counts can be seen in Table 3. Lozoff, B. with 98 documents, Zimmermann, M.B. with 76 documents, and Hurrell, R.F. with 66 documents ranked first to third highly-productive researchers, respectively. However, the most influential authors, based on their average rate of citations per publication (CPP), were Cook, J.D. (CCP=135.66), followed by Lozoff,

B. (CCP=91.93), and Beard, J.L. (CPP=86.11).

When ranked by their h-indices, the most influential authors were Lozoff, B. (h index=41) and both Zimmermann, M.B. (h-index=35 for each), Cook, J.D. (h-index=34), respectively. Considering the researchers' affiliations, seven out of 13 top authors (53.85%) were USA origin. Others six authors (46.15%) affiliated with Switzerland, Denmark, the UK, India, and the Netherlands.

Table 3. Top authors publishing on IDA (1934–2019)

Author name	Number of publications	Total citation	Color number <sup>b</sup>	Citations/publication (R)	h-index (R)	Institution	Country	
1st	Lozoff, B.	98	9009	Green (2)	91.93 (2)	41 (1)	University of Michigan	United States
2nd	Zimmermann, M. B.	76	4135	Red (1)	54.41 (6)	35 (2)	ETH Zürich, Human Nutrition Laboratory	Switzerland
3rd	Hurrell, R.F.	66	4020	Red (1)	60.91 (5)	35 (2)	ETH Zürich, Institute of Food	Switzerland
4th	Milman, N.	56	2431	Red (1)	43.41 (8)	28 (5)	University College Zealand	Denmark
5th	Jacobs, A.	54	1733	Green (2)	32.09 (11)	17 (10)	Cardiff University	United Kingdom
6th	Georgieff, M.K.	49	2261	Green (2)	46.14 (7)	27 (6)	University of Minnesota Medical School	United States
6th	Auerbach, M.	49	1434	Red (1)	29.27 (12)	20 (9)	Maryland General Hospital	United States
6th	Mehta, B.C.	49	134	Blue (3)	2.73 (13)	6 (11)	Dr JC Patel Medical Research Department	India
7th	Beard, J.L.	45	3875	Green (2)	86.11 (3)	30 (4)	Pennsylvania State University	United States
8th	Cook, J.D.	44	5969	Red (1)	135.66 (1)	34 (3)	University of Kansas Medical Center	United States
9th	Stoltzfus, R.J.	43	3391	Blue (3)	78.86 (4)	26 (7)	Goshen College	United States
9th	Swinkels, D.W.	43	1759	Red (1)	40.91 (10)	20 (9)	Radboud University Nijmegen Medical Centre	Netherlands
10th	Lönnerdal, B.	42	1799	Blue (3)	42.83 (9)	25 (8)	University of California	United States

SCR: Standard competition ranking; <sup>a</sup> Equal authors have the same ranking number. <sup>b</sup> Referring Figure 3 on co-citation map; R: Rank

Co-citation analysis for top active authors in IDA with at least 100 received citations was depicted in Figure 3. The produced map included 49 authors distributed into three clusters (red, green, and blue). The first cluster in red included 22 authors. The second one in green included 20 authors. The third cluster in blue consisted of seven authors. Some of the authors might not be shown clearly on the map because some of the names were overlapping.

When included in the same clusters, the authors in the cluster are more co-cited. Out of 13 top active authors, six authors (Zimmermann, M. B.; Hurrell, R.F.; Milman, N.; Auerbach, M.; Cook, J.D., and Swinkels, D.W.) were included in the red cluster and were more co-cited. This is the case regarding top four active authors in green cluster (Lozoff, B.; Jacobs, A.; Georgieff, M.K. and Beard, J.L) and top three active authors in the blue one (Stoltzfus, R.J.; Lönnerdal, B. and Mehta, B.C).



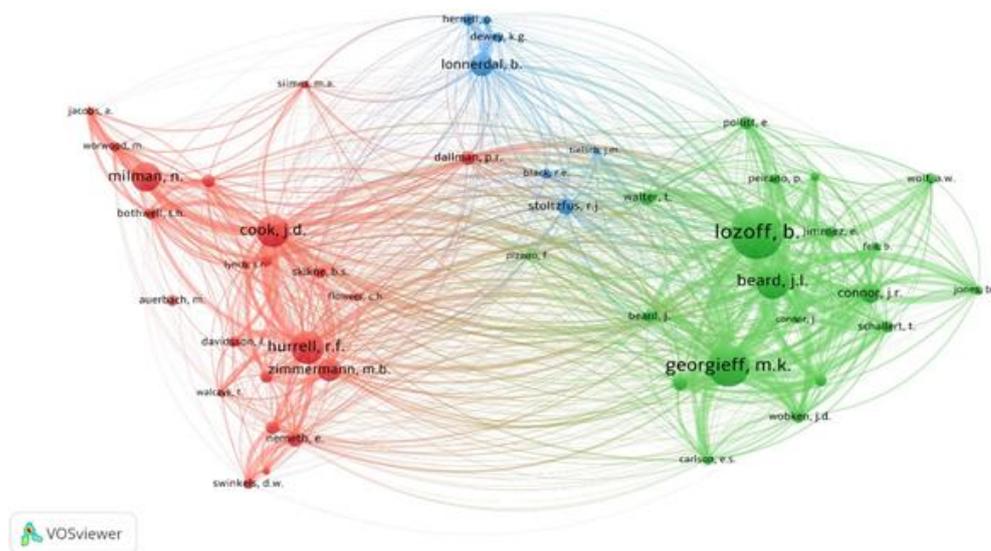


Figure 3. The co-citation network of top authors publishing on IDA (1934-2019)

**Highly-productive and more influential journals**

Table 4 shows the top ten active journals published on IDA. These journals published 2189 publications, amounted to 7.35% of total documents. Above 2% of the documents were published by the American Journal of Clinical Nutrition and Nutrition. However, when quality or influence was considered based on the average rate of citations per publication (CPP), the Lancet (CPP=122.24) ranked first, followed by the New England Journal of Medicine (CCP=84.47) and Blood (CCP=65.32). The first two journals mentioned above are highly prestigious journals in various medical fields, and Blood is one of the main core journals in hematology. Notably of these top journals, eight are ranked in Quartile 1, and only two have a Q2 rank.

**Highly-frequent Keywords, their clustering, and time-based map**

Figure 4 depicts the co-occurrence map of highly-frequent keywords. The most highly-frequent author-assigned keywords were Iron Deficiency Anemia, Human, Female, Iron, Male, Adult, Anemia, and Iron-Deficiency. The highly-frequent keywords were included in two main clusters: the first one in red with keywords related to epidemiology and management of IDA and the second one in green mainly related to iron metabolism and IDA pathophysiology.

Figure 5 depicts the time-based map of co-occurred keywords, as well as its guide under the right corner of the map. Keywords within the light green and yellow are ones occurred after 2004. Ones within heavy color backgrounds occurred before 2004. As can be seen, some keywords such as Hepcidin, Inflammation, Iron overload, Drug safety, and Mortality mainly occurred in about 2004 and then.

Table 4. Top ten journals publishing on IDA (1934–2019)

SCR	Journal title	Number of publications (%)	Number of citations (R)	Citations per publication (R)	h-index of publications (R)	SJR 2019 (R)	Quartile 2019	Citations/publication (R)
1st	American Journal of Clinical Nutrition	362	1.21	18983 (2)	52.44 (5)	77 (1)	2.704 (4)	Q1
2nd	Journal of Nutrition	272	0.91	14453 (4)	53.14 (4)	64 (2)	1.797 (7)	Q1
3rd	Blood	244	0.82	15938 (3)	65.32 (3)	63 (3)	5.416 (3)	Q1
4th	Lancet	238	0.80	29093 (1)	122.24 (1)	48 (4)	14.554 (2)	Q1
5th	British Journal of Haematology	225	0.76	5508 (6)	24.48 (7)	38 (6)	1.844 (6)	Q1
6th	BMJ Case Reports	183	0.61	369 (10)	2.02 (10)	8 (10)	0.204 (10)	Q3
7th	British Medical Journal	178	0.60	2851 (8)	16.02 (8)	26 (9)	2.049 (5)	Q1
8th	Journal of Pediatrics	170	0.57	4734 (7)	27.85 (6)	37 (7)	1.145 (8)	Q1
9th	New England Journal of Medicine	161	0.54	13600 (5)	84.47 (2)	38 (5)	18.291 (1)	Q1
10th	Acta Haematologica	156	0.52	1943 (9)	12.46 (9)	22 (8)	0.45 (9)	Q3

SCR: Standard competition ranking; R rank; SJR scientific journal rank.



## Discussion

This bibliometric study sheds light on how the status of global research on IDA has developed during the past 85 years (1934-2019). The gradual increasing trend of publication growth in IDA demonstrates the importance of research on it and being as an international concern. It can be concluded that IDA is a disease of international concern that has reached epidemic proportions at an international level and remains a significant threat to global health (19). Therefore, more influential research is needed to increase awareness on IDA and combat and control the disease.

As an internationally-scoped language for scientific communication, English was the top IDA publication language. One reason is that the Scopus database used in this study has better coverage of English language journals than those in other languages (20).

Original research article type as the most published type of publications in the field signifies the evolution and development of research in IDA. In many health-related fields, these kind of publications have been considered for evaluating field development and newly-emerged subfields, e.g., in radiomics (21).

Active countries in IDA research mainly were the USA and European countries. In a study by Bansal and Gupta(1), similar findings were highlighted during 2006-2015. Such an imbalanced distribution of research on IDA can be observed in top research institutes and highly-productive and more-influential authors that their countries of origin were mostly European countries or the USA. As an internationally-scoped issue, IDA needs to be investigated from many perspectives worldwide. This necessitates the main contributions of other countries, especially developing countries, where the disease has its causes and consequences due to certain economic, social, and cultural conditions (22). In addition, a wide-ranged co-authorship network of different countries will fuel the fire of research on IDA.

More active publishing and highly-cited journals in IDA are of prestigious and known journals in medical fields (such as the Lancet and the New England Journal of Medicine as the most widely read, cited, and influential general medical journals in the world) or in the hematology field (i.e., Blood as a specialized periodical published by the American Society of Hematology). Being Published in or receiving a citation from prestigious and high-quality journals can potentially widen the reach of publications and increase their readability rate and further citation rate (23) and consequently, researchers' more consideration of the topic at hand.

As keyword co-occurrence analysis and clustering may be

used for topic detection in a scientific field/subfield (24), these have some implications for IDA researchers. Considering the highly-frequent keywords used by authors in their publication, it can be said that research on IDA has found its way, and many topics have been and are considered, ranging from its epidemiology to its management and control in various human age and gender groups. Researchers can find newly-emerged or heavily-considered subjects (such as Hcpidin, inflammation, and iron overload) for further research as hot topics need to be immediately investigated.

## Conclusion

Despite some limitations, mainly due to selecting Scopus as a data collection source (25), the current study has the advantage of being the first to give a relatively full bibliometric overview and visualization of global research on IDA. As evaluative research, this study can provide useful information for those tasked with improving that the performance of research on IDA, as well as being a guide for researchers and authors interested in the topic in order to identify hot topics, heavily-regarded subjects, authors with common interests.

## Declarations

### Acknowledgement

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### Conflicts of Interests

The authors declare that they have no competing interests.

### Ethical statement

This study has been ethically approved by the Ethics Committee of Hamadan University of Medical Sciences with code number: IR.UMSHA.REC.1399.127.

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### Authors' contributions

H. R. S presented the idea and reviewed the manuscript. HM actively contributed to elements of the study and drafted the manuscript. M. K. S developed the research idea, designed the study, gathered data, analyzed data, and managed the research. A. H. and S. Z. M. contributed to the study design and reviewed the manuscript.

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