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Global evolution of nanotechnology research with special emphasis on health sciences : A bibliometric approach

Mohamed Idhris *
Abdurahiman Pattukuthu †
Directorate of Library Affairs
Imam Abdurrahman Bin Faisal University
Dammam
Saudi Arabia

Manuelraj Peter §
Jio Institute
Navi Mumbai
Maharashtra
India

Spurgeon Anandraj Samuel ‡
Directorate of Library Affairs
Imam Abdulrahman Bin Faisal University
Dammam
Saudi Arabia

Abdul Jaleel Pottachola @
College of Public Health and Health Informatics
King Saud bin Abdulaziz University for Health Sciences
Riyadh
Saudi Arabia

and

King Abdullah International Medical Research Center
Riyadh
Saudi Arabia

and

Ministry of the National Guard-Health Affairs
Riyadh
Saudi Arabia

Helan Petricia Devasagayam #
College of Nursing
Imam Abdulrahman Bin Faisal University
Dammam
Saudi Arabia

E-mail
* midhris@iau.edu.sa
† asali@iau.edu.sa
§ manuelraj.peter@jioinstitute.edu.in
‡ sasamuel@iau.edu.sa
@ pottachoiaa@ksau-hs.edu.sa
# hdevagayam@iau.edu.sa

* (Corresponding Author)

Mohamed Idhris
Abdurahiman Pattukuthu
Manuelraj Peter
Spurgeon Anandraj Samuel
Abdul Jaleel Pottachola
Helan Petricia Devasagayam

Purpose: **The scientific impact of every scientific publication is widely measured through bibliometric analysis. In this article we have conducted evidence-based bibliometric analysis of articles on nanotechnology. Literature on nanotechnology applications that has been published in journals across all fields of science and technology. The data is retrived from Medline database via Pubmed., Total 267 publications were retrieved and analyzed, The New England Journal of Medicine achieved the highest citation, "Corcoy Rosa" is the most productive author. Most of the publications are classified as Randomized controlled trials, despite this, there hasn't been a lot of in-depth research on the publication trends of nanotechnology in journals of the health sciences.**

Objective: **The objective of this study was to evaluate the publication trends in the field of Nanotechnology with special emphasis on health sciences.**

Methods: **The data was acquired from the MEDLINE database via PubMed on January 4, 2021, covering the years 2001 through 2020. The articles were sorted according to the Publication Type, Number of Publications (Pub), Relative Citation Ratio (RCR) and Total Citations (TC) influence. The tables are created in excel spread sheet which is download from "iCite" tool. Highly cited journals and author tables are created usning "VOS Viewer" visualization bibliometric tool.**

Findings: A total number of 267 records were retrieved, and a systematic review was carried out over 20 years between 2001 and 2020. The total number of RCR and citations are 545.44 and 5307 respectively. The New England Journal of Medicine (NEJM) received more citation which is n=214. "Corcoy Rosa" was the most productive author during the

study period, with n=9 publications with 608 citations aggregated. Most of the publications are classified as Randomized controlled trials, which account for 37% of all publications retrieved. The year 2019 has the most publications, with a total of n=29. European countries have leading publications and authors in this field of research; however, the rest of the world needs to apply more concentration to improve the development of this field.

Limitations: **The study was limited to twenty years period from 2001 to 2020, and the data was obtained from single database PubMed.**

Keywords: *Nanotechnology, Systematic review, Randomized controlled trial, Clinical trial, Meta-analysis, Bibliometrics.*

Introduction

Nanotechnology is a modern technology that can be used in several applications (such as drug delivery, tissue engineering, electronics, food science, defense, and smart [1], [2], [3]. Recently, Nanotechnology is a widely used technology in the development of sustainable agriculture and the potential to inspire agriculture and the food [4]. Interface and colloid science have contributed in many materials that may be useful in nanotechnologies, such as carbon nanotubes and other fullerenes, as well as various nanoparticles and nanotubes. Nanomaterials with fast ion transport are also related to nanoionics and nanoelectronics. Nanotechnology consists of a broad range of chemically modifiable surface materials to bind a variety of ligands that can turn these nanomaterials into biosensors, fluorescent molecular tags, imaging agents, targeted molecular delivery vehicles, and other biological [5]

In the recent past, Nanotechnology is widely used in health science and medical field termed as nanomedicine. There is high impact and advancement especially in medical science with nanodevices and materials. It has been used to detect cancer at its earliest stages, i.e. to show its role within the body and to provide unique anti-cancer medicines to malignant cells, and to decide whether malignant cells are killed is one of the major technologies in Nanotechnology. Carbon, silicon, and other materials that have special properties are made from nanowires. Nanowire sensors lie across a small fluid channel as particulate matter is flowing through the channel molecules are captured by the sensors and transmitted through the connections of the electrodes outside the body. Nanowires can be used to track the existence of altered cancer-related genes. New novel types of Nanoparticles are developed by researched it kills cancer tumor cells. [7]

Recent developments in Nanotechnology:

Nanotechnology is rapidly growing in all fields past 15 years. Nanoengineering is breaking the limits of traditional scientific activities in a modern environment where technology is changing at a rate much greater than any point in recorded history. In the medical field Nanotechnology to do this by non-invasive identification, diagnosis, and treatment of infertility-related disorders. The development of nano biosensors capable of detecting antigens, nucleic acids, antigens, species of nitrogen, and reactive oxygen is being studied and used for higher speed and greater sensitivity. Some applications of

nanotechnology in the treatment of diabetes include the use of artificial pancreas instead of beta cell transplantation to treat diabetes and the oral administration of biodegradable polymer nanospheres insulin to avoid gastrically. [8]

Data and Methods:

We searched via PubMed using the keywords "systematic review[pt] OR randomized controlled trial[pt] OR clinical trial[pt] OR Meta-analysis[pt]) AND ("nanotechnology" OR "nanotechnology"[MeSH Terms] OR Nanotechnologies". A total of 267 data were downloaded as CSV and text files from the PubMed database, and the PubMed IDs of the retrieved data were used in the "iCite" tool to analyze the Relative Citation Ratio (RCR) and Citations. VOS viewer visualization software was used to analyse highly cited publications and productive authors.

Results:

The twentieth year 2001-2020 contains 267 articles placed according to the date of publication. The annual trend of research publication type is shown in Table 1 and Figure 1. All publication types are gradually increased every five years. Randomized controlled trial (*n*=99) is leading the number of document types in this analysis followed by the Systematic review (*n*=56). The highest number of documents is in the five years from 2016 to 2020 with a total of (*n*=149) articles. The fact that the percentage of publications is increasing year by year shows the growth of medical publication types like this.

Table 1

Publication Type

Type	2001-2005		2006-2010		2011-2015		2016-2020		Total	
	N	%	N	%	N	%	N	%	N	%
Randomized Controlled Trial	1	0.37%	16	5.99%	30	11.2%	52	19.5%	99	37.08%
Systematic Review	0	0%	2	0.75%	13	4.87%	41	15.4%	56	20.97%
Clinical Trial	5	1.87%	6	2.25%	19	7.12%	19	7.12%	49	18.35%
Meta-Analysis	0	0%	1	0.37%	10	3.75%	28	10.5%	39	14.61%
Clinical Trial, Phase I	2	0.75%	0	0%	4	1.5%	5	1.87%	11	4.12%
Controlled Clinical Trial	1	0.37%	3	1.12%	3	1.12%	1	0.37%	8	3.00%
Clinical Trial, Phase II	0	0%	1	0.37%	1	0.37%	3	1.12%	5	1.87%
Total	9	3.37%	29	10.9%	80	30%	149	55.8%	267	100.00

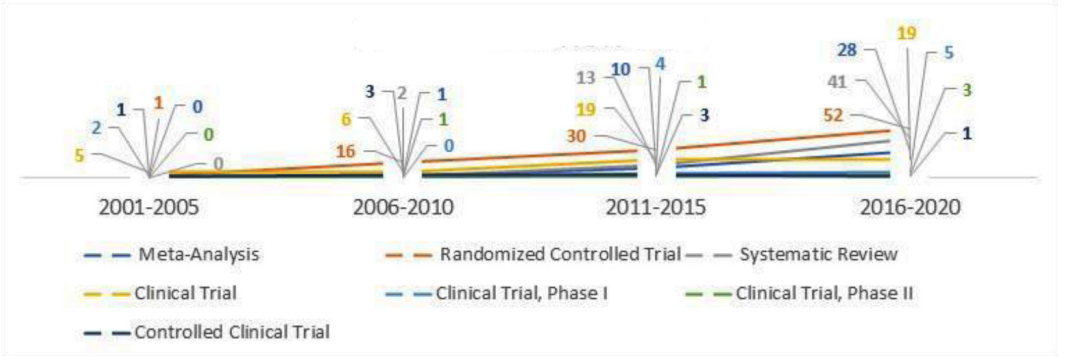

Figure 1
Publication Type

Table 2
Publication, RCR, and TC influence

Year	Pub	Authors	RCR	TC
2001	1	4	2.1	48
2003	3	11	4.23	104
2004	1	8	0.05	2
2005	4	17	5.96	148
2006	6	30	10.23	217
2007	6	27	7.97	139
2008	1	10	0.35	7
2009	6	27	9.14	160
2010	11	87	30.88	593
2011	8	43	9.77	191
2012	17	118	24.83	422
2013	11	46	9.34	118
2014	20	174	44.71	622
2015	24	239	66.77	**809**
2016	27	209	57.06	538
2017	31	277	79.8	555
2018	28	250	65.25	322
2019	**36**	**392**	**88.5**	233
2020	26	228	28.5	79
Total	267	2197	545.44	5307

Table 2, Figure 2 is expressed publication RCR and Total citations. These RCR and TC are getting from iCite, this new tool for bibliometric analysis from the National Institutes of Health (NIH). The Relative Citation Ratio (RCR) is the new metric analysis that uses citation rates to measure influence at the article level developed by the NIH - implemented by NIH and other (funding) organizations as an evaluation tool it is used to compares the influence of articles from different fields more fairly. The selected 267 research articles have been published during 2001 to 2020 by separate authors. 2019 contain the highest number of publication (n=36) as well as the highest number of Authors (n=392) and highest number of RCR values (N=88.5) in this analysis. The highest number of Total citations in 2015 with

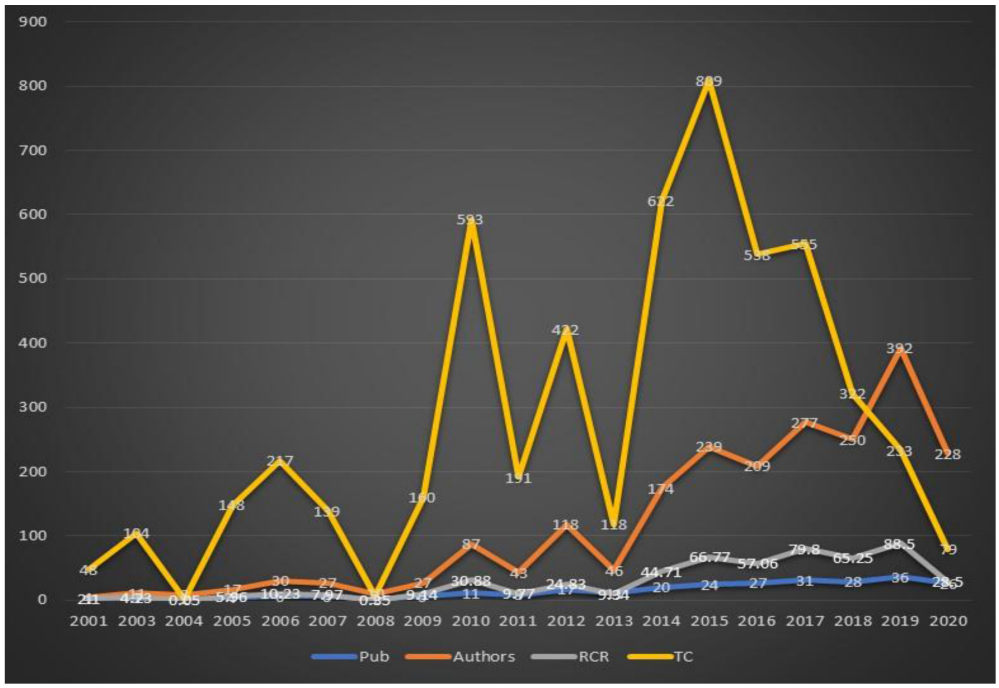

Figure 2

Evolution over the period

809. Table no.3 has a statistical outline derived from iCite, it consists of (CPY, RCR, CPP) MAX, MEAN, SEM, and MED values.

Calculation of the Relative Citation Ratio (RCR):

$$RCR = \frac{\text{Article citation Rate}}{\text{Expected citation Rate}}$$

Article Citation Rate (ACR): average number of citations that a reference article obtains per year

Field Citation Rate (FCR): is derived from the ACRs of the co-citation network

Expected Citation Rate (ECR): is the field normalized FCR.

Table 3

Statistical Outline

	MAX	MEAN	SEM	MED
Cites per Year	61.00	4.75	0.45	2.60
Relative Citation Ratio (RCR)	17.73	2.23	0.18	1.36
Citations Per Pub	214	19.88	1.82	9.00

*Total Pub: 267, Pubs per Year: 13.35, Weighted RCR: 545.44

Table 4

Top 10 Relative Citation Ratio (RCR) publications

Sl. No	Title	Journal	Year	RCR	Total Citations
1.	"Extracellular Vesicles Provide a Means for Tissue Crosstalk during Exercise".	Cell Metab.	2018	17.73	113
2.	"COVID-19 in cardiac arrest and infection risk to rescuers: A systematic review".	Resuscitation	2020	15.5	31
3.	"Treatment of Non-alcoholic Fatty Liver Disease with Curcumin: A Randomized Placebo-controlled Trial".	Phytother Res	2016	13.46	123
4.	"A systematic review on nanoencapsulation of food bioactive ingredients and nutraceuticals by various nanocarriers".	Crit Rev Food Sci Nutr	2019	12.75	21
5.	"Anti-PD-1 Antibody SHR-1210 Combined with Apatinib for Advanced Hepatocellular Carcinoma, Gastric, or Esophagogastric Junction Cancer: An Open-label, Dose Escalation, and Expansion Study".	Clin. Cancer Res.	2019	12.54	61
6.	"Diagnosis and Classification of 17 Diseases from 1404 Subjects via Pattern Analysis of Exhaled Molecules".	ACS Nano	2017	12.22	107
7.	"Glibenclamide, metformin, and insulin for the treatment of gestational diabetes: a systematic review and meta-analysis".	BMJ	2015	10.99	130
8.	"An evidence-based environmental perspective of manufactured silver nanoparticle in syntheses and applications: a systematic review and critical appraisal of peer-reviewed scientific papers".	Sci. Total Environ.	2010	10.11	213
9.	"Nanofiltered C1 inhibitor concentrate for treatment of hereditary angioedema".	N. Engl. J. Med.	2010	10	214
10.	"Adult lung function and long-term air pollution exposure. ESCAPE: a multicentre cohort study and meta-analysis".	Eur. Respir. J.	2015	9.6	116

In table no.4 the title starting with "Extracellular" is the highest RCR value with 17.73 and the second title starting with "covid 19" is ranked second with an RCR value of 15.5. In the above table serial No.9 highest number of total citations with 214 entitled starting "Nanofiltered" followed by serial No.8 with 213 Total citations. The highest RCR values in the tables given above are 2018 and the lowest RCR value is in the year of 2015.

Table 5

Top 10 highest citations publications

Sl. No	Title	Journal	Year	Total Citations	Citations Per Year	Field Citation Rate	NIH Percentile
1	"Nanofiltered C1 inhibitor concentrate for treatment of hereditary angioedema".	N. Engl. J. Med.	2010	214	21.40	3.57	98.2
2	"An evidence-based environmental perspective of manufactured silver nanoparticle in syntheses and applications: a systematic review and critical appraisal of peer-reviewed scientific papers".	Sci. Total Environ.	2010	213	21.30	3.49	98.3
3	"Glibenclamide, metformin, and insulin for the treatment of gestational diabetes: a systematic review and meta-analysis".	BMJ	2015	130	26.00	4.22	98.5
4	"Treatment of Non-alcoholic Fatty Liver Disease with Curcumin: A Randomized Placebo-controlled Trial".	Phytother Res	2016	123	30.75	4.14	99
5	"Adult lung function and long-term air pollution exposure. ESCAPE: a multicentre cohort study and meta-analysis".	Eur. Respir. J.	2015	116	23.20	4.34	98.1
6	"Extracellular Vesicles Provide a Means for Tissue Crosstalk during Exercise"	Cell Metab.	2018	113	56.50	5.99	99.4
7	"Meta-analysis of cellular toxicity for cadmium-containing quantum dots".	Nat Nano-technol	2016	110	27.50	5.63	98
8	"Diagnosis and Classification of 17 Diseases from 1404 Subjects via Pattern Analysis of Exhaled Molecules".	ACS Nano	2017	107	35.67	5.49	98.8
9	"Widespread nanoparticle-assay interference: implications for nanotoxicity testing".	PLoS ONE	2014	100	16.67	4.19	96.5

Contd...

10	"Dual therapy with lopinavir and ritonavir plus lamivudine versus triple therapy with lopinavir and ritonavir plus two nucleoside reverse transcriptase inhibitors in antiretroviral-therapy-naive adults with HIV-1 infection: 48 week results of the randomised, open label, non-inferiority GARDEL trial".	Lancet Infect Dis	2014	98	16.33	5.55	94.8

Table no 5 listed the top 10 highest citation publications created from NIH iCite bibliometric tool. The New England Journal of Medicine Journal got the highest citations with 214 titles starting with 'Nanofiltered " and the least number of citations with 98 in the journals of the Lancet Infectious Diseases title starting with 'Dual therapy with lopinavir". In the above table serial, No.6 got the highest number of NIH percentile (n=99.4) as well as the highest number of citations per year (n=56.50) entitled stating with "Extracellular Vesicles" followed by serial No.4 with 99 NIH percentile.

Table 6

Top 10 highly cited publications

Sl. No	Journal	Citescore 2019	SJR 2019	SNIP 2019	Citations
1	The New England Journal of Medicine	66.1	18.291	13.212	214
2	Science of the Total Environment	8.6	1.661	1.977	213
3	International Journal of Pharmaceutics	7.6	1.081	1.312	194
4	Nanomedicine	7.3	0.997	0.876	177
5	International Journal of Nanomedicine	7.1	1.061	1.208	155
6	Oncotarget	9.2	1.513	1.015	148
7	BMJ Best Practice Resources	6.5	2.049	3.999	130
8	Dental Materials	8.0	1.852	2.194	128
9	Phytotherapy Research	6.7	0.905	1.423	123
10	European Respiratory Journal	12.09	3.398	2.226	116

In this table, the top 10 highest citation sources are listed. Citescore, SJR, SNIP values are taken from the Scopus database. The New England Journal of Medicine journal got the highest number of citations with 214 as well as the highest values in the field of citescore, SJR, and SNIP.

Table 7

Most Productive Authors

Author	Country and Organization	Documents	No of Citations Aggregated
Corcoy, Rosa	Department of Endocrinology and Nutrition, Hospital de la Santa Creu i Sant Pau, Barcelona 08025, Spain CIBER Bioengineering, Biomaterials and Nanotechnology (CIBER-BBN), Instituto de Salud Carlos III, Madrid Department of Medicine, Universitat Autònoma de Barcelona, Bellaterra rcorcoy@santpau.cat	9	608
Haick, Hossam	Department of Chemical Engineering and Russell Berrie Nanotechnology Institute, Technion - Israel Institute of Technology, Haifa, Israel	6	556
Jaafari, Mahmoud Reza	Nanotechnology Research Center, Pharmaceutical Technology Institute, Mashhad University of Medical Sciences, Mashhad, Iran	5	132
Adelantado, Juan M	Institut de Recerca de l´Hospital de la Santa Creu i Sant Pau, Barcelona, Spain	4	220
Bertolotto, Alessandra	Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy	4	220
Damm, Peter	enter for Pregnant Women with Diabetes, Departments of Endocrinology and Obstetrics, Rigshospitalet, Institute of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark	4	220
Desoye, Gernot	Department of Obstetrics and Gynecology, Medical University of Graz, Graz, Austria	4	220
Devlieger, Roland	Department of Development and Regeneration, KU Leuven, University Leuven, Leuven, Belgium	4	220
Dunne, Fidelma	Galway Diabetes Research Centre and National University of Ireland, Galway, Ireland	4	220
Galjaard, Sander	Department of Development and Regeneration: Pregnancy, Fetus, and Neonate, Gynaecology and Obstetrics, University Hospitals, Katholieke Universiteit Leuven, Leuven, Belgium	4	220

The author in Table No. 7, Figure 3 has the Most Productive Authors publications focused on evidence-based nanotechnology studies. In the time between 2001 and 2020, 1980 authors are contributing 267 papers. Corcoy, Rosa, with nine articles with total citation n=608 aggregated followed by Haick, Hossam with 6 publications, 556 citations, and Jaafari, Mahmoud Reza with 5 articles, 132 citations, remaining seven authors contributing

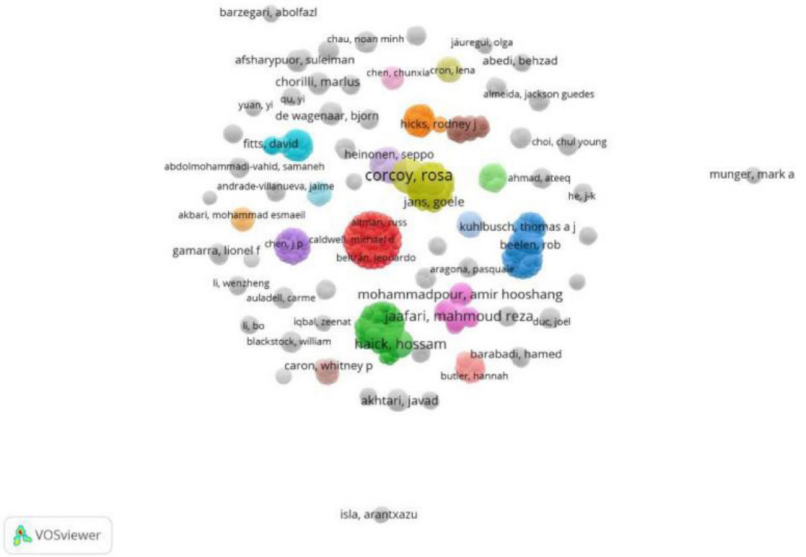

Figure 3

four articles each and 1540 citations for their publications all together. In the above table, Spain and Belgium country authors have two each, remaining authors are in Israel, Iran, Denmark, Australia, and Ireland each one publications.

Conclusion

The introduction of nanotech application drastically revolutionized diagnostic and therapeutic impact of medical science**.** Since the formal adoption of evidence-based medicine in 1992, evidence-based approaches or research have gained ground and have spread to the allied health professions, education, administration, law, public policy, and other fields.[9] This bibliometric study of the field of nanotechnology and visualization/ network relevant to evidence-based studies up to 2020. Over 20 years (2001-2020), this review spans the entire span of publication in this subject and helps to provide a large number of publications that allow a full overview to be produced. We have found through the search of articles in the PubMed database that there is a recent good phase of academic literature related to this topic, specifically from 2010 to date. The largest number of publications on the subject took place in 2019. In table 1 the highest number of publication types got n=99 on the topic of Randomized control trial, remaining publication types have the most growth in the five years from 2016 to 2020. In table no 2. got the highest number of publication, Authors, and Relative Citation Ratio in the year 2019, despite that in the year 2015 got the highest citations with (n=809). At the end of the above research, Europe and its affiliated countries have a higher number of publications and authors compared to other

countries. Since nanotechnology is a vital branch of knowledge to boost the advancement and development of all scientific fields, it would be highly recommended to increase the research and development in other countries also.

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