Scientometrics (2015) 105:311–321
DOI 10.1007/s11192-015-1676-5

Benchmarking bibliometrics in biomedical research: research performance of the University of Toronto's Faculty of Medicine, 2008–2012

James D. O'Leary[1,2] · Mark W. Crawford[1,2] · Eva Jurczyk[3] · Alison Buchan[3]

Received: 13 July 2015 / Published online: 20 August 2015

Abstract Bibliometrics are often used as key indicators when evaluating academic groups and individual researchers in biomedical research. Citation metrics, when used as indicators of research performance, require accurate benchmarking for homogenous groups. This study describes the research performance of academic departments in the University of Toronto's Faculty of Medicine using article-level bibliometrics for scientific papers published from 2008 to 2012. Eligible publications of all academic faculty members were verified from each researcher's curriculum vitae and Web of Science® (Thomson Reuters). For 3792 researchers, we identified 26,845 unique papers with 79,502 authors published from 2008 to 2012. The overall mean citations per paper for the faculty was 17.35. The academic departments with the highest levels of collaboration and interdisciplinary research activity also had the highest research impact. The citation window for biomedical scientific papers was still active at 5 years after publication, indicating that the citation window for publications in biomedical research is active longer than previously thought, and this may hinder the reliable use of bibliometrics when evaluating recent scientific publications in biomedical research.

✉ James D. O'Leary
james.oleary@sickkids.ca

Mark W. Crawford
mark.crawford@sickkids.ca

Eva Jurczyk
eva.jurczyk@utoronto.ca

Alison Buchan
alison.buchan@utoronto.ca

[1] Department of Anesthesia and Pain Medicine, Hospital for Sick Children, Rm 2212 J, 555 University Avenue, Toronto, ON M5G 1X8, Canada

[2] Department of Anesthesia, University of Toronto, Toronto, Canada

[3] Faculty of Medicine, University of Toronto, Toronto, Canada

Keywords Benchmarking · Research impact · Research productivity · Biomedical research · Citation window

Introduction

An accurate and reliable system of assessment is needed to evaluate and rank university departments' research activity and performance. Measuring impact, quality, and productivity of university-based research is a challenging task that traditionally relied on peer-review. Peer-review alone does not meet some standards needed for a reliable and reproducible system of assessment and poorly correlates with research impact (Derrick et al.2011). Many universities in an effort to be more transparent and objective have introduced bibliometrics as key indicators when evaluating academic departments and individual researchers (Directorate-General for Research and Innovation 2010).

Bibliometrics, and in particular article-level citation metrics, have become prominent among academic institutions for evaluating biomedical research. The limitations of these metrics are well known (Ball 2007), but importantly their use when evaluating university departments is often hindered by a lack of coherence between research disciplines (O'Leary and Crawford 2010). Several factors can significantly influence bibliometrics when comparing research disciplines or groups of researchers including differences in citation practices, numbers of researchers, levels of interdisciplinary research and collaboration, and time since publication for "young" researchers. To be meaningful, bibliometrics require homogenous populations; as a consequence, accurate benchmarking is needed for groups of researchers that often have disparate citation practices and citation windows.

The primary aim of this study was to describe the research performance of academic departments in the University of Toronto's Faculty of Medicine using article-level bibliometrics from a custom InCites^{TM} (Thomson Reuters) database for scientific papers published from 2008 to 2012. The secondary aim of the study was to assess the suitability of citation windows less than 5-years duration for determining bibliometrics in biomedical sciences.

These data will allow accurate and reproducible benchmarking of university-based research for departments in the University of Toronto's Faculty of Medicine and can be used to facilitate the evaluation of scholarly activity of university departments in other institutions.

Methods

This retrospective cohort study was approved by the Research Ethics Board (REB) at the Hospital for Sick Children, Toronto, and the requirement for written informed consent from participants was waived by the REB in accordance with the Tri-Council Policy Statement 2: Ethical Conduct for Research Involving Humans, Article 3.7 guidelines.

Data retrieval strategy

All faculty members with a primary academic appointment at the University of Toronto's Faculty of Medicine were included in the study. Due to known discrepancies in author, department, and institutional identification that can exist in scientific citation databases, data

from authors' curricula vitae and Web of Science® were combined to determine individual researcher publication profiles in a custom dataset in InCites™. InCites™ is a customized web-based analytics tool that evaluates institutional productivity and benchmarks research output using scientific publication and citation data sourced from Web of Science®.

Web of Science® was first searched for individual researchers' publications from 2008 to 2012 using all author name variations and local academic or hospital affiliations. Each researcher's electronic curriculum vitae at the University of Toronto's Faculty of Medicine was also searched for all academic publications during the study period. An electronic curriculum vitae (WebCV) is used by all University of Toronto's Faculty of Medicine academic members to organize and manage their scholarly activity for both individual processes (e.g. academic promotion or extramural funding applications) and for organizational reporting and planning.

The custom InCites™ database consisted of 54,607 source publications between 1980 and 2013 by the University of Toronto's Faculty of Medicine. At the time of data extraction for this study, citation data from InCites™ were last processed on April 22, 2014. We searched this InCites™ dataset for citation and collaboration bibliometrics for all departments in the University of Toronto's Faculty of Medicine from 2008 to 2012. All data analyses were performed in July 2014.

Outcomes

We report how we determined all data exclusions, all manipulations and all measures used in the study. Citation metrics included were the total number of papers, percentage of papers cited, mean citations per paper, second generation cites per paper, *h* index, journal actual/expected citations, category actual/expected citations, and average percentile. Only publication types *article, note, and review* are used by InCites™ to determine the percentile distribution and, as a consequence, the average percentile. The extent of concentration or dispersion of publications within scientific categories was measured using the disciplinarity index and interdisciplinarity index respectively. The extent of collaboration by departments was assessed using the mean number of authors per publication, mean number of institutions per publication, and mean number of countries or territories per publication. All citation metrics in this study are defined using InCites™ indicator descriptions and definitions (Available from: http://researchanalytics.thomsonreuters.com/incites/).

Statistical analysis

Data were analyzed using InCites™ and Prism 6 (GraphPad Software, San Diego, CA, USA). Bibliometric data for university departments are not normally distributed. Descriptive statistics (median, interquartile range, range, and percentiles) were determined as appropriate to the data distribution.

Results

For 3792 researchers affiliated to academic departments in the University of Toronto's Faculty of Medicine, we identified 26,845 unique papers with 79,502 authors published from 2008 to 2012. Academic departments ranged (median) in size between 9 and 734 (50) faculty members.

Publication types

The publication types were articles ($n = 20{,}135$), reviews ($n = 2{,}697$), proceedings papers ($n = 1{,}228$), editorials ($n = 2{,}233$), letters ($n = 418$), meeting abstracts ($n = 116$), corrections ($n = 7$), reprints ($n = 4$), news items ($n = 4$), and items about an individual ($n = 3$). The publication types with the highest impact (mean citations per paper) were reviews (24.40), articles (18.22), and proceedings papers (17.34). The distribution of paper types and their mean citations per paper for all departments in the University of Toronto's Faculty of Medicine are summarized in Table 1.

Citation metrics

Overall, 89 % of publications by the University of Toronto's Faculty of Medicine were cited at least once. Publications had on average 17.35 mean citations per paper, and second generation citing publications had 5.88 mean citations per paper. The overall number of publications per year ranged from 4818 to 5718 publications for the 5-year period. The citation activity for each year, measured using the total number of citations and the mean citations per paper cited by all subsequent years, did not peak within the study-window. The citation impact was greatest initially within the first 3 years after publication, but the mean number of citations per paper continued to increase throughout the study period (Fig. 1).

The total number of publications among departments for the 5-year period ranged (median) from 92 to 8926 (783). The range [interquartile range (IQR)] of mean citations per paper was 5.66–32.65 (9.47–20.14). The median (IQR) *h* index for departments was 43 (28–74). Department-level citation metrics for the University of Toronto's Faculty of Medicine are summarized in Table 2.

The median (IQR) journal and category actual/expected citations for all departments was 1.86 (1.66–1.98) and 2.57 (2.15–3.20), respectively. Normalized and percentile citation metrics for all departments for both journal and scientific category are summarized in Table 3.

Collaborative metrics

On average, publications had 8.07 authors per paper, and 3.79 institutional affiliations from 1.85 countries per paper. The overall University of Toronto's Faculty of Medicine disciplinarity index and interdisciplinarity index were 0.03 and 0.76 respectively. The median (IQR) disciplinarity and interdisciplinarity index for all departments was 0.09 (0.06–0.15) and 0.58 (0.53–0.64) respectively. The collaboration metrics for all departments are summarized in Table 4.

Discussion

This study describes article-level bibliometrics of academic departments in the University of Toronto's Faculty of Medicine for scientific papers published from 2008 to 2012 using a custom dataset of scientific publications determined from researchers' curricula vitae and Web of Science®. For 3792 researchers, we identified 26,845 unique papers with 79,502 authors published from 2008 to 2012. The overall mean citations per paper for the faculty

Table 1 Distribution of the major article types, and the mean citations per paper type, published by the University of Toronto's Faculty of Medicine between 2008 and 2012 (measured July 2014)

Department	Faculty, *N*	Total papers, *N*	Article		Review		Proceedings paper		Editorial		Letter	
			N (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*
Anesthesia	226	967	719 (74.4)	12.69	124 (12.7)	22.03	38 (3.9)	10.00	85 (8.8)	3.65	1 (0.1)	0.00
Biochemistry	18	333	282 (84.7)	24.13	27 (8.1)	52.93	8 (2.4)	15.25	16 (4.8)	1.38	0 (0.0)	0.00
Biomaterials and biomedical engineering	48	851	690 (81.1)	15.31	56 (6.6)	43.77	87 (10.2)	4.34	16 (1.9)	11.56	2 (0.2)	20.00
Cellular and biomolecular research	43	783	652 (83.3)	33.32	69 (8.8)	45.88	25 (3.2)	10.40	36 (4.6)	10.39	1 (0.1)	38.00
Family and community medicine	331	806	595 (73.8)	10.76	50 (6.2)	16.88	22 (2.7)	19.59	139 (17.2)	3.14	0 (0.0)	0.00
Health policy, management and evaluation	18	279	213 (76.3)	8.22	10 (3.6)	36.10	7 (2.5)	8.14	46 (16.5)	7.65	3 (1.1)	0.33
Immunology	9	120	87 (72.5)	25.29	21 (17.5)	19.05	1 (0.8)	2.00	11 (9.2)	7.18	0 (0.0)	0.00
Laboratory medicine and pathobiology	302	3468	2815 (81.2)	16.02	276 (8.0)	23.00	122 (3.5)	17.84	148 (4.3)	4.18	96 (2.8)	6.92
Medical biophysics	84	1609	1329 (82.6)	21.67	111 (6.9)	48.13	124 (7.7)	3.73	45 (2.8)	6.89	0 (0.0)	0.00
Medical imaging	182	1347	1110 (82.4)	10.75	61 (4.5)	9.93	56 (4.2)	12.64	83 (6.2)	5.11	25 (1.9)	2.96
Medicine	734	8926	6613 (74.1)	24.75	908 (10.2)	26.83	306 (3.4)	37.56	810 (9.1)	6.51	241 (2.7)	3.52
Molecular genetics	64	1244	1052 (84.6)	29.99	103 (8.3)	52.99	17 (1.4)	13.29	72 (5.6)	5.83	0 (0.0)	0.00

Table 1 continued

Department	Faculty, *N*	Total papers, *N*	Article		Review		Proceedings paper		Editorial		Letter	
			N (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*	*N* (%)	Mean citations per paper, *N*
Nutritional sciences	19	408	349 (85.5)	13.17	38 (9.3)	17.63	12 (2.9)	21.33	9 (2.2)	1.89	0 (0.0)	0.00
Obstetrics and gynaecology	221	618	480 (77.7)	10.33	54 (8.7)	10.59	33 (5.3)	5.94	50 (8.1)	2.10	1 (0.2)	0.00
Occupational science and occupational therapy	31	300	243 (81.0)	7.56	27 (9.0)	25.74	24 (8.0)	3.33	5 (1.7)	1.80	0 (0.0)	0.00
Ophthalmology and vision sciences	43	389	300 (77.1)	10.47	15 (3.9)	7.47	36 (9.3)	11.00	38 (9.8)	1.39	0 (0.0)	0.00
Otolaryngology	30	396	316 (79.8)	8.37	26 (6.6)	8.23	45 (11.4)	5.27	9 (2.3)	1.78	0 (0.0)	0.00
Paediatrics	277	2879	2266 (78.7)	14.33	290 (10.1)	15.92	104 (3.6)	17.61	218 (7.6)	2.39	1 (<0.1)	0.00
Pharmacology and toxicology	50	443	370 (83.5)	11.44	40 (9.0)	27.42	8 (1.8)	11.12	25 (5.6)	2.52	0 (0.0)	0.00
Physical therapy	41	419	352 (84.0)	7.41	34 (8.1)	10.38	11 (2.6)	10.82	18 (4.3)	1.44	3 (0.7)	0.00
Physiology	50	594	508 (85.5)	18.92	60 (10.1)	21.35	8 (1.3)	12.62	17 (2.9)	2.29	1 (0.2)	0.00
Psychiatry	539	1589	1196 (75.3)	13.18	224 (14.1)	18.43	30 (1.9)	19.67	109 (6.9)	3.73	8 (0.5)	0.00
Radiation oncology	154	1259	972 (77.2)	14.02	108 (8.6)	24.19	124 (9.9)	11.50	54 (4.3)	3.02	1 (<0.1)	0.00
Speech-language pathology	12	92	77 (83.7)	5.09	6 (6.5)	11.00	7 (7.6)	8.86	2 (2.2)	0.50	0 (0.0)	0.00
Surgery	266	4378	3117 (71.2)	15.05	426 (9.7)	24.49	280 (6.4)	11.54	454 (10.4)	1.90	62 (1.4)	2.03

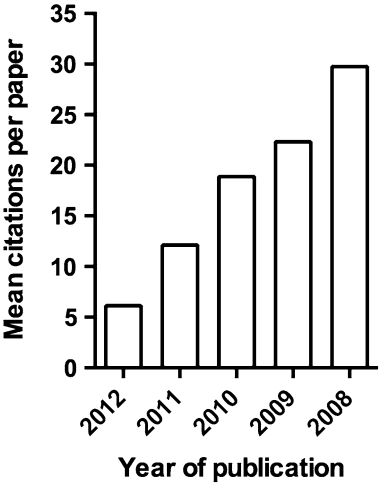

Fig. 1 Mean citations per paper (measured July 2014) for publications from each year cited by subsequent years in the study period, for all departments at the University of Toronto's Faculty of Medicine

Table 2 Citation metrics for University of Toronto's Faculty of Medicine Departments between 2008 and 2012 (measured July 2014)

Department	Percentage cited, %	Mean citations per paper, *N*	Second generation mean cites per paper, *N*	*h* index
Anesthesia	92	12.98	3.55	42
Biochemistry	95	25.16	6.70	43
Biomaterials and biomedical engineering	89	16.00	6.03	52
Cellular and biomolecular research	97	32.65	7.46	77
Family and community medicine	87	10.07	3.19	37
Health policy, management and evaluation	89	9.04	1.91	24
Immunology	98	22.34	8.49	29
Laboratory medicine and pathobiology	93	15.82	4.72	80
Medical biophysics	91	21.70	5.99	81
Medical imaging	86	10.21	2.77	46
Medicine	93	23.04	5.95	176
Molecular genetics	97	30.27	8.39	86
Nutritional sciences	92	13.58	4.03	35
Obstetrics and gynaecology	85	9.44	3.02	33
Occupational science and occupational therapy	85	8.73	3.16	22
Ophthalmology and vision sciences	86	9.51	3.53	27
Otolaryngology	87	7.86	3.06	24
Paediatrics	91	13.70	4.40	71
Pharmacology and toxicology	88	12.38	4.18	32
Physical therapy	88	7.41	1.77	26
Physiology	95	18.57	5.98	48
Psychiatry	90	13.16	4.59	55
Radiation oncology	90	14.16	4.04	56
Speech-language pathology	87	5.66	1.38	13
Surgery	89	14.07	3.53	88

Table 3 Normalized and percentile citation metrics for University of Toronto's Faculty of Medicine Departments between 2008 and 2012 (measured July 2014)

Department	Journal actual/ expected citations	Category actual/ expected citations	Average percentile
Anesthesia	1.71	2.53	46.40
Biochemistry	1.81	3.29	36.54
Biomaterials and biomedical engineering	2.17	2.95	46.45
Cellular and biomolecular research	2.14	4.62	33.76
Family and community medicine	1.73	2.56	48.28
Health policy, management and evaluation	1.53	2.78	56.70
Immunology	1.66	3.25	38.37
Laboratory medicine and pathobiology	1.97	2.73	47.85
Medical biophysics	1.94	3.57	42.69
Medical imaging	1.84	2.09	55.22
Medicine	2.32	4.13	44.06
Molecular genetics	1.95	4.11	35.93
Nutritional sciences	1.55	2.17	49.14
Obstetrics and gynaecology	1.59	1.90	54.01
Occupational science and occupational therapy	2.01	2.27	56.57
Ophthalmology and vision sciences	1.87	2.35	56.11
Otolaryngology	1.62	2.09	56.07
Paediatrics	1.90	2.66	48.27
Pharmacology and toxicology	1.74	2.12	48.84
Physical therapy	1.74	1.77	58.62
Physiology	1.61	2.55	43.14
Psychiatry	1.99	2.58	48.84
Radiation oncology	1.95	2.60	51.71
Speech-language pathology	1.65	1.89	59.15
Surgery	2.21	3.15	49.47

was 17.35. The citation window for biomedical scientific papers was still active at 5 years after publication.

Bibliometrics are only one facet of scientometrics, but they are a central component of many systematic processes used to evaluate research impact in universities. Within the biomedical academic community, scientometrics used to evaluate research impact vary between journal-level metrics, article-level metrics, and other altmetrics (Holbrook et al. 2013), but as a consequence of the diversity that exists between disciplines, benchmarking among specialties and groups of researchers is essential to ensure that appropriate comparisons can be made between and within groups. In this study, we describe article-level bibliometric profiles of the University of Toronto's Faculty of Medicine. These bibliometric data, as expected, confirm that departments differ substantially in scientific output and impact using non-normalized citation metrics. Using normalized metrics, the bibliometric performance of all departments was greater than expected for both scientific category and journal defined citation counts—the actual to expected ratio for both metrics was greater than 1.5 for all departments. However, for more than one-third of departments the average percentile for ranked publications was less than 50 %. Overall, our data are

Table 4 Collaboration metrics for University of Toronto's Faculty of Medicine Departments between 2008 and 2012 (measured July 2014)

Department	Mean authors per paper, *N*	Mean institutions per paper, *N*	Mean countries per paper, *N*	Disciplinarity index	Interdisciplinarity index
Anesthesia	18.06	3.53	1.75	0.116	0.56
Biochemistry	9.54	3.80	1.70	0.187	0.46
Biomaterials and biomedical engineering	4.64	2.07	1.32	0.042	0.70
Cellular and biomolecular Research	10.00	3.65	1.85	0.068	0.59
Family and community medicine	6.67	3.56	1.39	0.600	0.64
Health policy, management and evaluation	5.49	3.03	1.31	0.072	0.61
Immunology	7.52	2.56	1.72	0.211	0.41
Laboratory medicine and pathobiology	9.78	4.20	1.85	0.040	0.69
Medical biophysics	9.46	3.61	1.85	0.052	0.66
Medical imaging	6.83	2.65	1.53	0.126	0.53
Medicine	8.93	4.57	2.03	0.036	0.70
Molecular genetics	15.31	6.65	2.61	0.088	0.57
Nutritional sciences	6.27	2.61	1.52	0.123	0.53
Obstetrics and gynaecology	6.98	2.91	1.54	0.098	0.58
Occupational science and occupational therapy	5.48	2.96	1.39	0.081	0.61
Ophthalmology and vision sciences	5.94	2.51	1.47	0.383	0.35
Otolaryngology	6.30	2.10	1.38	0.198	0.44
Paediatrics	8.73	4.26	1.92	0.053	0.66
Pharmacology and toxicology	6.61	2.82	1.70	0.055	0.64
Physical therapy	5.74	3.19	1.41	0.069	0.61
Physiology	7.51	2.66	1.65	0.094	0.54
Psychiatry	6.84	3.66	1.73	0.105	0.58
Radiation oncology	8.79	3.84	1.62	0.168	0.51
Speech-language pathology	4.11	2.70	1.37	0.107	0.52
Surgery	7.70	3.32	1.66	0.077	0.61

consistent with the trends observed in the CWTS (Centre for Science and Technology Studies) Leiden Ranking for leading universities in the medical sciences—that compared with leading universities, the University of Toronto has high levels of research productivity in medical sciences but when normalized to scientific categories much of the output is considered lower impact. (http://www.leidenranking.com, accessed 28 November 2014). However, we were prevented from making direct comparisons with our study data as these datasets differ in both timeframe and methodology.

In this study, we observed a continued increase in citation activity for each year (each year cited by all subsequent years) throughout the study period. This finding contravenes

existing literature, in which researchers recommend that an analysis of citations can be considered meaningful for publications after a citation window of only 3 years (Wang 2013). For bibliometrics to be comparable across researchers or groups, the rate of change of citation activity needs to be consistent or citation activity needs to plateau, neither of which occurred in this cohort. This has important implications for using bibliometrics to assess research impact for researchers seeking academic promotion or tenure, most significantly for "young" researchers. Our findings support the notion that bibliometrics should not be used for assessing research before a minimum "academic age", or that the citation window of publications is acknowledged or standardized when comparing individual researchers or groups.

Collaboration is increasingly recognized as an central component of increased research impact and productivity for leading researchers (Catala-Lopez et al. 2014). This premise is supported by our findings, as the academic departments in this cohort with the highest levels of collaboration and interdisciplinary research also had the highest research impact. As a consequence of research diversity and an increasing emphasis by universities and funding agencies on collaboration and interdisciplinary research to promote knowledge integration, we anticipate that it will be increasingly important to consider strategies which include measures of collaboration, such as social network analysis (Rosas et al. 2011), when measuring university-level research impact.

The aim of our data retrieval strategy—using publications identified from both advanced search strategies in Web of Science® and also from authors' own curricula vitae—was to remove much of the confounding that can occur when citation databases are used in isolation. Using citation databases alone to determine authors' productivity can be unreliable when attempting to determine the true number of researchers' publications, depending on the scope of the databases or the methodology used to identify authors or institutions. In this instance, numbers of publications for researchers from University of Toronto's Faculty of Medicine determined using author name only in Web of Science® alone overestimated research productivity by 16 % on average compared with the strategy used in this study and, conversely, researchers' curricula vitae underestimated the true numbers of publications by researchers. Citation databases and researchers have attempted to reduce this ambiguity by creating unique author identifiers for individuals, such as ResearcherID™ (Thomson Reuters), Scopus® Author Identifier (Elsevier BV), and Open Researcher and Contributor ID (ORCID). However, these initiatives are also limited by the need for researchers to verify and update their publication profiles and, at present, advanced search strategies of citation databases are still necessary to determine accurate and reproducible bibliometrics.

There are some limitations to this study. The relatively short time since publication and active citation window for more recent publications in this study may have underestimated the true impact of some research. The timeframe for included publications, although representative of contemporary research activity in departments, does not represent previously productive researchers who have had a publishing hiatus but still contribute to the overall scientific impact of academic departments. Also, the custom dataset and resulting citation profiles, although greatly improved, may not be complete as InCites™ only include publications or citations by journals indexed in Web of Science®.

In conclusion, this study benchmarks research performance using article-level bibliometrics for academic departments in the University of Toronto's Faculty of Medicine for scientific publications from 2008 to 2012. These data can be used to facilitate the evaluation of the scholarly activity of university departments in other institutions. These results also indicate that the active citation window for publications in biomedical research is

longer than previously thought, and this will hinder the use of bibliometrics when evaluating recent scientific publications.

Acknowledgments The authors wish to acknowledge the contribution of Cathy Grilo, Special Projects and Evaluation Coordinator, Office of the Vice Dean, Research and International Relations, Faculty of Medicine, University of Toronto to this project.

Author contribution James D. O'Leary, Mark W. Crawford, Eva Jurczyk, and Alison Buchan helped design the study, analyzed the data, and wrote the manuscript. James D. O'Leary conducted the study.

Compliance with ethical standards

Conflict of interest None.

References

Ball, P. (2007). Achievement index climbs the ranks. *Nature, 448*(7155), 737.

Catala-Lopez, F., Alonso-Arroyo, A., Hutton, B., Aleixandre-Benavent, R., & Moher, D. (2014). Global collaborative networks on meta-analyses of randomized trials published in high impact factor medical journals: A social network analysis. *BMC Medicine, 12*, 15.

Derrick, G. E., Haynes, A., Chapman, S., & Hall, W. D. (2011). The association between four citation metrics and peer rankings of research influence of Australian researchers in six fields of public health. *PLoS One, 6*(4), e18521.

European Commission Directorate-General for Research and Innovation. (2010). Assessing Europe's University-Based Research—Expert Group on Assessment of University-Based Research. http://ec.europa.eu/research/science-society/document_library/pdf_06/assessing-europe-university-based-research_en.pdf. Accessed 28 November 2014.

Holbrook, J. B., Barr, K. R., & Brown, K. W. (2013). We need negative metrics too. *Nature, 497*, 439.

O'Leary, J. D., & Crawford, M. W. (2010). Bibliographic characteristics of the research output of pediatric anesthesiologists in Canada. *Canadian Journal of Anaesthesia, 57*(6), 573–577.

Rosas, S. R., Kagan, J. M., Schouten, J. T., Slack, P. A., & Trochim, W. M. (2011). Evaluating research and impact: A bibliometric analysis of research by the NIH/NIAID HIV/AIDS clinical trials networks. *PLoS One, 6*(3), e17428.

Wang, J. (2013). Citation time window choice for research impact evaluation. *Scientometrics, 94*(3), 851–872.