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Measuring Knowledge Translation Uptake Using Citation Metrics: A Case Study of a Pan-Canadian Network of Pharmacoepidemiology Researchers

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ABSTRACT

Collecting citation metric data is important, as research funders are increasingly demanding impact assessment, but there is limited consensus on the most rigorous and accurate approach. We compared three sources of citation counts (Google Scholar, Web of Science, Scopus) to determine their reliability, comprehensiveness, and currency. We identified each tool's strengths and limitations, particularly when considering team outputs. Citation counts varied, with poor overall agreement: Fleiss' kappa, 0.075 (95% CI [0.01, 0.12]). Researchers, funders, and administrators need to understand each tool's unique strengths and limitations and develop guidelines for use within specific contexts.

KEYWORDS

Bibliometrics; citation metrics; knowledge translation; research impact

Introduction

The use of research productivity metrics is entrenched in many countries where institutional funding is formally tied, in part, to metrics intended to ensure accountability. The use of metrics in North America, however, is largely less formal and guided. Funders, government agencies, and academic institutions are increasingly requiring that their individual researchers and research networks document the uptake and impact of their research to ultimately demonstrate value for research investment (Hanney et al. 2013; Nelson et al. 2014; Soper and Hanney 2007). But clear guidelines on compilation and use of quantitative metrics are often lacking. There are many ways to examine the impact of research. One widely accepted metric is the analysis of citations in traditional academic publications (Sahel 2011; Sibbald et al. 2015; Smith, Crookes, and Crookes 2013).

Citation counts demonstrate research impact under the assumption that the citation of an article in a subsequent article indicates that the first influenced the second in some way. Citation metrics are used as indicators of individual professional success such as academic rank, tenure and promotion, honors

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and awards, and successful grant applications, as well as institutional and national success (Bornmann and Daniel 2008; Hanney et al. 2005, 2006; Rinia et al. 1998; Wilsdon et al. 2015). However, consensus on the most accurate and rigorous methods to collect and analyze citation metrics, particularly when determining the uptake of articles written by research teams, is limited.

Studies comparing tools that provide citation counts proliferated in the years immediately following the introduction of Scopus and Google Scholar (GS) in 2004 (Bakkalbasi et al. 2006; Bar-Ilan 2008; Bould et al. 2011; De Winter, Zadpoor, and Dodou 2014; Falagas et al. 2008; Kulkarni et al. 2009; Levine-Clark and Gil 2008; Li et al. 2010; Meho and Yang 2007). In a study of highly cited Israeli researchers in all fields, Bar-Ilan (2008) found that the number of citations returned by the three tools and the h-indices[1] they informed varied widely according to the researcher's field. Levine-Clark and Gil (2008) found a higher number of citations from GS, with an average of 27.03 citations per article in all journals under consideration, while only 9.06 in Scopus and 8.06 in Web of Science (WoS) respectively (Levine-Clark and Gil 2008). In a study of physics articles, Bakkalbasi et al. (2006) found that GS returned the fewest (143, of which 50 were unique), while Scopus returned 162 (25 unique) and WoS 212 (63 unique). Similar returns were noted for oncology articles in the same study, with GS finding 324 citing articles, WoS 431, and Scopus leading with 469 (Bakkalbasi et al. 2006). The general lack of agreement among the three tools found by Bakkalbasi et al. (2006) is consistent with Meho and Yang (2007) where the overlap among all three tools did not reach above 31 percent in their searches.

We build on this work by applying the three major citation tools available to Dalhousie University (Halifax, Canada)—WoS, (Thomson Reuters 2016), Scopus (Elsevier 2016), and GS (Google 2016)—to determine which sources of citation counts were most reliable, comprehensive, and current for evaluating Canadian Network of Observational Drug Effect Studies (CNODES)'s research impact. In doing so, we also identified challenges, strengths, and limitations in assessing the impact of a research team through a small body of recently published articles. In this case study, we sought to determine the uptake of publications from the Canadian Institutes of Health Research (CIHR)-funded CNODES. A collaborating center of the Drug Safety and Effectiveness Network (Canadian Institutes of Health Research 2012), CNODES is a national network of researchers, dispersed across seven provinces (CNODES n.d.; Suissa et al. 2012). Our objectives were to determine the quantity and characteristics of citations from CNODES's publications.

[1]The h-index is a metric that integrates a researcher's productivity and citation impact. It is calculated as a researcher's score when she has *N* articles with at least *N* citations (Hirsch 2005, 16569–16572).

Methods

Three citation tools were used to collect and analyze citation metrics for this case study: WoS, Scopus, and GS. WoS and Scopus are both databases; their content is curated, stable, and focused on academic publications. Scopus indexes over 21,000 journals, in addition to conference proceedings and books, and is updated daily (Elsevier 2015). WoS indexes more than 12,000 journals in addition to conference proceedings (Thomson Reuters 2015) and is updated weekly (Thomson Reuters n.d.). Both are only available via libraries with paid subscriptions. GS is a freely available tool that uses a proprietary algorithm to search Internet content, including academic journals, repositories that hold preprint or postprint content, organization websites, and other sources of content. The focus is intended to be academic in nature, but the precise parameters are unclear (De Winter, Zadpoor, and Dodou 2014; Jacsó 2005; Kulkarni et al. 2009).

CNODES's first five articles (Dormuth et al. 2014, 2013; Filion et al. 2014; Lipscombe et al. 2015; Suissa et al. 2012), authored by team members with CNODES credited as an additional author, were searched by title in Scopus, WoS, and GS to identify the number of publications citing them (referred to as the "citing articles" henceforth). More recently published articles were not included in this case study because they had not yet had an opportunity to accrue citations. For each search in each tool, the number of citing articles was recorded, and the data were cleaned (Figure 1).

The search of the three tools was repeated over the course of the eight-month study period, with the final search conducted November 16, 2015. Repeated searching permitted documentation of lag time of a citing article between its appearances in all the tools. Self-citations (citations by other CNODES-authored articles) and team citations (citations made by CNODES

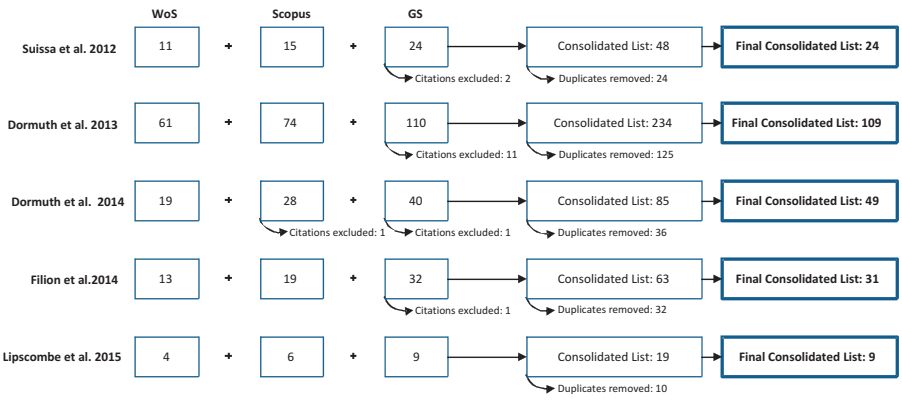

Figure 1. Total number of citations collected for each CNODES article from the three tools: Google Scholar (GS), Scopus, Web of Science (WoS).

Table 1. An Example of Data Collected for an Article Citing Dormuth et al. 2013 (Athyros et al. 2015).

Citing Article	Citing Article Appeared in …			Publisher	Country Affiliation(s) of Authors	Institutional Affiliation(s) of Authors
	GS	Scopus	WoS			
Athyros et al. 2015	Yes	Yes	Yes	Taylor & Francis Group	Greece	Aristotle University of Thessaloniki, Hippocration Hospital, Medical School, Second Propedeutic Department of Internal Medicine, Thessaloniki, Greece

Abbreviations: WoS = Web of Science; GS = Google Scholar.

team members in articles not authored by CNODES itself) were few and not removed before analysis.

We collected the following information for each citing article in the consolidated lists: in which tool the article was available, the publisher of the journal in which the article appears, and the national and institutional affiliations of all listed authors (Table 1). Each country and institution was listed only once per article.

We used Fleiss' kappa (Fleiss 1971) to measure agreement among all three tools and Cohen's kappa (Cohen 1960) for the three pairwise comparisons. Counts and proportions were calculated and presented for summarizing the articles returned, both by article and by publisher. Logistic regression was used to compare tools among publishers, first comparing all three tools and second only comparing WoS and Scopus.

Results

Citations from the three tools

Table 2 provides a summary of the results, illustrating significant differences among the three tools. The overall agreement (Fleiss' kappa) was poor (0.075 (95% CI [0.01, 0.12])). The pairwise agreement measures (Cohen's kappa) were 0.464 for WoS and Scopus, –0.138 for Scopus and GS, and 0.012 for WoS and GS.

Table 2. Summary of the Number of Articles Returned by Each Tool and the Number of Articles Shared between Tools.

	N	WoS	Scopus	GS	WoS & Scopus	WoS & GS	Scopus & GS	All
All	222	108 (0.48)	142 (0.63)	200 (0.9)	95 (0.42)	98 (0.44)	122 (0.54)	87 (0.39)
Suissa et al. 2012	24	11 (0.46)	15 (0.62)	22 (0.92)	9 (0.38)	11 (0.46)	13 (0.54)	9 (0.38)
Dormuth et al. 2013	109	61 (0.55)	75 (0.69)	99 (0.9)	56 (0.5)	58 (0.52)	66 (0.59)	54 (0.49)
Dormuth et al. 2014	49	19 (0.39)	27 (0.55)	39 (0.8)	14 (0.29)	12 (0.24)	18 (0.37)	8 (0.16)
Filion et al. 2014	31	13 (0.41)	19 (0.59)	31 (1)	12 (0.38)	13 (0.41)	19 (0.59)	12 (0.38)
Lipscombe et al. 2015	9	4 (0.44)	6 (0.67)	9 (1)	4 (0.44)	4 (0.44)	6 (0.67)	4 (0.44)

Abbreviations: WoS = Web of Science; GS = Google Scholar.

The different citation numbers resulted in different h-indices from the three tools. At the time these data were analyzed, CNODES as an author had an h-index of 5 in Scopus and GS and an h-index of 4 in WoS.

Country affiliations

The number of articles produced by each country was recorded for comparison from Scopus and the consolidated list (Table 3). Both Scopus and WoS, the two databases, provide this information automatically. Of the two, Scopus provided the higher number of citing articles. The consolidated list, which returned higher numbers overall, included the addition of four countries not found on the Scopus list.

Table 3. List of Country Affiliations for Articles Citing Dormuth 2013 as of October 2015.

Scopus		Consolidated List (Scopus, WoS, GS)	
Country or Territory	Number of Citing Articles	Country or Territory	Number of Citing Articles
United States	21	United States	29
United Kingdom	10	Canada	16
Canada	9	United Kingdom	14
Spain	9	Spain	11
Italy	8	Australia	9
Australia	7	Italy	8
France	5	South Korea	7
India	5	India	6
Greece	4	Japan	6
Japan	4	France	5
Netherlands	4	Taiwan	5
Taiwan	4	Greece	4
Poland	3	Netherlands	4
South Korea	3	Germany	3
Sweden	3	Poland	3
Bulgaria	2	Russian Federation	3
Czech Republic	2	Sweden	3
Finland	2	Switzerland	3
Germany	2	Bulgaria	2
Hungary	2	Czech Republic	2
Oman	2	Finland	2
Romania	2	Hungary	2
Russian Federation	2	Iran	2
Serbia	2	Oman	2
Slovakia	2	Romania	2
Slovenia	2	Serbia	2
Belgium	1	Slovakia	2
Denmark	1	Slovenia	2
Iran	1	Belgium	1
Switzerland	1	Croatia	1
		Denmark	1
		New Zealand	1
		Pakistan	1
		South Africa	1

Abbreviations: WoS = Web of Science; GS = Google theScholar.

Lag time

The interval between when an article was published and when it appeared in the list of citing articles varied among the three tools. One example article (Lo and Mashimo 2015) cited CNODES publication Filion et al. 2014. According to the publisher's website for Lo and Mashimo (2015), it was published in October 2015 but appeared online prior to print publication. Our search on August 5, 2015, found the article in GS but not the other two tools. In mid-October 2015, the article appeared in our searches for both GS and Scopus. The article did not appear in WoS until our search in mid-November 2015.

Publisher information

Table 4 presents the citations identified by each tool, stratified by publisher. GS returned significantly more articles than the other two tools. A second test was completed to compare WoS and Scopus. Publications in Elsevier journals were well indexed by Scopus, which is an Elsevier product.

Discussion

Using the tools WoS, Scopus, and GS to determine citation metrics for the CNODES research team yielded different results for every article, and these numbers of citing articles steadily increased over the course of the brief study period. No one tool comprehensively indicated the extent of research impact on the basis of citation counts.

Tools to demonstrate research impact through citation counts

In seeking to capture a comprehensive picture of research impact of CNODES publications, we considered the respective strengths and weaknesses of each tool.

Table 4. Comparing and Analyzing the Tools, Stratified by Publisher of the Citing Articles.

	N	WoS	Scopus	GS	*P* Value (3 tools)	*P* Value (WoS vs. Scopus)
All	222	108 (0.48)	142 (0.631)	202 (0.901)		
Elsevier	38	21 (0.538)	33 (0.846)	33 (0.868)	.0010	.0027
Wolters Kluwer	10	7 (0.7)	6 (0.6)	8 (0.8)		
BMJ	18	15 (0.833)	17 (0.944)	14 (0.778)	.3182	.2791
John Wiley	10	7 (0.7)	9 (0.9)	10 (1)		
Springer	26	8 (0.308)	15 (0.577)	26 (1)	<.0001	.04913
Nature Publishing	5	4 (0.8)	5 (1)	4 (0.8)		
Other	115	46 (0.393)	57 (0.496)	105 (0.913)	<.0001	.1444

Abbreviations: WoS = Web of Science; GS = Google Scholar.

Google Scholar

Searches in the three tools revealed that GS consistently yielded the highest number of citing articles. As previous researchers have noted, the GS results were of varying quality (Boeker, Vach, and Motschall 2013; De Winter, Zadpoor, and Dodou 2014). Some items from the list of citing articles were duplicates from different sources or incomplete. A further problem stems from the fact that GS is not a database with curated content, but a search engine drawing from the web. Therefore, the continued availability of an item found using GS is unreliable, and an article found during one update might disappear before the next (Boeker, Vach, and Motschall 2013), though in practice we only observed this once. Some of the challenges to using GS included uncertainty as to what GS was searching; inclusion of blog posts, duplicates, and fragmentary citations; and the time and patience to clean the data. While the data require cleaning, they are nonetheless valuable. A further advantage of GS was the timeliness of its results.

Scopus and Web of Science

Scopus consistently returned a higher number of citing articles than WoS. Nevertheless, WoS did return some unique results. This lack of correlation between the two databases is consistent with results in other studies (Kulkarni et al. 2009; Levine-Clark and Gil 2008; Meho and Yang 2007). We found in the course of repeated searches over time that citing articles first found in GS sometimes appeared in the results of the other sources at a later time.

Advantages and disadvantages of using multiple tools to determine citation metrics

Our study did not point to a single optimal tool to measure research impact using citation metrics. Using multiple tools added citations, but creating a consolidated list using manual analysis was time intensive. Subscribing to several databases incurred additional institutional cost.

Bakkalbasi et al.'s (2006) study that compared WoS, Scopus, and GS for two disciplines (oncology and condensed matter physics) found that GS returned a smaller number of references, though more unique references, than the other two. They concluded that "… GS alone might not replace other scholarly search tools" (Bakkalbasi et al. 2006). De Winter, Zadpoor, and Dodou's (2014) more recent article found that the coverage offered by GS had improved dramatically since its inception and foresaw that it would not be long before coverage by GS would completely overlap coverage by WoS. Our own study suggests that for recently published articles in the fields of interest to CNODES studies, GS offers considerable value. Whether or not it is an adequate, exclusive option for tracking citation counts remains to be determined according to the needs, priorities, and resources of those who use them.

On the other hand, the difference of a few citations that GS did not find can be significant, particularly when the raw citation counts are used in the calculation of indices that may be used by tenure and promotion committees, research granting councils, and university league tables (Wilsdon et al. 2015).

Insights into what the tools reveal about what audiences are reached

Publisher information

Considering the publisher of citing articles is useful for understanding which publishers are indexed well by which tools. This information was analyzed to learn how CNODES might maximize impact with future publications. The publisher information revealed that some publishers were better indexed than others.

Citing countries

WoS and Scopus provide analysis tools for considering citing articles according to different variables. WoS and Scopus differed slightly in how they reported the affiliated countries of citing authors. In one instance, Scopus grouped together citing authors within the United Kingdom, and WoS chose to separate England, Wales, and Northern Ireland.

CNODES's studies use data from seven Canadian provincial databases and two international databases from the United States and the United Kingdom. It is not surprising that the top three countries citing CNODES work were the United States, Canada, and the United Kingdom, and there is limited uptake in low–middle-income countries.

Lag time between publication and appearance in tools

While both WoS and Scopus frequently update their databases, they do not include information on lag time between publication of an article and its appearance in a database. This is a point of value when the articles under consideration are recent, still accruing significant citations on a monthly basis, and metrics need to be used for a specific immediate purpose, such as a grant application.

Team-related challenges when considering citation metrics

An underlying challenge of this study was the fact that the publications were from a team or network of researchers from a range of specialties studying pharmacoepidemiologic challenges. Most previous comparisons of citation tools have been limited to specific disciplines. This is done because the degree to which citations are used and how citation tools apply varies by discipline.

The fluid nature of the CNODES team created problems for counting self-citation. Though self-citations proved to be of minor significance, we

explored what constituted a self-citation. Was it any citation of a CNODES team member to a CNODES article, or citations by any listed author?

A challenge raised by consideration of the work of a team was that searching by author was not always successful, given the way CNODES has been presented as an author in its articles. Individual authorship varied and "CNODES" was not credited in a consistent way (e.g., sometimes with an acronym, sometimes without). The tools were inconsistent in their ability to find articles based on CNODES authorship. WoS's "Group Author" field was effective and accurate, while Scopus and GS could not find CNODES articles with an author search. The need for individual researchers to use consistent nomenclature and make use of tools such as ORCID to be appropriately credited for their work is well known (Wilsdon et al. 2015). However, such tools are not readily available for groups, which makes it difficult to ensure that CNODES articles can be found, used, and cited.

Assessment of the CNODES publication output is also challenging given the tools usually used are intended primarily for the use of individual researchers. CNODES is a new team; as a consequence, its h-index is low. This low score does not reflect the experience and expertise of individual researchers involved in CNODES, many of whom have personal h-indices that are high compared to their peers. It is thus a misleading score, inappropriate for comparison to those of individuals. At the same time, CNODES, as a team, has the potential to conduct research and produce publications far more quickly than an individual might be able to do. To the extent that scientific research is increasingly collaborative and team based (Cooke and Hilton 2015; Wilsdon et al. 2015), it is worth considering how teams can be fairly assessed as a unit.

Strengths and limitations of our study

Our study examined the citation metrics of a single research network, CNODES, in real time to determine research impact using citation metrics prior to grant renewal. We systematically collect and then analyze citation counts available from three major citation metric tools.

This study considered recent publications that were still accruing citations, which may have limited conclusions. A further time-related limitation to any assessment of WoS and Scopus is that the content of the databases themselves is changing. Information about the coverage offered by these two tools becomes quickly outdated as coverage increases (Moed 2009).

Most databases offer different ways to add precision to a search, or search according to different variables, unique to that database. Our study was only looking at a limited number of preidentified articles, so we did not consider the unique search features of each of these tools. This may be an important aspect for researchers in other circumstances to consider.

A citing article is only included in the data set if it was identified by one of the three tools, meaning there are no articles on which all three "agree" to a no-citation. This means that the agreements that include GS should be interpreted with caution, but even with this caveat none of the four agreements presented here is strong.

Conclusions

Our study shows that using three tools (WoS, Scopus, GS) to determine citation metrics as indicators of research performance and impact provided varying results, with poor overall agreement among the three: Fleiss' kappa, 0.075 (95% CI [0.01, 0.12]). No one tool was available to provide reliable and comprehensive numbers. Judicious use requires an understanding of the strengths and limitations of each tool; researchers are advised to perform their own tests of the available tools to determine which might be most appropriate for their own disciplines and institutions. The comprehensiveness, accuracy, timeliness, usability, and costs for the different tools need to be considered. Funders and administrators also need to understand that these different tools may not always deliver comparable results and should develop guidelines for their use within specific contexts.

The challenges associated with using citation tools and the citations themselves is a call to librarians to be able to not only guide patrons in the use of these tools but in their strengths and limitations and participate in the development of guidelines and standards to improve their use. Granting councils and universities that implement use of research impact metrics should be familiar with their strengths and limitations and consider the human and technical resources needed to apply them wisely. Researchers, particularly those in the early stages of their careers, need to be aware of how to use citation tools to their best advantage, both in terms of their capacity to demonstrate research impact and to mobilize research results. Citation metrics will continue to play a prominent role in demonstrating research impact, and all stakeholders need to invest in ensuring that they are used wisely.

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