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Abstract

As bibliographical classification of published journal items affects the denominator in this equation, we investigated how the numerator and denominator of the impact factor (IF) equation were generated for representative journals in two categories of the *Journal Citation Reports* (JCR). We performed a full text search of the 1st-ranked journal in 2004 JCR category "Medicine, General and Internal" (*New England Journal of Medicine*, *NEJM*, IF=38.570) and 61st-ranked journal (*Croatian Medical Journal*, *CMJ*, IF=0.690), 1st-ranked journal in category "Multidisciplinary Sciences" (*Nature*, IF=32.182) and journal with a relative rank of *CMJ* (*Anais da Academia Brasileira de Ciencias, AABC*, IF=0.435). Large journals published more items categorized by Web of Science (WoS) as non-research items (editorial material, letters, news, book reviews, bibliographical items, or corrections): 63% out of total 5193 items in *Nature* and 81% out of 3540 items in *NEJM*, compared with 31% out of 283 items in *CMJ* and only 2 (2%) out of 126 items in *AABC*. Some items classified by WoS as non-original contained original research data (9.5% in *Nature*, 7.2% in *NEJM*, 13.7% in *CMJ* and none in *AABC*). These items received a significant number of citations: 6.9% of total citations in *Nature*, 14.7% in *NEJM* and 18.5% in *CMJ*. IF decreased for all journals when only items presenting original research and citations to them were used for IF calculation. Regardless of the journal's size or discipline, publication of non-original research and its classification by the bibliographical database have an effect on both numerator and denominator of the impact factor equation.

Introduction

From its beginning in the 1955, when it was developed to ease the selection of journals into a bibliographical database,[1] the impact factor (IF) of scientific journals has become the centerpiece of scientific enterprise. Although it was developed primarily as a bibliographical tool, IF is often used as proxy for the quality of research and researchers,[2] and is equally important to both authors and editors: authors depend on it for career promotion and research funding, and editors care about it because high IF attracts more and better papers.

Impact factor has been the subject of many heated debates.[2-9] A major criticism is that IF calculation is not transparent and that it is property of a private company from the USA, Thompson Scientific, which releases journals' annual IFs in its product Journal Citation Reports® (JCR).[5] There have also been allegations that journals could manipulate their IF[5-7] by affecting the numbers that go into the impact factor equation – the ratio between the citations journal articles from two previous years receive in the current year and number of articles published in the two previous years. The numerator in the impact factor formula includes all citations, regardless whether they are to original research work or non-research items, such as letters, comments and editorials; the denominator includes only the journal items that are considered citable, ie, published items categorized as "Article" or "Review" by the experts at the Thompson Scientific.[1,3,5,7]

Although much has been written about IF equation and how it can be effected,[1-9] there has not been much evidence[2-4] that would systematically address IF calculation across different journals. To provide necessary evidence for this important debate, we analyzed the bibliographical classification of published items and elements of the IF equation for typical journals from two prestigious categories of the JCR – "Multidisciplinary science" and "Medicine, general and internal". The analysis included the first ranked, weekly published journals in the categories (*Nature* and *New England Journal of Medicine*) and a smaller journal from the middle of the impact factor ranking in each category (*Anais da Academia Brasileira de Ciencias*, a quarterly journal from Brazil, and *Croatian Medical Journal*, a bimonthly journal from Croatia, respectively).

Methods

The study included the first and middle-ranking journals in two categories of the 2004 Journal Citation Reports, which was available at the start of the study (Figure 1): 1) *New England Journal of Medicine* (*NEJM*, IF=38.570) and *Croatian Medical Journal* (*CMJ*; IF=0.690), ranked 61st out of 103 journals in "Medicine, General and Internal" category and 2) *Nature* (IF=32.182) and *Anais da Academia Brasileira de Ciencias* (*AABC*; IF=0.435), ranked 26th (the same relative rank as the *CMJ*) out of 45 journals in "Multidisciplinary Sciences" category. Journals were available in print, except for *AABC*, which had full text available on-line (http://www.scielo.br/scielo.php?script=sci_serial&pid=0001-3765).

We first performed full text search of all published items in 2003 and 2004 volumes for all 4 journals. Volumes 2003 and 2004 were selected because they served as the basis for calculating 2005 IF, which was still not officially released at the time of our analysis. Each published item (3640 items for *NEJM*, 290 for *CMJ*, 5193 for *Nature*, and 126 for *AABC*; Figure 1) was read and assessed for originality, which was defined as presentation of novel, previously unpublished research results expressed in a numerical of graphical form, regardless of the formal structure of the published item.

We then performed the search of Thomson Scientific electronic database *Web of Science* (*WoS*) database (http://portal.isiknowledge.com/portal.cgi) to confirm indexing and identify bibliographical classification of published items. All items identified by hand search of the journals were identified in the database, except a single article (Nankivell BJ et al; *N Engl J Med* 2003;349(24):2326-33); this item was excluded from further analysis. Bibliographical items were categorized into the following categories by WoS: "Article", "Review", "Editorial Material", "Letter", "News Item", "Bibliographical Item", "Book Review" and "Correction". Data on all 9249 published items were entered into an electronic database, including the title of the article, authors'

names, source journal, and article classification according to 1) databases, 2) journal's own categorization, and 3) presentation of original research results.

Finally, citations for individual indexed items were identified by Cited Reference search of the *WoS* database. Data categorization and collection was performed in June 2006, when the data on 2005 citations to 2003 and 2004 published items should have been entered into *WoS* but before the official release of the journals' impact factors (IFs) for 2005 in summer of 2006 (Figure 1), in order to exclude any bias on our side related to the knowledge of 2005 *JCR* data and elements of the IF. Official data on IF were collected from the 2005 JCR edition, released in summer 2006. According to the JCR Notices (http://portal.isiknowledge.com/portal.cgi?DestApp=JCR&Func=Frame), there were no data adjustments in the JCR or changes in the impact factor or ranking for the 4 journals since the initial 2005 JCR release.

Results

Most of the published items in *Nature* and *NEJM* were non-research items, classified by WoS database as editorial material, letters, news, book reviews, bibliographical items, or corrections (62.6 % and 81.3%, respectively; Table 1). Smaller journals published fewer non-research items, *CMJ* 30.8% and *AABC* just 2 (1.6%) items (Table 1). The analysis of full text articles showed that the bibliographical classification into citable items (articles and reviews) corresponded to the original research content of items only in *AABC*, which published almost exclusively original research articles and reviews. For other journals, original research results were presented in bibliographical items that are not included in IF equation, whereas some of the items classified by *WoS* as original articles did not contain original research data (Table 1). For *Nature*, original research data could be identified in 94.7% items classified as original articles and in 9.5% of items classified as editorial material or letters. In *NEJM*, 92.2% of the original article items and 7.2% of

editorial material or letters contained research data (Table 1). In *CMJ*, these percentages were 91.2% and 13.7%, respectively (Table 1).

The analysis of citations that items published in 2003 and 2004 received in 2005, showed that items classified as non-citable items by WoS, and thus not included in the denominator of the IF equation, received a significant number of citations, which are included in the numerator of the IF equation: 6.95% of all citations in Nature, 14.7% in NEJM, 18.5% in CMJ and none in AABC (Table 1). Most of these citations were to items that did not present original research according to our analysis: 64.8% in Nature, 83.4% in NEJM, and 83.3% in CMJ.

In *NEJM*, the categories editorial material and letters, regardless of whether they contained original research data, received a total of 4195 citations, which is considerably more than 3401 citations to all review articles (Table 1). In *Nature*, the majority of items classified as non-original by *WoS* but receiving considerable number of citations were "Brief Communications". Out of these 311 items, 90 (28.9%) were classified by WoS as "Articles", and the rest were classified as "Editorial Matter" or "Letters", although 250 (80.4%) out of all Brief Communications contained original research results, and received 1983 citations. In CMJ, non-original items that received many citations were essays written for the forum on the Revitalization of Academic Medicine, which ran for more than a year and essays cited each other over this period.

The total number of citations retrieved by cited reference search of *WoS* was smaller than that declared by *JCR* for all journals except for *CMJ*, and comprised 95.5% (*Nature*), 87.6% (*AABC*) and 95.6% (*NEJM*) of total citations reported by JCR (Figure 1). The denominator of IF equation (items likely to receive citations) in the JCR differed from the number of such items identifiable in *WoS* database for *Nature* and *NEJM*. For *Nature*, we could identify 1935 items as "Articles" and "Reviews" in *WoS*, whereas *JCR* declared 1737 items. *NEJM* had 679 such items registered in *WoS*, but 682 in JCR. The number of these items for AABC and *CMJ* was the same in *WoS* and *JCR* (Figure 1 and Table 1).

When we entered into the IF formula the number of published items with original data and the number of citations to these items from WoS database, the IFs decreased for all journals: 21.3% for *Nature*, 12.2% for *AABC*, 32.2% for *NEJM*, and 15.7% for *CMJ* (Table 2).

Discussion

Our study showed that impact factor equation is most relevant for journals that publish almost solely original research articles and reviews. When a journal publishes items other than research articles and reviews and these contain original research data information relevant for science, these items get a significant number of citations, which increase the numerator of the IF equation. This is true for both large and small journals, and for different disciplines. In our study, the two first ranked journals from two different JCR categories (*Nature*, the leading multidisciplinary journal, and *New England Journal of Medicine*, the leading general medical journal) and a small journal from the middle of its JCR category (*Croatian Medical Journal*) had a similar relative change in the impact factor because of the citations to items other than articles and reviews. Only *Anais da Academia Brasileira de Ciencias,* journal that publishes almost exclusively research articles and reviews, was affected by the changes in the numerator of the IF equation.

Journal items that were classified as non-original or non-substantive items by the Thompson scientific contained results of original research and received considerable citations, thus increasing the impact factor. The editors at the Thompson Scientific emphasize that errors may occur during bibliographical classification of items published in journal and that they "attempt to count only the truly scientific papers and review articles".[3,7] This is also the limitation of our study because the judgment on the originality of the work presented in the journal item was made by individuals who could have been biased and could have made errors. We addressed this limitation by strict criteria for the originality of the research described in a journal item: research data presented in numbers, either in the text or/and in a table or figure, and no citation to previous publication of these results.

The latter criterion was defined as the absence of citation to the original work in the journal item; we did not verify this by full literature search so it is possible that some authors deliberately did not refer to the original publication. The assessment of journal items was performed by experienced medical doctors (MR and RG), who received formal and mandatory education in the types structure of the scientific article and bibliographical and citation databases.[10] In cases where the two investigators could not agree, they consulted the senior author (AM), and reached consensus on the item classification. Another limitation of the study is that it was restricted to only 4 journals. Because it would be very difficult to use a random sample of published items as the analysis of IF equation requires the number of published items in two full years, we chose to analyze the typical journals from representative JCR categories: most prestigious journals with high impact factor and "average" journals from the middle of the JCR IF ranking list of the category. Thus we analyzed 9249 published items in journals of different size, influence and prestige, and from different scientific fields and JCR categories. Similarity of findings for both prestigious journals and the small medical journals that published items other than articles and reviews indicates that our findings are generalizable.

There were few random errors detected in the *WoS* database, such as the absence of a single *NEJM* item from the citation database. We obtained differences in the number of citable items and total citations between the output generated by searching the WoS database for individual articles and the numbers in the official JCR output. The number of items deemed citable ("Articles" and "Reviews") was lower in JCR than in WoS for *Nature*, greater for *NEJM* and identical for *CMJ* and *AABC*. The total number of citations was greater in JCR than in WoS for all journals except for *CMJ*. These differences were probably random and did not greatly affect IF calculation. They may stem from the errors in reference lists in citing articles,[8] errors in entering data into the database, or the timing of the citation entry into the database. It is also possible that the sources for the citations quoted in the JCR are not restricted to the WoS database.

The letters and editorial items published in *NEJM* were categorized as such and received a substantial number of citations that went into the IF equation In *Nature*, Brief Communications were, although being original research items, mostly classified as editorial material by the Thomson Scientific. Thomson Scientific, in admitting the possibility of errors, welcomes advice from journals,[3] and some journals claim that they negotiate IF elements with Thomson Scientific.[3,6,7]. This is probably the reason for systematic error in the IF denominator, such as was the case for *Nature's* Brief Communications. The outcome of such error is that journal items with obviously original work are classified as non-original by the journals. An illustrative example for misclassification of journal items is the study by Martison et al[11] on misbehavior among researchers. Their study, funded by the Office of Research Integrity and National Institutes of Health in the USA was published as a Commentary in *Nature* in 2005. The article does not have a typical structure of the research article but has all relevant elements, including detailed methodology and a table with the results of the study survey. According to the reference list, this was an original publication, as there were no citations to the authors' work on this topic. The article is classified as "Editorial Material" in *WoS*, and has received 62 citations as of October 2007.

Many large journals have adapted their content and classification to the "requirements" of the IF equation. For example, the last Brief Communication was published in *Nature* in December 2006. *The Lancet*, which started its Research Letters in 1997 and experienced a fall in the IF,[3,4] published fewer and fewer of these items, and finally discontinued them in December 2005. *BMJ* discontinued publishing its short research papers without an abstract, which were grouped with full articles under the section "Papers", in December 2005. This section now carries the title "Research" and contains the same number of full research articles as before.

What is the solution to the problematic IF equation? Many researchers and journals would say that IF should be abandoned,[8,9,12] but this is easier said then done, because many academic and research communities have incorporated IF firmly into the criteria for career advancement or research funding.[5,7] Changing these criteria would need a consensus of many stakeholders and their active

involvement in the change, which may not be realistic at the moment, when journals publish editorials and other items about the misuse of IF but still proudly market their IF and carefully supervise its calculation. Even the proposals for novel indicators, such as Y-factor or Eigenfactor (www.eigenfactor.org), which use an algorithm similar to the Google's PageRank, incorporate impact factor as an important element in calculation.[13]

The solution may come from the IF producers themselves – Thomson Scientific is now offering a new database, Journal Performance Indicators, JPI.[1,14] This database links each source item to its citations, something that was not possible in the JCR, and includes only citations to the items used in the IF denominator. This is a better equation than the current IF in the JCR,[1] and journals may start using it as a more adequate representation of their value. Two problems remain. The first is that a new system, with a price tag attached to it, should be accepted by the research and academic communities – without it there is no way out of the IF vicious circle for authors and journals. The second and more important one is that it still is not clear which items are or should be in the denominator, which criteria will be used for their selection, and who will make a final decision.

Contributions

AM, MM, and NK conceived and designed the study; MR and RG collected all data, and analyzed them with AM. AM wrote the manuscript and MR, RG, NK and MM revised it for important intellectual content. All authors approved the final version of the manuscript for submission.

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Competing interests

AM and MM are Coeditors in Chief of the *Croatian Medical Journal*. NK is Book Review Editor fro the *Croatian Medical Journal*. None of them receives any pay for their work in the journal.

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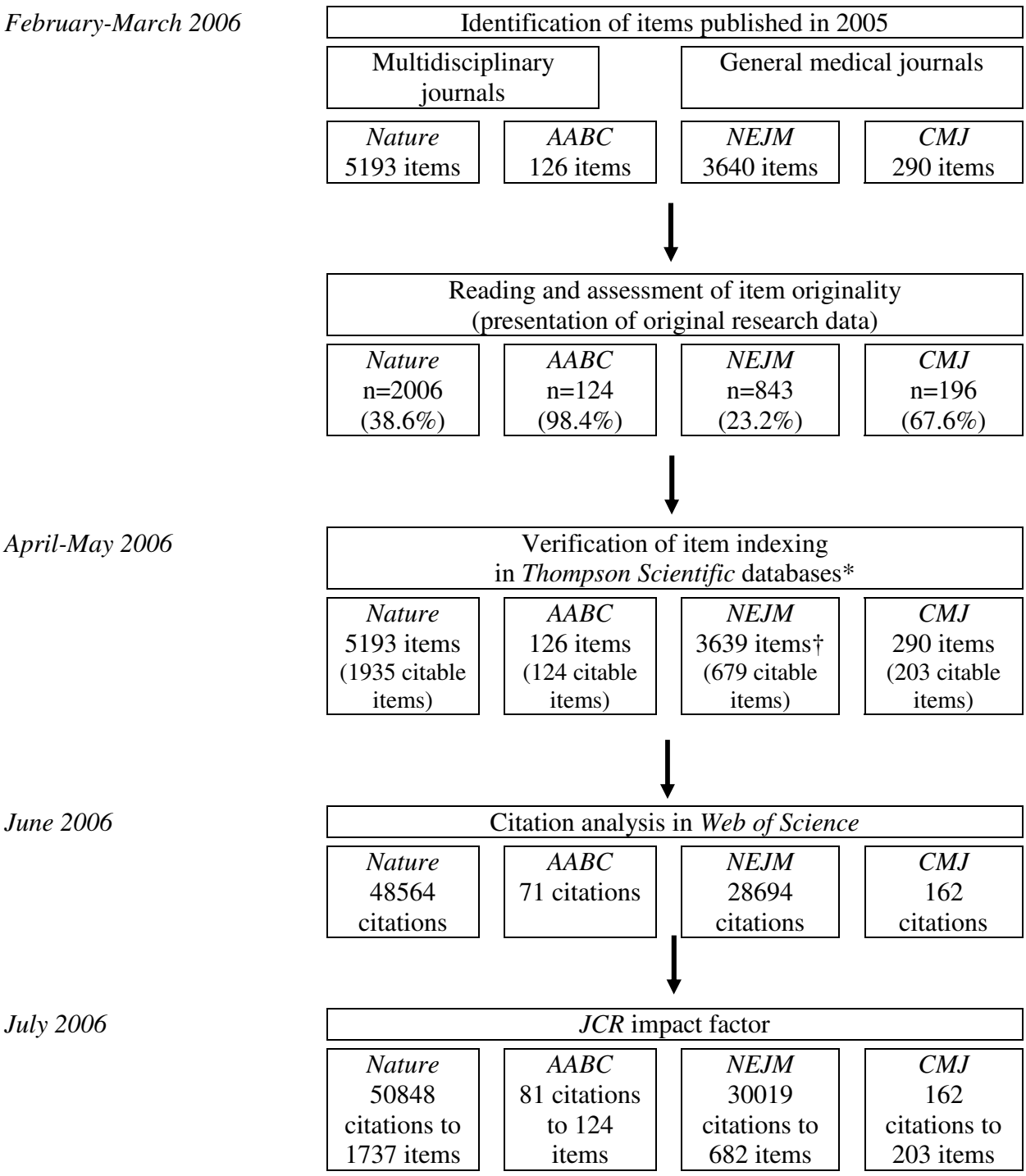

Figure 1. Study protocol and data collection.

* Indexing classification of all published items identified by hand search of printed journal issues were verified by a search in the *Current Contents* database via Gateway Ovid and by General Search of the *Web of Science* database. Citable items are those used in IF calculation and include "articles" and "reviews".

†One article could not be found in either database (Nankivell BJ et al; N Engl J Med. 2003;349(24):2326-33).

Table 1. Originality of published items in 2003 and 2004 and citations to these items in 2005 in 4 scientific journals

Journal and type* of published item	No. (%) of items in *WoS*	No. of items with original research data‡	Citations to items in *WoS* with original data	Citations to items in *WoS* without original data
Nature:				
Articles	1869 (36.0)	1770 (94.7)	41057	153
Reviews	66 (1.3)	66 (100.0)	3977	-
Editorial material	1270 (24.4)	166 (13.1)	1184	1547
Letters	351 (6.7)	4 (1.1)	5	86
Other†	1637 (31.5)	0	0	555
Total	5193 (100.0)	2006	46223	2341
AABC:				
Articles	121 (96.0)	121 (100.0)	63	0
Reviews	3 (2.4)	3 (100.0)	8	0
Editorial material	1 (0.8)	0	0	0
Letters	0 (0.0)	-	-	-
Other	1 (0.8)	0	0	0
Total	126 (100.0)	124	71	0
N Eng J Med:				
Articles	563 (15.5)	519 (92.2)	21046	33
Reviews	116 (3.2)	116 (100.0)	3401	0
Editorial material	860 (23.6)	88 (10.2)	97	3172
Letters	2043 (56.1)	120 (5.9)	601	325
Other	58 (1.6)	0	0	19
Total	3540 100.0	843	25145	3549
Croat Med J:				
Articles	202 (71.4)	184 (91.2)	126	5
Reviews	1 (0.3)	1 (100.0)	1	0
Editorial material	80 (28.3)	11 (13.7)	5	24
Letters	-	-	-	-
Other	7 (2.5)	0	0	1
Total	283 (100.0)	196	132	30

* Bibliographical classification of the item according to WoS database.

† "Other" items included news items, bibliographical items, book reviews and corrections in *Nature*; bibliographical items and corrections in *NEJM*; and news items and bibliographical items in *Croat Med J*; *AABC* published a single correction.

‡ Percentage of all items in the category (in the column to the left).

Table 2. Corrected impact factors for four scientific journals

Impact factor calculation*	Impact factor			
	Nature	*AABC*	*NEJM*	*Croat Med J*
Total JCR citations / JCR citable items (impact factor declared in JCR)	29.273	0.653	44.014	0.798
Citations to original items in *WoS* / items with original data	23.042	0.573	29.828	0.673

* Abbreviations: JCR – Journal Citation Reports and WoS – Web of Science, databses of the Thomson Scientific.