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Review Article

Citation analysis and journal impact factors in ophthalmology and vision science journals

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ABSTRACT

Citation analysis has evolved over the last 50 years as one parameter for assessing the quality of research published in scientific, technology and social science journals. This is based on the assumption that influential research is widely cited by other scientists and clinicians. With the advent of the Internet, Journal Citation Reports from the Institute for Scientific Information (ISI-JCR) have become widely available to individuals and institutions. In an increasingly competitive research environment, aspects of citation analysis have been suggested as simple proxy, objective measures to evaluate the research quality of a journal, published articles, research institutions and even individual researchers. This review article provides an overview of citation analysis, including definitions, uses of these reports, and related controversies and potential abuses. As it has become the most commonly used indicator, there is a particular focus on the use of the Journal Impact Factor (JIF). This is a widely quoted measure indicating the frequency with which the average article published in a journal of interest will be quoted within a specified time frame that therefore allows approximate comparisons of journals within a particular field of interest. Given the relative paucity of information in this area, emphasis is placed on citation analysis within ophthalmology, in particular in regard to the 43 ophthalmology, vision science and optometry journals that are listed in the ISI-JCR 2001 reports.

Key words: citation analysis, journal impact factors, journal citation reports, ophthalmology, optometry, vision science.

INTRODUCTION

In an increasingly performance driven and fiscally conscious academic work environment there is a growing trend toward monitoring the performance of individuals, and academic departments, through assessment of the quality of their research. However, such an approach raises several difficult questions: how can the true impact, or utility, of an article or the standard of publications in a journal be evaluated, how do researchers choose which journal is the most appropriate to submit scientific papers, and finally, will the choice of a particular journal make any difference to the exposure an article receives, or the ultimate impact it will have on its target audience? Citation analysis and Journal Impact Factors (JIF) have been proposed as one method of achieving some measure of performance. A detailed examination of these issues may help answer some of these questions.

Intuitively we might believe that 'quality' articles are those that are innovative, use appropriate methods and analysis, contain a considered discussion and are a useful resource for other clinicians and scientists. Citation analysis has evolved as one parameter that, theoretically, might be used as a benchmark for quality assessments. It is based on the assumption that frequently cited journals or articles have most impact, or influence, on the scientific community.[1–3] Citation analysis is a general term encompassing measurement variables such as JIF, the immediacy index and cited and citing half-lives.

This review article provides an overview of citation analysis, definitions, uses, related controversies and potential abuses. There is a particular focus on the use of the JIF as this has become the most commonly used indicator. Emphasis is placed on citation analysis within ophthalmology and vision science given the relative paucity of information in this arena.

Historical background

Analysis of the citation characteristics of individual articles and scientific journals as a measure of 'impact' was first proposed in 1955 by Eugene Garfield.[1,4,5] In 1963, the first Science Citation Index was published by the Institute for Scientific Information and this provided citation analysis on

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Table 1. Ophthalmology, including vision science and optometry, journals ranked by citation count; that is, the total number of times that each journal has been cited by all journals included in the Institute for Scientific information database within the current year. Only the top 20 ranked journals, of 43 in this field, are listed. This ranking should be compared with Table 2, where ranking is based on Journal Impact Factor. (As listed in the Institute for Scientific Information: Journal Citation Reports 2001 (ISI-JCR 2001))

Rank	Journals in the ISI-JCR 2001 'Ophthalmology' field	2001 total cites	2001 articles
1	*Investigative Ophthalmology and Visual Science*	17330	470
2	*Archives of Ophthalmology*	13904	258
3	*Ophthalmology*	13623	323
4	*American Journal of Ophthalmology*	11823	375
5	*Vision Research*	10997	302
6	*British Journal of Ophthalmology*	6548	268
7	*Experimental Eye Research*	4901	151
8	*Journal of Cataract and Refractive Surgery*	4309	307
9	*Acta Ophthalmologica Scandinavica*	2864	132
10	*Current Eye Research*	2794	92
11	*Visual Neuroscience*	2408	61
12	*Graefe's Archive for Clinical and Experimental Ophthalmology*	2337	146
13	*Survey of Ophthalmology*	2298	58
14	*Eye*	2195	111
15	*Cornea*	1884	188
16	*Ophthalmic Surgery and Lasers*	1869	96
17	*Retina*	1644	149
18	*Klinische Monatsblatter fur Augenheilkunde*	1312	144
19	*Optometry and Vision Science*	1172	101
20	*Journal of Refractive Surgery*	1069	92

most of the major scientific journals covering the year 1961.[6] The JIF was developed as a tool to allow comparison between journals.[1,6]

Since 1975, the Institute for Scientific Information have published Journal Citation Reports (ISI-JCR) as an annual supplement to the Science Citation Index.[2,4] These provide a summary of the information contained in the index to help readers 'evaluate and compare scholarly journals'.[6] It is important to note that the Institute for Scientific Information highlight that the information contained in these reports is intended as a supplement, and not a replacement, to traditional measures of quality such as peer-review.[6]

Approximately 5000 science and technology journals are evaluated in the Science edition of the Science Citation Index each year and 1500 journals are covered in the Social Sciences edition.[6] This information is now widely available through an Institute for Scientific Information website (http://isiknowledge.com).

Information Available Through Citation Analysis

Parameters evaluating journal and article citation characteristics available through the Science Citation Index include:

1. Citation counts for journals and individual articles
2. Journal Impact Factors
3. Immediacy index
4. Cited half-life
5. Citing half-life

Citation counts for journals and individual articles

The fundamental measure in citation analysis is the citation count. This is the frequency with which articles published in a journal are cited in other articles. The total citation count is listed in the annual journal citation report and this shows the total number of times that a particular journal has been cited by all journals listed in the database.[6] The total citation count includes self-citations; that is, citations to articles previously published by the same journal.[6] Citation counts for individual articles can also be calculated.

In the ISI-JCR 2001 (Science edition), in regard to journals listed under 'Ophthalmology' (includes ophthalmology, vision science and optometry journals), the total citation count ranged from 40 to 17 330, for the least (the newly established *Clinical and Experimental Ophthalmology*) and most (*Investigative Ophthalmology and Visual Science*) cited journal, respectively (Table 1).

Practical application

The implicit, though potentially erroneous, assumption in regard to using citation counts to evaluate journals or individual papers is that 'high quality' research will have high impact on its target audience and will therefore become an important source of reference for other researchers. Theoretically, such articles will subsequently be cited more frequently than 'poorer quality' papers.[7] Citation counts may also provide an indication of the frequency with which

researchers use particular journals.[6] Although citation counts may provide valuable information about individual articles, it is difficult to extrapolate this data to estimate the quality *per se* of the journal publishing the article. Indeed, if citation counts are compared between journals the results will be biased against small journals, given the smaller number of articles that can be cited. Absolute citation counts may also give higher rank to older journals with established reputations.[4]

Journal impact factors

The JIF was developed to provide a more complete evaluation of journals than is possible through absolute citation counts alone.[4] It indicates how frequently an average article published in a given journal will be cited within a specified time-frame. Specifically, the JIF is calculated by dividing the number of citations in a given year (e.g. 2001) to any items published in the journal in the previous 2 years (i.e. 1999 and 2000) by the number of 'substantive articles' published in the same 2 years.[4–6] It is important to note that the 'substantive articles' considered in the Journal Citation Report calculations include: review articles, original research and clinical case reports, but letters or abstracts are excluded.[4] In contrast, the journal citations can come from any item published in a journal, including letters and editorials. The calculation of the JIF for 2001 for the *British Journal of Ophthalmology* (1.942) is highlighted below:

Cites to articles published
2000 = 363
1999 = 567
2000 + 1999 = 930
No. of articles published
2000 = 257
1999 = 222
2000 + 1999 = 479
JIF calculation: Cites to recent articles/No. of recent articles
930/479 = 1.942

The 2001 Journal Citation Reports highlights *Progress in Retinal and Eye Research* as the ophthalmology journal with the highest JIF (5.333). This suggests that articles published in this journal within the specified preceding 2-year time period (1999–2000) were cited, on average, 5.3 times in a particular year. In contrast, the *Australian and New Zealand Journal of Ophthalmology*, which was ranked 30th overall in the field of ophthalmology, had an impact factor of 0.659, suggesting that an 'average article' would have had only a two-thirds possibility of being cited once in a particular year.

Interestingly, relative ranking of ophthalmology and vision science journals on the basis of total citations (Table 1) and JIF, highlights a number of important similarities and dissimilarities. Interestingly, of the 10 top-ranked journals on the basis of JIF (Table 2), six also appear in the 10 top-ranked journals based on total citations: *Investigative Ophthalmology and Visual Science*, *Ophthalmology*, *Archives of Ophthalmology*, *Experimental Eye Research*, *Vision Research*, and the *Journal of Cataract and Refractive Surgery*. In contrast, the top-ranked journal on the basis of JIF, *Progress in Retina and Eye Research* (JIF 5.333), is ranked 23rd on the basis of a total 2001 citation of 890, whereas *Molecular Vision*, ranked 5th on the basis of JIF (2.779), falls to 36th of 43 journals on total citation-ranking with 2001 total cites of only 361 (one below the *Australian and New Zealand Journal of Ophthalmology* with 496 total cites). Although there is obviously a great deal of correlation between the top 10 and top 20 ranked journals based on JIF or total citation, it is worth considering the apparent paradox that *Molecular Vision*, with a total citation of only 361 cites in 2001, is ranked immediately above a much more widely cited journal, *Archives of Ophthalmology* (2001 total cites of 13 904), when only the JIF-ranking is applied.

Practical application

The major advantage of the JIF is that it enables comparison between journals within a given scientific field regardless of their size or reputation.[4,5] In respect to such comparisons, it is absolutely critical to remember that the Journal Citation Reports highlight that the JIF helps establish the relative importance of a particular journal compared to other journals in the same discipline; that is, not across disciplines. Unfortunately, inappropriate comparisons across disciplines by research institutions may erroneously suggest poorer performance, in terms of scientific publication, by those researchers in smaller disciplines. In recent years the impact factor has evolved to be a widely used and quoted measure in citation analysis.[6]

Immediacy index

The immediacy index indicates how quickly the average article in a journal is cited.[6] It is calculated by dividing the number of citations to articles published in a year by the number of articles published by the journal in that same year.[6]

Practical application

The immediacy index gives useful additional information when evaluated along with other citation statistics such as the impact factor of a journal. Slowly changing fields often have lower impact factors but accumulate increasing citations with time and this will be reflected in the immediacy index.[6] In the ISI-JCR 2001, *Progress in Retinal and Eye Research* exhibited a high immediacy index of 1.407, meaning that a large number of citations are made within 12 months. (It is not accurate to say that all of the articles are cited at least once within one year given that it is possible for a small number of articles to attract a disproportionate number of

Table 2. Ophthalmology, including vision science and optometry, journals ranked by journal impact factor as listed in the Institute for Scientific Information: Journal Citation Reports 2001 (ISI-JCR 2001). The immediacy index is also listed for each journal for reference. Only the top ranked 40 journals, of 43 journals in the field, are included.

Rank	Journals in the ISI-JCR 2001 'Ophthalmology' field	Journal impact factor	Immediacy index
1	*Progress in Retinal and Eye Research*	5.33	1.407
2	*Investigative Ophthalmology and Visual Science*	4.172	0.781
3	*Ophthalmology*	3.066	0.396
4	*Survey of Ophthalmology*	2.807	0.431
5	*Molecular Vision*	2.779	0.349
6	*Archives of Ophthalmology*	2.424	0.508
7	*Visual Neuroscience*	2.351	0.197
8	*Experimental Eye Research*	2.18	0.424
9	*Journal of Cataract and Refractive Surgery*	2.13	0.274
10	*Vision Research*	2.013	0.351
11	*Journal of Refractive Surgery*	1.995	0.196
12	*British Journal of Ophthalmology*	1.942	0.284
13	*American Journal of Ophthalmology*	1.828	0.229
14	*Journal of Glaucoma*	1.371	0.127
15	*Eye*	1.364	0.243
16	*Current Eye Research*	1.3	0.087
17	*Cornea*	1.255	0.133
18	*Graefes Archive for Clinical & Experimental Ophthalmology*	1.192	0.082
19	*Optometry and Vision Science*	1.151	0.267
20	*Journal of Ocular Pharmacology and Therapeutics*	1.085	0.102
21	*Ophthalmic Research*	0.934	0.175
22	*Retina—The Journal of Retinal and Vitreous Disorders*	0.909	0.148
23	*Ophthalmologica*	0.843	0.105
24	*Ophthalmic and Physical Optics*	0.795	0.25
25	*Journal of AAPOS*	0.793	0.024
26	*Ophthalmic Plastic and Reconstructive Surgery*	0.792	0.038
27	*Ocular Immunology and Inflammation*	0.785	0.182
28	*Journal of Neuro-ophthalmology*	0.778	0.068
29	*Ophthalmic Surgery and Lasers*	0.745	0.031
30	*Australian and New Zealand Journal of Ophthalmology*	0.659	0
31	*European Journal of Ophthalmology*	0.633	0.068
32	*Japanese Journal of Ophthalmology*	0.602	0.036
33	*Acta Ophthalmologica Scandinavica*	0.561	0.076
34	*Ophthalmologie*	0.552	0.097
35	*Journal of Toxicology— cutaneous and ocular toxicology*	0.55	0.167
36	*Canadian Journal of Ophthalmology*	0.534	0.111
37	*Klinische Monatsblatter fur Augenheilkunde*	0.521	0.076
38	*Journal of Pediatric Ophthalmology and Strabismus*	0.47	0.032
39	*International Ophthalmology Clinics*	0.469	0.105
40	*Clinical and Experimental Ophthalmology*	0.358	0.062

Note that due to a title change in 2000 the journal of the Royal Australian and New Zealand College of Ophthalmologists appears as two titles: 30, *Australian and New Zealand Journal of Ophthalmology*; and 40, *Clinical and Experimental Ophthalmology*, each having an impact factor based on 1 rather than 2 years. The unified journal impact factor for the combined titles over the 2 year period would be 0.503

citations.) In contrast *Ophthalmology*, ranked 3rd by JIF, has a much lower immediacy index of 0.396.

The different citation characteristics of rapidly changing clinical and scientific areas, compared to more stable fields, will be expanded upon later. Interestingly, the ISI-JCR 2001 website notes that comparison of the immediacy index also helps adjust for larger compared to smaller journals as it produces a 'per article average'; however, journals that have frequent issues during a year may have an advantage, as regards the immediacy index, as an article published early in the year is more likely to be cited within the same year.[6]

Citing $T^1/_2$ and cited $T^1/_2$ indices

The citing half-life (citing $T^1/_2$) in essence indicates the number of publication years that account for 50% of the citations published by a journal in the reference section of articles; that is, citations *from* the journal. It therefore evaluates the age of the majority of articles cited by a journal.[6] The ISI-JCR 2001 notes that *Survey of Ophthalmology* had a citing $T^1/_2$ of 9.1 years, indicating 50% of articles cited by contributing authors were published before 1992. In contrast, the

journal *Molecular Vision* has a citing $T^1/_2$ of approximately 5 years, which may, in part, reflect a rapidly changing area of research, whereas, as *Survey of Ophthalmology* primarily publishes review articles these will, by their nature, acknowledge intellectual debt to earlier articles by forerunners in the field.

The cited half-life (cited $T^1/_2$) indicates the number of years accounting for 50% of current citations that a journal receives; that is, citations *to* the journal.[6] It therefore helps a reader evaluate the age of the majority of articles published in the journal that are subsequently cited.[6] Thus, *Survey of Ophthalmology*, with its emphasis on publishing review articles, had a cited $T^1/_2$ of 8.0 years in 2001. This indicates that articles published by the journal between 1993 and 2001 attracted 50% of citations in the year 2001, and 50% of cited articles cited are older than 1993.

Factors Influencing the Interpretation of Citation Analysis

Although citation analysis provides useful and expedient information, it is far from being a perfect analytical tool and many factors can influence the results. It is important to understand these factors in order to interpret any citation reports sensibly and apply the observations appropriately. The JIF has undoubtedly become the most controversial of the citation analysis tools and this often relates to use without appropriate regard to its limitations.[1,5,7,8] The JIF will therefore be the main focus for further discussion in regard to:

1. Field effect
2. Inconsistencies in calculation
3. Inaccuracies in database processing
4. Bias against non-English language journals
5. Self-citation
6. Time taken to review manuscripts

Field effect

The ISI-JCR 2001 website emphasizes that the JIF enables comparison of journal performance within a scientific field.[6] However, problems occur if one attempts to extrapolate this to compare impact factors between different clinical or scientific fields.[4,6,9,10]

Comparison between medical fields

Medical fields that are rapidly expanding and changing tend to have very high impact factors compared to other disciplines.[4,7] This variation between disciplines is a reflection of how rapidly research within various medical disciplines changes and the size of the field, rather than being a direct reflection of the quality of research in each discipline. For example, it has been noted that impact factors of the top-ranked molecular biology and biochemistry journals are over twofold higher that those of top-ranked mathematics journals.[10]

In the 2001 Journal Citation Reports, the journal *Cell* had a JIF of 29.219 and the *New England Journal of Medicine* had a JIF of 29.065; however, in comparison, the ophthalmology journal ranked highest on the basis of JIF, *Progress in Retinal and Eye Research*, had approximately a six-fold lower JIF of only 5.333.

Comparisons within a medical field

It has been observed that each individual research area also functions as a 'unique microfield' with distinct citation characteristics and, as a consequence, even within a single discipline area such as ophthalmology, care should be exercised when comparing impact factors.[10] In ophthalmology and vision science, for example, one might conjecture that clinical oculoplastic research is perhaps a less rapidly changing field than molecular retinal research. All citation studies should therefore be interpreted with caution in order to take into account the characteristics of field and citation practices, such that inappropriate comparisons are avoided.[5]

Field effect and other citation parameters

In certain research fields a cumulative impact factor is more relevant because of the time required before a clinical or experimental result is seen.[1,4] The immediacy index will also indicate how quickly the average article in a journal is cited and hence provide information regarding the rapidity of change within a given field.

Inconsistencies in calculation

Although now well-established, ongoing controversy and criticism continues in regard to the way the JIF is calculated.[1,9] The denominator uses only normal articles and reviews as citable articles but in the numerator (citations) all types of articles such as letters, editorials and abstracts are applicable.[1,2,6,9] The ISI-JCR website, under 'using the JCR wisely' notes that these latter items are not included in the numerator because they are not generally cited, although they may influence the JIF.[6] In calculating citation data, the Institute for Scientific Information manually codes each published article in the stipulated categories but the many citations to other communications cannot practically be manually coded. This results in the lack of article differentiation in the denominator.[6]

This practice may have some bearing on the JIF. Indeed, the nature of this calculation means that journals that include a large number of editorials, abstracts and letters can artificially inflate their impact factor even though the inclusion of more of these items arguably has little or no impact on the actual quality of the journal.[1,9]

Inaccuracies in database processing

When processing more than 10 million citations a year, database processing can inevitably lead to inaccuracies in the results of citation analysis.[8] Problems with database processing and misprinting were estimated by one author to reduce the recovery of citations by up to 50%.[10] In 1996, the *European Journal of Cancer* reported that its true JIF of 2.141 had wrongly been calculated and published by the ISI-JCR as 0.789, causing it to be ranked 59th instead of 24th in its field.[11]

Bias against non-English language journals

The Institute for Scientific Information notes a bias towards English language journals given that these tend to be the most widely used worldwide.[2] This can lead to a lower JIF for non-English language or non-roman alphabet journals that are included in the database. These journals often cite, and are cited by, papers published in the same language; however, only journals listed in the science citation index will count when calculating the impact factor.[2,9] Interestingly, for the ISI-JCR 2001, there is only one non-English language journal in the top 20 JIF-ranked journals listed in the ophthalmology field.

There are also reports of distinct national bias in citations.[12] *Acta Paediatrica* identified that North American journals tend to preferentially cite articles published in North American journals, whereas the prominence of American journals, in terms of citations, is less obvious when authors are from countries outside the USA.[7,12] A similar trend has been observed by other authors and theoretically this may raise the mean citation rate and JIF for North American journals by as much as 30% above the world average.[9]

Self-citation

Self-citation occurs when authors cite their own work or when an article published in a journal cites other articles published in the same journal. These citations are included in the numerator when calculating the JIF and hence journals with a high self-citation rate will increase their JIF. Estimated self-citation rates range between 10 and 25%.[13] Although self-citation by authors to their own work is a legitimate process, which frequently reflects continuing work in a specific area of interest or a narrow area of expertise, there is potential to misuse self-citations in order to increase the JIF.[9,14] In recent years one journal was alleged to have made a deliberate attempt to manipulate the JIF, in order to increase its relative journal ranking, by asking all contributing authors to add references in the bibliography to articles published in the same journal to which they were submitting the article.[15]

Time taken to review manuscripts

Journals with a short publication lag from submission of an article to publication will contain more current citations and therefore contribute to the impact factor of all the journals cited in its references.[5] If the journal self-cites, for example through discussion in an editorial, this will also increase the journals own JIF.[9] Conversely, delayed review and publication times will result in more of the references being older and hence they may no longer be eligible for inclusion in the JIF calculation.[2,5,9]

Validity of Citation Analysis as a Research Tool

Increasingly, citation analysis is being used in making assessments not only of journals but also, in some circumstances, of the performance evaluations of academic institutions and even individual clinicians and academics. In many institutes researchers are being reviewed on an annual basis on the number and quality of their publications.[9,12] The 'quality' assessment is not infrequently addressed by examining the JIF of the journal in which the investigators publish. The increasing utilization of citation analysis suggests that we should carefully consider its validity as an assessment tool and how accurately it informs us about the quality of the journals it surveys and the quality of individual articles.

How does citation analysis compare to peer evaluation of research quality?

If citation analysis were a good measure of journal quality we would expect it to conform to more traditional methods of evaluation such as peer review, although only a small number of authors have examined the validity of this assumption. In 1989, Cole published results of a survey of 300 full professors employed in five different scientific disciplines who were asked to indicate the relative importance of the work of selected scientists.[16] This peer-based measurement of research quality was compared to individual citation analysis characteristics for each selected scientist. Correlation coefficients within the five disciplines ranged from 0.59 to 0.70 and these results were interpreted by the author as evidence that citation analysis is 'a good rough indicator of the quality of work as it is perceived by other scientists'.[16]

Is there concordance between JIF and individual article citations?

Increasing ease of access to the Journal Citation Reports makes it tempting to use JIF as a surrogate measurement of article impact. Interestingly, some academic institutions have suggested multiplying their publications by the JIF of the journals in which they are published and then summing up 'impact points' to indicate the quality of publications from their institution.[7] For this to be an accurate practice then most articles published in a journal should have an actual article citation rate that closely corresponds to the overall impact factor.

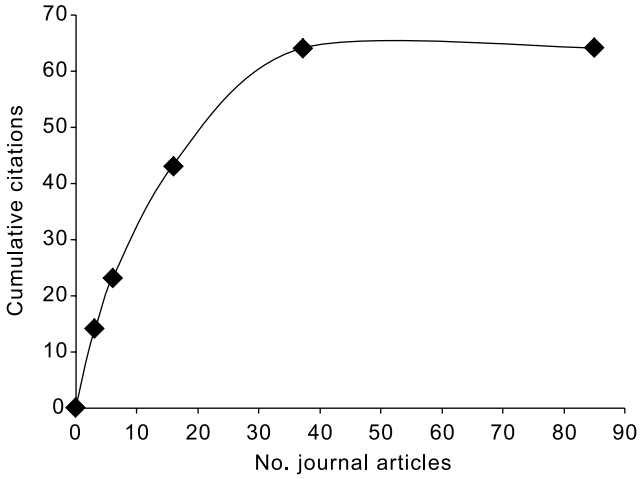

Figure 1. Cumulative contribution of articles with different citation rates to overall citations attracted by *Australian and New Zealand Journal of Ophthalmology* in 1991. Note that 13% of published articles account for 50% of citations and that, theoretically, the cumulative citations could have been reached by a little over one-third of the published articles.

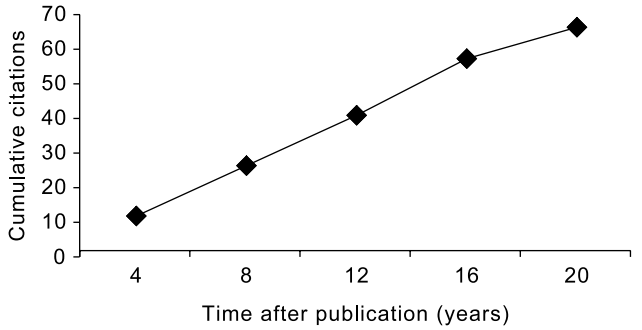

Figure 2. Accumulation of citations (n = 66) with time after publication illustrating that influential papers may continue to be cited many years after publication. Cited article: Molteno ACB, Ancker E, Van biljon G. Surgical technique for advanced juvenile glaucoma. *Arch Ophthalmol* 1984; **102**: 51–7.

Several authors have examined the relationship between individual article citation and the JIF; unfortunately, it appears that that most articles in a journal have vastly differing citation rates rather than being normally distributed around a mean. In practice, in most journals a relatively small percentage of articles tend to be responsible for the majority of citations. Indeed, Chew and Reylea-Chew found that 10% of papers in a group of radiological journals accounted for 50% of the citations.[14] Similarly, Seglan, in an assessment of three biochemical journals, demonstrated a skewed distribution of article citation rates with only a small number falling close to the calculated JIF. In this study 15% of the articles accounted for 50% of the citations, 50% for 90% of citations, and the remaining articles were cited either infrequently or never.[9]

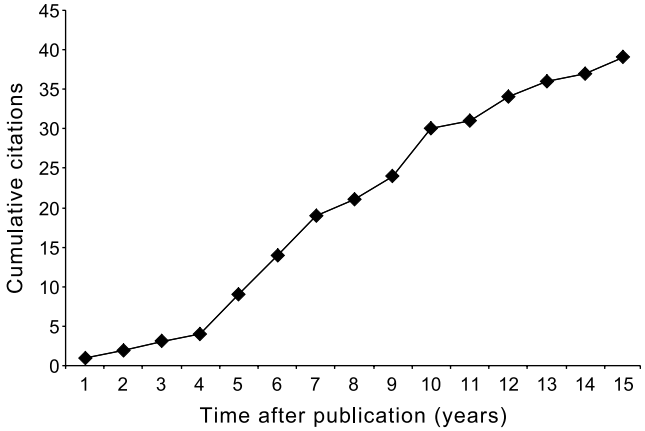

Figure 3. Accumulation of citations (n = 39) with time after publication in a journal with a relatively low journal impact factor at the time of publication. Cited article: Ancker E, Molteno ACB. Molteno drainage implant for neovascular glaucoma. *Trans Ophthalmol Soc UK* 1982; **102**: 122–4.

We reviewed articles published in the *Australian New Zealand Journal of Ophthalmology* in 1999 and found that 13% of published articles accounted for 50% of the citations, whereas 56% of articles were not cited at all in the first 2 years following publication (Fig. 1).

Does citation analysis reflect lasting impact?

Citation analysis, and in particular the JIF, does not provide a complete picture of slowly changing research fields given that it assesses only citations accumulated over a 2-year period.[5,10] It has been noted that, although the JIF identifies papers of current interest, these will not necessarily have lasting influence on the scientific community.[10] Furthermore, seminal papers of gradually increasing importance may be underestimated if assessed primarily in respect to the JIF.

As an illustration, in regard to the accumulation of citations following scientific publication, we have used citation analysis of several papers published by a New Zealand based, international authority on glaucoma, Professor Tony Molteno. Analysis of these demonstrated that, in selected cases, citations are still continuing to accrue, sometimes up to 20 years after initial publication (Figs 2,3). Obviously, this provides some indication of lasting impact on the target audience. If we were only to look at the citations accumulated within 2 years of publication (deliberately choosing a short-term measure given that the JIF is a similarly short-term index), the number of citations is remarkably lower. In other words, JIF-based citation analysis can underestimate the long-term contribution of certain works.

Can citation analysis identify outstanding researchers?

One of the more controversial aspects of citation analysis has been the use of statistics such as the JIF as a proxy measurement of individual performance.[9,12] The main impetus for this practice seems to be the relative ease with which one can check the JIF for a journal compared to checking individual article citations. In contrast, it is a relatively tedious and time-consuming job to evaluate individual authors and the ISI-JCR website is less user friendly for this task.

Several authors have looked at Nobel Prize laureates in science, in order to determine whether citation analysis does indicate outstanding researchers. It has been demonstrated that the Nobel laureates have high citation rates even before they receive a Nobel Prize.[3] The average article citation rate for Nobel Prize winners in physics, who were awarded the prize between 1962 and 1965, was 62 citations in 1961 (before they had received their awards) compared to 5.5 for cited authors overall.[3] This suggests that, despite its complexities, citation analysis has some merit in recognizing high quality articles and in reflecting research that has high impact on its audience. Interestingly, in 1970, *Nature* reported that of the 50 most cited scientists in the 1967 Science Citation Index, two had been awarded Nobel prizes.[17]

Conversely other authors have reported a poor correlation between citation analysis and expert evaluations of performance.[3,10] One author examined the actual citation rate of papers he had published compared to the impact of the journals in which they were published and found that there was no correlation between the two parameters, with the average JIF of the journals being 3.1 while the average article citation was 7.0.[3] Similarly, another author found that ranking of research groups on the basis of JIF showed little correlation to a ranking of the same groups on the basis of citation frequency.[10] Lack of correspondence between the JIF and effective article citation of articles could certainly bias institutional Journal Citation Report-based assessment of an author who is frequently cited, but who chooses to publish in an appropriate but lower JIF-ranked journal.[3]

Should citation analysis influence submission of articles?

Any answer to this question is likely to be contentious. One of the implicit assumptions made in submitting work is that publishing in a high-JIF journal may raise the awareness, and subsequent citation, of an individual article. There is some debate about whether this assumption is true and one author has concluded that ultimately the citation rates of the articles determine the JIF but not vice versa.[9,18] In a separate paper, the same author examined the citation frequencies of articles published by single research groups in different journals and found that there was no correlation between citation frequency and corresponding JIF.[10] Despite this evidence, it is arguable that publishing in a higher-JIF journal may increase an article's circulation and audience exposure to its contents, even if this does not translate into accumulation of citations.

Which articles attract the most citations?

Review articles contribute more to the impact factor of a journal as they usually contain a large number of citations.[4] Intuitively it would seem that these articles also form an important core resource for researcher and clinicians alike. Interestingly, *Progress in Retinal and Eye Research* and *Survey of Ophthalmology* almost exclusively publish review articles and are ranked first and fourth by JIF of 43 journals listed under Ophthalmology in the Institute for Scientific Information database for 2001. Laboratory science papers generally attract more citations and this may in part reflect the different citation dynamics of rapidly changing areas. Multi-author and multinational articles also tend to receive a larger number of citations than single author, single centre papers.[1]

In contrast, clinical case reports tend to be cited much less frequently, if at all, compared to other substantive articles and therefore may lower the JIF of journals that have a high emphasis on this type of article. Interestingly, in 1999, case reports accounted for 20% of the substantive articles published in the *Australian and New Zealand Journal of Ophthalmology* yet these only attracted 12.5% of total citations. However, from an educational perspective, it could reasonably be argued that good case reports remain an important educational aid for professional colleagues but such benefit is not yet subject to empirical measurement.

Conclusions

If the 'research world' is increasingly conscious of citation analysis in the evaluation of the quality of research then it is worth considering further the influences that modify citation statistics of ophthalmology and other journals. First, by assessing and addressing such influences this may provide information that can help increase the quality of a journal. Second, and more cynically, if journal and article evaluation are increasingly being performed using citation analysis then authors, researchers and editors need to become more attuned or else risk being relegated to 'low impact' status. If the JIF of a journal does not remain strong, theoretically, it will become increasingly difficult to attract high quality submissions and the JIF may slide. Unfortunately, as has been noted in *Acta Paediatrica*, some journals are in distinct danger of becoming 'obsolete' in this current climate.[12]

In considering how to improve the genuine impact of current research it is essential to consider what factors truly seem to raise the quality of a journal and which changes would merely represent a covert manipulation of the citation numbers. Factors such as an increased focus on review articles and laboratory science have already been discussed

as tending to improve article citation and improve the educational content of a journal. Several journals, such as the *British Journal of Ophthalmology*, have also moved towards publishing case reports as 'letters' rather than substantive articles. This retains the clinical niche and keeps the educational value of such reports intact, yet has the bonus of improved JIF characteristics and frees additional space for other articles.

Decreasing the submission to publication lag also improves the impact factor of all cited articles because the cited research is more likely to be current and valid for inclusion in the JIF calculation.[5] As a by-product, a reputation for prompt and efficient handling of submitted articles also increases the appeal of a journal to prospective authors.

One of the major advantages of citation analysis is the provision of an objective measurement of journal and article impact, although, as we have demonstrated, this does not equate to being an unbiased measure. A perfect analytic tool for research publications should be easy to use, reliable, free from bias, easily accessible, and be 100% in concordance with peer assessment of quality. Unfortunately citation analysis does not fulfil all of these criteria and this is perhaps unsurprising given the inherent difficulties in trying to quantify an essentially intangible concept – the relative quality and importance of research. Although this limits its application, to some extent, it nevertheless can provide an expedient and useful framework for journal and article evaluation if used in conjunction with more traditional means of evaluation. It is important to note that despite becoming popularized as a way of making quick assessments of research publications and their authors, the JIF is certainly not suitable as a means to circumvent or substitute peer review of research or individual clinicians/scientists. It is paramount that the Institute for Scientific Information's core advice – that users do not depend on citation analysis in isolation when making journal and article evaluations – is recalled when applying these data. As noted by Eugene Garfield, the pioneer of citation analysis, 'use of the impact factor to weight the influence of a paper amounts to a prediction, albeit coloured by probabilities'.[5]

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