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Journal weighted impact factor: A proposal

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ABSTRACT

The impact factor of a journal reflects the frequency with which the journal's articles are cited. It is the best available measure of journal quality. For calculation of impact factor, we just count the number of citations, no matter how prestigious the citing journal is. We think that impact factor as a measure of journal quality, may be improved if in its calculation, we not only take into account the number of citations, but also incorporate a factor reflecting the prestige of the citing journals relative to the cited journal. In calculation of this proposed "weighted impact factor," each citation has a coefficient (weight) the value of which is 1 if the citing journal is as prestigious as the cited journal; is >1 if the citing journal is more prestigious than the cited journal; and is <1 if the citing journal has a lower standing than the cited journal. In this way, journals receiving many citations from prestigious journals are considered prestigious themselves and those cited by low-status journals seek little credit. By considering both the number of citations and the prestige of the citing journals, we expect the weighted impact factor be a better scientometrics measure of journal quality.

1. Introduction

Everyday, hundreds of scientific journals are published. Such a large number of publications result in a rapidly growing body of knowledge. To manage the enormous scientific enterprise, one should assess the effectiveness and influence of this accumulating knowledge on different disciplines of science and measure the impact of each published piece of information on science. The use of citation analysis has been advocated to provide a quantitative means to measure the influence of each journal on science.

In 1927, the first article on the use of citations in determining the importance of scientific journals was published (Gross & Gross, 1927). Later on, in 1936, Cason and Lubotsky (1936) proposed journal to journal cross-citations as a measure of the influence of one journal on the other journals and one scientific discipline on another subfield. None of these proposals, however, gained the success of the "journal impact factor" (IF) created in 1955 by Garfield (1955).

IF is now one of the most frequently used scientometrics indices reported by Thomson Scientific (formerly, Thomson ISI). The IF of a journal reflects the frequency with which the journal's articles are cited in scientific literature. A journal's IF is a quotient the numerator of which is the number of citations in the current year to items published in the previous two years; the denominator is the number of substantive articles published within the same two years (Garfield, 2006). For example, if the number of substantive articles published in a journal in 2004–2005 is designated by *P*, the IF of that journal in year 2006

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is given as

$$\mathrm{IF} = \frac{C}{P} \tag{1}$$

where C designates the number of citations made in year 2006 to articles published in 2004–2005 in the same journal (Garfield, 2006).

Unlike some of the previous scientometrics indices proposed, IF is size-independent (Moed, 2005). Journals show substantial differences with respect to the number of documents they publish each year. IF is a ratio (Eq. (1)) and the number of citations to each journal is adjusted by the total number of published articles in that journal. Although, there are many critiques against the efficacy of IF, some authors believe that it is a valid measure of quality for general medical journals (Saha, Saint, & Christakis, 2003). As an indicator of journal quality, IF is usually employed by librarians in selecting appropriate journals for libraries. In some countries, the IF is even used to determine the value of individual researchers or research centers for purposes of academic career promotion or research grant allocation (Lowy, 1997; Seglen, 1997).

IF, however, has some limitations. One of the limitations, as mentioned by many authors, is that in calculation of IF, all citations are being counted with equal weight, regardless of the prestige of the citing journal. To develop a measure of quality/importance of journals, it seems more reasonable to give higher weight to citations coming from a prestigious journal than to citations made by a low-profile journal.

The idea of counting a reference from a more prestigious journal more heavily is, nonetheless, not new and has also been suggested by Kochen (1974), and Pinski and Narin (1976). Pinski and Narin suggested a normalization scheme and proposed the following quotient as the first approximation for the weight of a certain journal (or "unit," as mentioned in the original text) (Pinski & Narin, 1976).

$$W = \frac{\text{total number of citations to a certain journal from other journals}}{\text{total number of references from that journal to other journals}} \tag{2}$$

Based on these assumptions, they then formulated an eigenvalue problem and solved it for the weights through an iterative procedure (Pinski & Narin, 1976).

Another algorithm that does not give equal weights to citations is the PageRank algorithm which is currently used by Google™ robots to rank web pages (Rogers, 2006). In determining the PageRank of a web page, through an iterative algorithm, Google™ not only considers the number of links that page receives from other pages but also takes into account how important the citing page is.

Another weighting scheme which is indeed a combination of journal IF and PageRank algorithm, was proposed by Bollen, Rodriguez, and Van de Sompel (2006). They proposed an index, the so-called Y-factor the value of which for a certain journal is defined as:

$$Y = \mathrm{IF} \times \mathrm{PR} \tag{3}$$

where IF and PR represent the impact factor and PageRank value assigned to that journal, respectively (Bollen et al., 2006).

Incorporating the number of references from a certain journal to other journals, as was used by Pinski and Narin (1976) (Eq. (2)), PageRank algorithm (Rogers, 2006) and thus, in calculation of Y-factor (Eq. (3)), make all these ranking systems vulnerable to manipulation by journal owners.

Herein, we would like to present a weighting scheme in calculation of which we try to consider not only the number of citations a journal receives from other journals, but to take into account the prestige of the citing relative to the cited journal. But, the very first step would be to declare what we mean by saying "prestige."

The status of a scholarly publication is very similar to recognition of a scientist. Some scientists are popular and well known by people. Some are famous among their own peers. Prestige is the level of respect at which one is regarded by others. The status of a person can be defined in terms of two major components—popularity and being recognized by prestigious people. Although recognition by all people with various stands gives us credit, recognition by those with higher standing than us, gives us more credit and respect than recognition by those with the same or lower standing than us. And, that is why progress becomes more difficult as our standing becomes higher and higher—then, there are only few persons with higher ranks than us who can recognize our work and give credit to us.

The status of a journal has also two major components; the number of citations to the articles published in that journal (popularity) and the frequency with which it is cited by high-profile journals (prestige). Not mentioning the prestige of the citing journals relative to the cited journal, traditional IF is only an index of popularity. By introduction of "weighted impact factor" (WIF), we meant to incorporate the overlooked component—the prestige of the citing journal.

2. The proposed weighted impact factor

Assume that we have n journals. Let us indicate the ith journal by J_i. Assume that the number of citations from J_k in the current year to items published in J_i in the previous two years is $C_{k,i}$, and that J_i has published P_i substantive articles during

the same two years. The IF of J_i (i.e., IF_i) is then

$$IF_i = \frac{\sum_{k=1}^{n} C_{k,i}}{P_i} \tag{4}$$

In the calculation of IF (Eq. (4)), as was mentioned earlier, all citations are being counted with equal weight of 1, regardless of the prestige of the citing journal. Taking into account a weight for each citation, the WIF of J_i (i.e., WIF_i) would then be calculated as:

$$WIF_i = \frac{\sum_{k=1}^{n} w_{k,i} \times C_{k,i}}{P_i} \tag{5}$$

where $w_{k,i}$ designates the weight of J_k relative to J_i.

2.1. Derivation of weights

As explained earlier, the weight should reflect the prestige of the citing relative to the cited journal. Since there is no universally accepted method for measuring and comparing the quality of journals, we used the best available yardstick. It has been reported that IF may be a valid measure of quality for general medical journals (Saha et al., 2003). Assume that J_k has cited an article published in J_i. The easiest way to compare the prestige of the citing journal J_k relative to the cited journal J_i would be to compare their IFs and to develop the following quotient:

$$q_{k,i} = \frac{PYIF_k}{PYIF_i} \tag{6}$$

where $PYIF_i$ designates IF of J_i in the previous year.

Currently, the reported IF values for journals range from a minimum of zero to a maximum of almost 50. As a consequence, the quotient of two IFs (Eq. (6)) would vary from zero (0/50) to as high as infinity (50/0), depending on what journal cites which journal. Having such a wide range for the weights is certainly not acceptable. Therefore, using a logistic function, the quotient in Eq. (6) was normalized so that the weight ranges from 0.1 to 10 (arbitrary chosen values). In this way, citations from a journal with a very low-IF to a prestigious journal are given a minimum weight of 0.1, while citations from a very prestigious journal to a low-profile journal are given a maximum weight of 10. The weight is 1, if the IFs of the citing and cited journals (i.e., their prestige) are the same. For normalization, we used the following logistic function, the value of which ($w_{k,i}$) was used in Eq. (5), as the weight of citations made from journal J_k to J_i:

$$w_{k,i} = 10 \times \frac{1 - 0.828 \times e^{-q_{k,i}}}{1 + 16.183 \times e^{-q_{k,i}}} \tag{7}$$

where $q_{k,i}$ is the quotient of two journals' PYIFs (Eq. (6)). The values of coefficients in Eq. (7) are chosen in such a way to provide the properties we need; to produce a weight between 0.1 and 10, and to map the quotient (Eq. (6)) of 1 to a weight of 1. This function smoothly transforms the quotients in the range of $[0, +\infty)$ to the interval of [0.1, 10).

3. Example of derivation of weighted impact factor for 70 biomedical journals

3.1. Data collection

To examine the proposed weighting scheme under a real situation, we tried to calculate the WIF for year 2006 for 70 journals with the highest 2006 IF in the "MEDICINE, GENERAL and INTERNAL" subject category of Science Edition of Journal Citation Report (JCR) of Thomson ISI Web of Knowledge℠ (http://isiknowledge.com) (Table 1). From that database, for each journal J_i from the set of 70 journals studied, we retrieved the number of substantive articles it published in years 2004–2005 (P_i; Eqs. (4) and (5)), total cites it received in 2006 (Table 1), and the number of times articles published in 2006 in J_k cited articles published in 2004–2005 in J_i ($C_{k,i}$; Eqs. (4) and (5)). The 2005 IF of journals (PYIF), for derivation of weights (Eqs. (6) and (7)) were also retrieved from 2005 edition of the database.

3.2. Handling the missing values

For the calculation of weights (Eqs. (6) and (7)) of different citing journals relative to a certain cited journal, we have to know the PYIF of all the citing and the cited journals. If the PYIFs of all the citing and the cited journals are non-zero, the calculations are straight forward; we just follow the equations (Table 2). However, we may face other situations that need special attention.

3.2.1. When the PYIF of a citing journal is reported 0.000

For some citing journals, the reported PYIF may be 0.000. As an example, the 2005 IF of *NEURO-OPHTHALMOLOGY*, which in the year 2006 cited twice the articles published in 2004–2005 in *NEW ENGL J MED*—one of the 70 studied journals—was 0.000. If the PYIF for the cited journal is non-zero, the quotient in Eq. (6) becomes zero and the weight, as calculated by Eq.

Table 1
The number of citations, published articles and impact factors of the 70 studied journals

Rank		Abbreviated journal title	Articles published in 2004–2005	Total cites received in 2006	Year 2006	
IF	WIF				IF	WIF
1	2	*NEW ENGL J MED*	624	32,009	51.296	14.472
2	4	*LANCET*	776	20,021	25.800	9.078
3	5	*JAMA-J AM MED ASSOC*	674	15,620	23.175	8.869
4	6	*ANN INTERN MED*	364	5,380	14.780	7.410
5	1	*PLOS MED*	108	1,485	13.750	14.475
6	3	*ANNU REV MED*	59	781	13.237	10.593
7	10	*BRIT MED J*	910	8,413	9.245	5.934
8	13	*ARCH INTERN MED*	589	4,665	7.920	5.662
9	15	*CAN MED ASSOC J*	210	1,441	6.862	5.032
10	30	*MEDICINE*	66	341	5.167	3.854
11	11	*J INTERN MED*	256	1,211	4.730	5.906
12	7	*ANN MED*	138	634	4.594	7.209
13	14	*AM J MED*	512	2,313	4.518	5.613
14	19	*MAYO CLIN PROC*	319	1,283	4.022	4.510
15	32	*ANN FAM MED*	142	540	3.803	3.803
16	23	*AM J PREV MED*	340	1,189	3.497	4.053
17	24	*CURR MED RES OPIN*	449	1,375	3.062	4.016
18	18	*J GEN INTERN MED*	364	1,079	2.964	4.612
19	17	*EUR J CLIN INVEST*	236	672	2.847	4.812
20	21	*QJM-INT J MED*	152	421	2.770	4.192
21	22	*MED J AUSTRALIA*	464	1,198	2.582	4.076
22	48	*PAIN MED*	76	186	2.447	2.776
23	34	*J PAIN SYMPTOM MANAG*	245	597	2.437	3.681
24	28	*PREV MED*	521	1,245	2.390	3.916
25	16	*AM J MANAG CARE*	252	519	2.060	4.902
26	12	*MED CLIN N AM*	147	302	2.054	5.833
27	47	*PALLIATIVE MED*	147	285	1.939	2.825
28	39	*BRIT J GEN PRACT*	225	436	1.938	3.484
29	8	*AMYLOID*	67	128	1.910	6.763
30	56	*J URBAN HEALTH*	150	285	1.900	2.623
31	54	*BRIT MED BULL*	59	111	1.881	2.638
32	20	*J LAB CLIN MED*	149	270	1.812	4.243
33	9	*J WOMENS HEALTH*	180	308	1.711	6.066
34	55	*PANMINERVA MED*	50	84	1.680	2.631
35	25	*J INVEST MED*	82	137	1.671	3.962
36	43	*AM FAM PHYSICIAN*	323	522	1.616	2.963
37	37	*FAM PRACT*	208	324	1.558	3.516
38	65	*SCAND J PRIM HEALTH*	85	131	1.541	1.724
39	67	*J AM BOARD FAM MED*	137	208	1.518	1.518
40	45	*INTERN MED J*	229	321	1.402	2.887
41	29	*AM J MED SCI*	245	332	1.355	3.874
42	50	*SWISS MED WKLY*	191	257	1.346	2.703
43	33	*J TRAVEL MED*	138	184	1.333	3.723
44	61	*MED CLIN-BARCELONA*	428	568	1.327	2.149
45	46	*CLIN MED*	129	167	1.295	2.862
46	49	*FAM MED*	173	223	1.289	2.759
47	60	*J FAM PRACTICE*	126	161	1.278	2.169
48	59	*J EVAL CLIN PRACT*	118	149	1.263	2.177
49	27	*J NATL MED ASSOC*	243	305	1.255	3.930
50	38	*SAMJ S AFR MED J*	126	155	1.230	3.498
51	26	*INDIAN J MED RES*	277	339	1.224	3.936
52	41	*INT J CLIN PRACT*	554	658	1.188	3.417
53	58	*CLEV CLIN J MED*	151	178	1.179	2.267
54	31	*NETH J MED*	154	179	1.162	3.826
55	35	*POSTGRAD MED J*	321	351	1.093	3.618
56	51	*MT SINAI J MED*	126	134	1.063	2.688
57	64	*TOHOKU J EXP MED*	251	254	1.012	1.975
58	52	*NATL MED J INDIA*	85	85	1.000	2.679
59	40	*SOUTH MED J*	453	447	0.987	3.444
60	53	*YONSEI MED J*	334	284	0.850	2.659
61	62	*AVIAT SPACE ENVIR MD*	377	313	0.830	2.141
62	68	*CROAT MED J*	206	170	0.825	1.497
63	63	*WIEN KLIN WOCHENSCHR*	311	250	0.804	2.081
64	36	*INTERNAL MED*	467	372	0.797	3.525
65	44	*ANN ACAD MED SINGAP*	289	223	0.772	2.953
66	42	*MIL MED*	427	319	0.747	3.385
67	70	*DM-DIS MON*	47	35	0.745	0.729
68	57	*J KOREAN MED SCI*	378	274	0.725	2.539

Table 1 (*Continued*)

Rank		Abbreviated journal title	Articles published in 2004–2005	Total cites received in 2006	Year 2006	
IF	WIF				IF	WIF
69	66	*AM J CHINESE MED*	186	132	0.710	1.724
70	69	*CAN FAM PHYSICIAN*	117	82	0.701	1.222

Table 2
Calculation of weight in different conditions

		Previous year impact factor of the cited journal		
		≠ 0	0.000	Not reported
Previous year impact factor of the citing journal	≠ 0	By Eqs. (6) and (7)	10	1
	0.000	0.1	1	1
	Not reported	1	1	1

(7), becomes 0.1. If the PYIF of the cited journal was also 0.000, the quotient of PYIFs (Eq. (6)) turns to an indeterminate form of 0/0; but, since the PYIFs of both the citing and the cited journals are the same, we assume that the prestige of the citing journal is similar to that of the cited journal and thus, give a weight of 1 to such citations (Table 2).

3.2.2. When the PYIF of a cited journal is reported 0.000

Some cited journals have a PYIF of 0.000. The quotient of Eq. (6) the denominator of which is 0, is either infinity (when the PYIF of the citing journal is non-zero) or turns to an indeterminate form of 0/0 (when the PYIF of the citing journal is also 0.000). If the quotient of Eq. (6) becomes infinity, the weight becomes 10 (Eq. (7)). If the quotient turns to the indeterminate form of 0/0, since the PYIF of both the cited and citing journals are the same (0.000), we assume that the prestige of both journals are the same and thus, give a weight of 1 to such citations (Table 2).

3.2.3. When the PYIF of a citing journal is not reported

When a journal is accepted to be indexed by ISI, no IF will be reported for it for the first three years; that is why some journals indexed by ISI do not have a PYIF. As an example, *CLIN RES CARDIOL* which cited 55 times articles published in 2004–2005 in *NEW ENGL J MED*, had no reported 2005 IF. Since we cannot calculate a weight for such citations, like what we do for calculation of the traditional IF, we give a weight of 1 to citations coming from such journals, regardless of the PYIF of the cited journal (Table 2).

3.2.4. When the PYIF of a cited journal is not reported

We cannot calculate the WIF for a journal which has no PYIF, since the very first step in the calculation of the weight is to derive a quotient (Eq. (6)) the denominator of which is the PYIF of the cited journal. For such journals, we should still report the traditional IF (Table 2). This means that we inclusively assume a weight of 1 for all citations.

4. Results

The 70 journals studied, their citation information as well as their IF and WIF in 2006 are shown in Table 1. These journals were ranked both according to their IF and WIF (Table 1).

IF and WIF of these 70 journals were not normally distributed ($p < 0.01$; one-sample Kolmogorov–Smirnov test). Some important descriptive statistics of IF and WIF are presented in Table 3. Rank of journals based on traditional IF and WIF was significantly different ($p < 0.001$; Wilcoxon signed ranks test). A more quantitative analysis of the overlap and discrepancies between the IF and WIF is shown in Fig. 1. The values of IF and WIF although significantly different, have a significant overall correlation (Spearman's $\rho = 0.776$, $p < 0.001$).

Table 3
Descriptive statistics of traditional impact factor and weighted impact factor

Statistics	Year 2006	
	IF	WIF
Number of journals	70	70
Minimum	0.701	0.729
Maximum	51.296	14.475
Skewness	4.614	2.278
25%ile	1.175	2.654
Median	1.644	3.572
75%ile	2.989	4.662

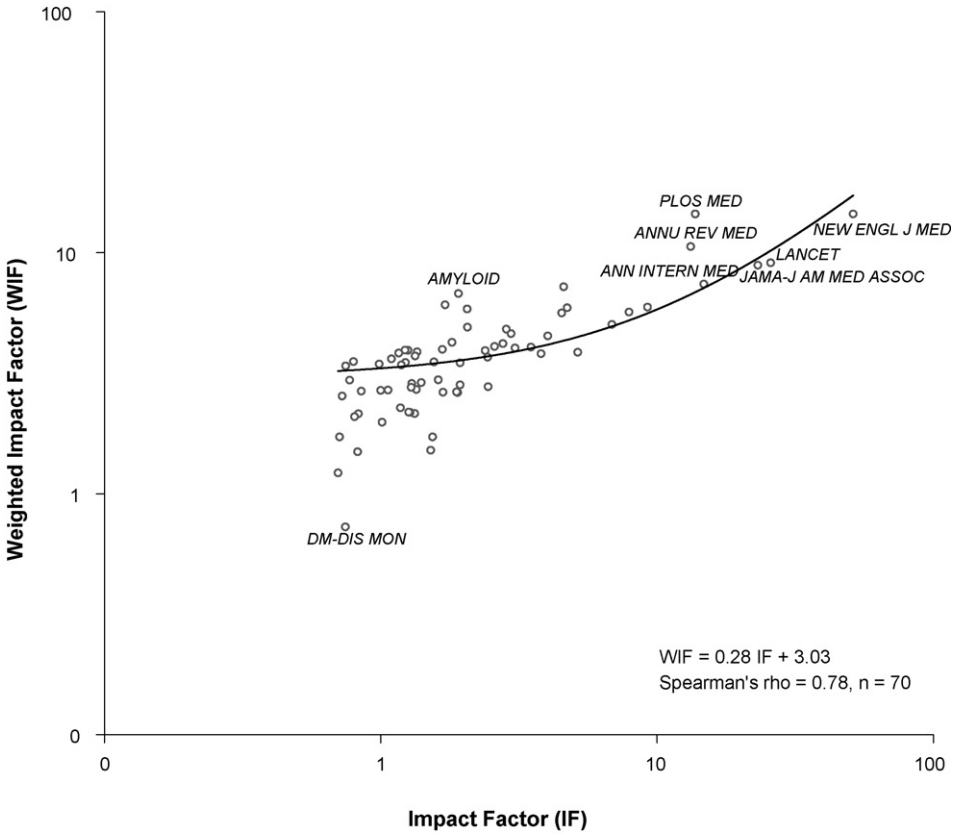

Fig. 1. Scatter plot showing the relationship between the weighted and traditional impact factors of 70 biomedical journals studied. Note that the scale of both axes is logarithmic.

We noted that the six journals *NEW ENGL J MED, LANCET, JAMA-J AM MED ASSOC, PLOS MED, ANNU REV MED*, and *ANN INTERN MED* are positioned in the top-right corner of the scatter plot (Fig. 1), indicating that they have both high IF and high WIF values. This means that all these six journals were often cited (popularity)—as indicated by high IF and WIF—and were cited by prestigious journals—as shown by high WIF.

The WIF values of *PLOS MED* and *AMYLOID* are markedly higher than that we expected (Fig. 1). Almost 36% of citations *PLOS MED* received, and 20% of citations *AMYLOID* received were from journals with 2005 IF > 5. On the other hand, none of the citations *DM-DIS MON* received were from journals with 2005 IF > 2.5, hence, its WIF value which not only reflects popularity but also is an indicator of prestige, was markedly lower than we expected (Fig. 1).

While the 2006 IF (which only reflects popularity) of both *SWISS MED WKLY* (IF rank 42) and *J TRAVEL MED* (IF rank 43) are almost equal (1.346 vs. 1.333, respectively) (Table 1), the difference in the prestige of the citing journals relative to the cited journal is clearly reflected in their 2006 WIF values (2.703 vs. 3.723, respectively)—5.1% of citations to *SWISS MED WKLY* and 19.0% of citations to *J TRAVEL MED* came from journals with 2005 IF > 5 (Fig. 2). On the other hand, 63.4% of citations to the former journal and 34.8% of citations to the latter journal originated from journals with 2005 IF < 1. All these clearly indicated that *J TRAVEL MED* has been cited more frequently than *SWISS MED WKLY* by prestigious journals, hence, the former journal should indeed have a higher quality/prestige than the latter one. This difference in quality, although could not be revealed by traditional IF, is clearly reflected in their WIF (3.723 vs. 2.703) (Table 1).

The distribution of citations received by *ANN INTERN MED* and *JAMA-J AM MED ASSOC* is very similar (Fig. 2). Therefore, the only determinant of quality for comparing these two journals is their popularity (i.e., their IF). In such conditions, the calculated WIF is in keeping with the reported IF values (Table 1).

Considering the traditional IF, *NEW ENGL J MED* with a 2006 IF of 51.296 occupied the first rank (Table 1). Using WIF instead of IF, *PLOS MED* with a WIF of 14.475 became the first journal followed by *NEW ENGL J MED* with a WIF of 14.472. This is indeed a combination of the two components mentioned; while *NEW ENGL J MED* was more popular (higher IF), *PLOS MED* received many citations from prestigious journals (Fig. 2). The two components of popularity and prestige of the citing journals (relative to the cited journal) combined to give almost the same WIF value for these two journals (Table 1).

ANN FAM MED and *J AM BOARD FAM MED* had no reported 2005 IF, hence, their WIF became equivalent to their IF (Table 1).

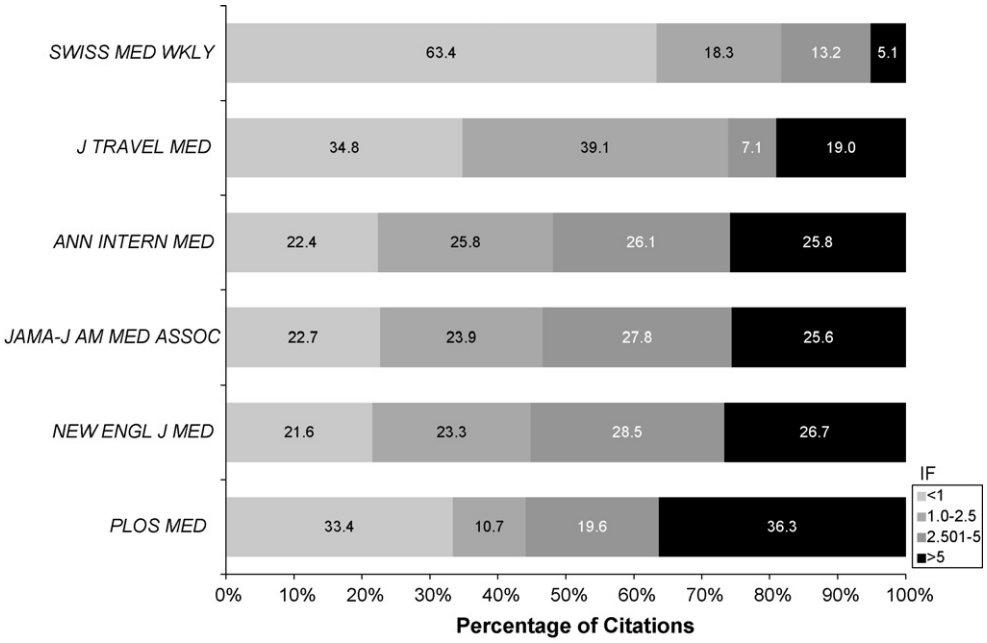

Fig. 2. Distribution of journals citing six journals according to their 2005 journal impact factor.

5. Discussion

Prestige of a certain person/journal is the standing or estimation in the eyes of other people/journals. This respect should be given by other journals/authors to a journal because of its reputation for high quality, its success and its influence. In other words, prestige is the level of respect at which one is regarded by others. This respect, however, has two important components—popularity and being recognized by prestigious people.

In the calculation of WIF, we use the basis of IF and therefore, consider the popularity of the cited journal. We also use a weighting scheme which incorporates a factor indicating the prestige of the citing journal relative to the cited journal. All citations give credit to the cited journal. The extent of this credit/respect depends on the standing of the citing journal relative to the cited journal.

As was mentioned earlier, a journal may intentionally decrease the number of references it makes to other journals and factitiously inflates its PageRank (Rogers, 2006), and *Y*-factor (Eq. (3)). This is also true for IF and hence, WIF, the calculation of which basically depends on the IF, by decreasing the number of substantive articles a journal publishes in one year. Nonetheless, this is a temporary phenomenon which will be corrected over the next year when the number of citations to those articles will also decrease.

The way a certain journal cites other journals does not affect its WIF; it just affects WIF of the cited journals. This weighting scheme caused the distribution of WIF to be less skewed than that of the traditional IF (Table 3) making the distribution becomes more close to a normal distribution.

The six journals *NEW ENGL J MED, LANCET, JAMA-J AM MED ASSOC, PLOS MED, ANNU REV MED*, and *ANN INTERN MED* had both high IF and high WIF values (Fig. 1). These journals were both popular—as indicated by high IF and WIF—and were cited by prestigious journals—as shown by high WIF. These six journals occupy the top six ranks by both IF and WIF (Table 1). This is in accord to a previous report which indicated that four of these journals—*NEW ENGL J MED, LANCET, ANN INTERN MED*, and *JAMA-J AM MED ASSOC*—are also considered highly important by physicians (Saha et al., 2003).

We showed the effect of popularity (*ANN INTERN MED* vs. *JAMA-J AM MED ASSOC*), the effect of prestige of the citing journals (*SWISS MED WKLY* vs. *J TRAVEL MED*), and a combination of these two effects (*NEW ENGL J MED* vs. *PLOS MED*) on the calculated WIF (Table 1, Fig. 2).

We explained why 2006 WIF of *PLOS MED* was higher than that of *NEW ENGL J MED*, however, another factor contributing to this observation would be the fact that the 2005 IFs of these two journals were very different. As explained earlier, the 2005 IF of the cited journal is used as the denominator of a quotient (Eq. (6)) to compute the weights reflecting the prestige of the citing journals relative to the cited journal. If a journal has a low 2005 IF, many journals are considered more prestigious relative to that journal and their citations to that journal are then given a weight more than 1. As an example, using Eqs. (6) and (7), any citations from a journal, like *LANCET* with 2005 IF of 23.407, to *PLOS MED* (with 2005 IF of 8.389) are given a weight of 4.761, while similar citations to *NEW ENGL J MED* (with 2005 IF of 44.016) are given a weight of 0.489; the *LANCET* is considered more prestigious (weight > 1) than *PLOS MED*, but less prestigious (weight < 1) than *NEW ENGL J MED*.

Using Eq. (5), the WIF of a journal J_i can vary from a minimum of

$$\mathrm{WIF}_{i,\min} = \frac{w_{\min,i} \times \sum_{k=1}^{n} C_{k,i}}{P_i} \tag{8}$$

where $w_{\min,i}$ designates the weight when all citations to J_i have come from a journal with the lowest IF (prestige), to a maximum of

$$\mathrm{WIF}_{i,\max} = \frac{w_{\max,i} \times \sum_{k=1}^{n} C_{k,i}}{P_i} \tag{9}$$

where $w_{\max,i}$ represents the weight when all citations have come from a journal with the highest IF. Using Eq. (4), the WIF of J_i can then vary from

$$(w_{\min,i} \times \mathrm{IF}_i) \quad \text{to} \quad (w_{\max,i} \times \mathrm{IF}_i) \tag{10}$$

However, $w_{\min,i}$ is never less than 0.1 and $w_{\max,i}$ is never more than 10, for the normalization applied (Eq. (7)). Therefore, the WIF of J_i can theoretically vary from 0.1 to 10 times of its IF. This may explain some parts of the correlation exists between the IF and WIF values of journals we studied (Fig. 1).

In the calculation of the weights, we made several assumptions that need further considerations. We used a logistic function that mapped all values in the range of $[0, +\infty)$ to the interval [0.1, 10). The values of 0.1 and 10 were arbitrarily chosen. In this way, we assigned a minimum weight of 0.1 to a citation made from a very low-profile journal to a very prestigious journal, and gave a maximum weight of 10 to a citation came from a very prestigious journal to a low-status journal. This method prevents exaggerated increase in the WIF of a low-impact journal, if, rarely occurred, it receives a single citation from a main-stream journal. Choosing this interval, indeed reflects how we like to weight the two components of the journal quality – the popularity (number of citations) or prestige of the citing journal. If we choose the interval of [1, 1], then we came back to the traditional IF and give a weight of 1 to all citations. This means that we do not believe that citations from a prestigious journal should receive a higher weight than citations from a low-profile journal. On the other hand, if we choose the interval of $[0, +\infty)$, then we believe that the prestige component and the quality of the citing journal is a very important factor in calculating the quality of the cited journal. Further studies are needed to determine what interval gives an optimum balance between the two components of quality—number of citations and prestige of the citing journal.

For the calculation of the weights, we used the journal PYIFs. However, after calculation of the journal WIFs, for the next year, these values can be used as better estimates of journal quality, to calculate the weights for derivation of WIF. To have a better view of the situation, it is certainly better to compute the WIF for the whole set of journals indexed by Thomson Scientific.

The traditional IF has serious variations over the time. As an example, the IF of *PLOS MED* increased dramatically by 63.9% from a value of 8.389 in 2005 to 13.750 in 2006. The IF of *NEW ENGL J MED* increased by 16.5% from 44.016 in 2005 to 51.296 in 2006. Such a dramatic increase is unlikely to occur in WIF since as soon as the WIF of a journal grows, other journals will be treated less prestigious relative to it, and hence, the weight of citations from those journals becomes less than 1. This will control the rapid growth of WIF. On the other hand, if WIF of a journal drops markedly, the weight of citations from other journals becomes more than 1 and hence, it is unlikely that the WIF changes dramatically.

6. Conclusions

Since there is no universally accepted index for measuring journal quality, we cannot compare the efficacy of the proposed WIF compared to the traditional IF. We could only indicate that WIF does not only reflect the number of citations but also take into account the prestige of the citing journal relative to the cited journal. The traditional IF, although good, can be further improved. Since the information necessary for the calculation of WIF is already available to indexing systems, it can be calculated easily. We believe that WIF provides a better yardstick for assessing the quality of journals as compared to the traditional IF.

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References

Bollen, J., Rodriguez, M. A., & Van de Sompel, H. (2006). Journal status. *Scientometrics*, *69*(3), 669–687.
Cason, H., & Lubotsky, M. (1936). The influence and dependence of psychological journals on each other. *Psychology B*, *33*, 95–103.
Garfield, E. (1955). Citation indexes for science: A new dimension in documentation through association of ideas. *Science*, *122*(3159), 108–111.
Garfield, E. (2006). The history and meaning of the journal impact factor. *JAMA*, *295*(1), 90–93.
Gross, P. L. K., & Gross, E. M. (1927). College libraries and chemical education. *Science*, *66*(1713), 385–389.
Kochen, M. (1974). *Principles of information retrieval*. New York: Wiley.
Lowy, C. (1997). Impact factor limits funding. *Lancet*, *350*(9083), 1035.

Moed, H. F. (2005). Citation analysis of scientific journals and journal impact measures. *Current Science*, *89*(12), 1990–1996.
Pinski, G., & Narin, F. (1976). Citation influence for journal aggregates of scientific publications: Theory, with application to literature of physics. *Information Processing & Management*, *12*(5), 297–312.
Rogers, I. The *Google pagerank algorithm and how it works*. Retrieved 1 August, 2006, from http://www.iprcom.com/papers/pagerank/.
Saha, S., Saint, S., & Christakis, D. A. (2003). Impact factor: A valid measure of journal quality? *Journal of the Medical Library Association*, *91*(1), 42–46.
Seglen, P. O. (1997). Why the impact factor of journals should not be used for evaluating research. *BMJ*, *314*(7079), 498–502.