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Abstract

Purpose – The purpose of this paper is to examine the variability of the impact factor (IF) and additional metrics in biomedical journals to provide some clues to the reliability of journal citation indicators.
Design/methodology/approach – Having used ISI Journal Citation Reports, from 2005 to 2011, the authors extracted 62 subject categories related to biomedical sciences. The category lists and citation profile for each journal were then downloaded and extracted. Coefficient of variation was applied to estimate the overall variability of the journal citation indicators.
Findings – Total citation indicators for 3,411 journals were extracted and examined. The overall variability of IFs and other journal citation measures in basic, clinical or translational, open access or subscription journals decreased while the quality and prestige of those journals developed. Interestingly, journal citation measures produced dissimilar variability trends and thus highlighted the importance of using multiple instead of just one measure in evaluating the performance and influence of biomedical journals. Eigenfactor™, Article's Influence and Cited Half Life proposed as more reliable indicators.
Originality/value – The relative variability of the journal citation measures in biomedical journals would decrease with a development in the impact and quality of journals. Eigenfactor™ and Cited Half Life are suggested as more reliable measures indicating few changes during the study period and across different impact level journals. These findings will be useful for librarians, researchers and decision makers who need to use citation measures as evaluative tools.

Keywords Variability, Bibliometrics, Biomedical journals, Journal impact factors
Paper type Research paper

Background

By indicating citations to a journal's papers over time, the journal citation measure is one of the most popular tools designed to assess a journal's significance, quality and scientific prestige (Glänzel and Moed, 2002). These measures, as a proxy of journal characteristics and research impact are widely used as evaluative indicators and a practical alternative to subjective judgements (Glänzel and Moed, 2002). Therefore,

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journal citation measures have become increasingly popular as an indicator of scientific credibility of journal papers and substitute for comprehensive research evaluations. Among a variety of available journal citation measures, the journal impact factor (IF) is perhaps the most commonly used measure of quality (*Nature Materials*, 2013; Neff and Olden, 2010), prestige, performance and impact in biomedical journals (Krell, 2012). Journal editors usually use IF as a performance indicator and change their editorial strategies to increase their IFs. Moreover, authors refer to journals' IFs when deciding where to submit their papers. Increasingly, many countries and research institutions use IF as a measure of quality, excellence and research merit when making decisions on research grant allocations, promotion and recruiting academic staff (Ha *et al.*, 2006; *PLoS Medicine*, 2006).

While the rankings of the IF have been increasingly applied in ways not originally expected (Garfield, 2005; Vanclay, 2012), controversies have cast some doubt on the validity and reliability of the IF as a sole measure of scientific quality (Vanclay, 2012). There has been a rich body of literature indicating the inherent flaws and practical limitations of the IF in evaluating the quality of journals, individual papers and even individual authors (Kurmis, 2003; Amin and Mabe, 2000; Bornmann *et al.*, 2011; Campanario, 2010; Ha *et al.*, 2006; Krell, 2012). One reason is that IF correlates poorly with the citation rates of individual papers (Bornmann *et al.*, 2011). Citations follow non-parametric distributions within a journal's papers as many papers published in a journal never receive any citations and about 20 per cent of papers account for more than 50 per cent of the total citations (Rizkallah and Sin, 2010). Moreover, the uncertainty regarding "citable" documents counted in the dominator of the IF formula has raised serious debates on the validity and credibility of this measure as a surrogate measure of scientific influence and quality. The short citation window of IF is another limitation as some fields do not reach their citation peak until three years or longer after publication (Campanario, 2010).

In an attempt to address these concerns about IF and to overcome its technical and methodological shortcomings, since 2007 ISI Thomson Reuters has proposed several other journal citation measures in addition to the IF. The five-year IF (IF5), Cited Half Life (CHL), Eigenfactor (Escore), and Article Influence (Influence) scores are the prime examples and modifications published annually in the Journal Citation Reports (JCR) along with the IF. While the former complements the short time span of IF for indicating the prestige and influence of journals, the latter two reflect both the quality and quantity of citations received (Rizkallah and Sin, 2010) (see the Appendix for more explanations).

CHL is perhaps one of the most often used measures, reflecting the speed at which the frequency of received citations to papers published in a journal reduces over time. The journal CHL is the median age of the papers cited in current JCR and defines the number of years (age) required to receive half of the journal's total citations. CHL indicates for how long papers published in a journal are used by the scientific community and continue to have an impact on science (Bornmann *et al.*, 2011). Empirical studies have indicated variations in the cited journal half-life among different fields of science and journal types (Leydesdorff, 2008; Nederhof *et al.*, 1989; De Solla Price, 1970).

Despite the different ways in which these citation measures are derived, studies have shown that IF5 and Escore values correlate very well with those based on traditional IF and therefore produce similar rank orders for biomedical journals (Campanario, 2010; Rizkallah and Sin, 2010). While the new measures have become increasingly popular, the questions of which citation measures are the most reliable and "which aspects of journal performance for these measures are assumed to indicate" (Glänzel and Moed, 2002, p. 186) are challenging. It is therefore recommended to look closely at the reliability of the new measures and analyse citations more comprehensively.

The journal citation measures change moderately over time, as for a typical journal these values for a year will be some distance away from their average values. Therefore, most journals do experience variability in their citation measures. In general, variability is defined as the extent to which citation measure values differ from each other for a journal. In this context the statistical variability of journal citation measures sheds some light on the reliability of these measures when deciding on the quality of scholarly journals. Consequently, several efforts have been made to explore the reliability of citation measures. Some of the important implications and findings of these studies involve the use of standard error values for citation rate comparisons (Schubert and Glänzel, 1983), estimating citation measure variations and the source of these variations in scientific journals (Amin and Mabe, 2000; Ogden and Bartley, 2008).

In recent years a growing body of literature has emerged focusing on the importance of bibliometrics and application of citation analysis techniques in evaluating research performance specifically in the area of biomedical sciences (van Eck *et al.*, 2013; Hack *et al.*, 2010, 2014; Patel *et al.*, 2011; Sharma *et al.*, 2013; Jones *et al.*, 2012). Mapping the geography of sciences and publications (Pagel and Hudetz, 2011a; Garrard, 2013; Zacca-González *et al.*, 2014), evaluating individual researchers (Chen and Guan, 2011; Pagel and Hudetz, 2011b) and proposing new journal rankings (Owlia *et al.*, 2011; Siebelt *et al.*, 2010; Rizkallah and Sin, 2010) are the most important research domains. However, to date the exact nature, extent and credibility of the journal impact measures in biomedical sciences remain unclear. Biomedical sciences have been identified as a major source of scholarly publications so the accelerated pace of discoveries in biomedical sciences provides significant opportunities for scientists as well as funding organisations and research policy makers.

Citation measures and particularly journal citation measures follow different patterns across different disciplines and subject categories. In this context a great body of literature has emerged on the comparison of citation measures across fields and research domains (Colliander and Ahlgren, 2011; Waltman and van Eck, 2013; Kaur *et al.*, 2013; Radicchi and Castellano, 2012). It is therefore important to consider the context and environment of received citations when comparing different subject categories and disciplines. While biomedical sciences cover a diverse range of basic, applied or translational research conducted to support new health challenges and address the recent needs for translation of scientific discoveries into practice, the lack of credible and reliable evaluation devices is challenging. Biomedical journals comprise a large proportion of scholarly publications so providing insights into the application of new evaluative measures and reliable devices would be a challenging research domain.

In summary, research supports the contention that journal impact measures play an important role in evaluation of research quality and excellence. Despite growing efforts to propose new indicators and measures of impact in recent years, we do not have much data concerning the reliability of widely used impact measures in biomedical sciences. We do not know what factors may be the most predictive of the degree of variability or reliability of scholarly journals in biomedical sciences. Nor do we have much research examining the interaction of publication status (open access vs subscription) with the changes of journal impact measures across basic, clinical or translational sciences. Therefore, we intend to give an overview of the statistical variability of IF as well as other journal impact measures as a strategy for improving or recommending it in biomedical journals.

Methodology

Journal selection

Using ISI JCR from 2005 to 2011, 62 category lists (subject categories) were included in the area of biomedical sciences; among these, 32 belonged to the field of clinical or translational medicine while 30 had basic approaches (Table I). The category lists and citation profile for each journal under those categories were then downloaded and extracted.

Generally we only included those journals with positive (larger than zero) IFs during a period between 2005 and 2011 under the above mentioned categories. The journals that were indexed but did not receive any IF were then excluded. Since some journals were included in JCR for one year and therefore had one or two observations, and as the variances based on such small samples might be not reliable, these journals were then excluded.

The citation profiles extracted for each journal included: the total papers, total citations, IF, immediacy index (IIF) and CHL for all journals in addition to the IF5, Escore and Influence for journals indexed since 2007.

The publishing status of included journals (open access or subscribed journals) was then identified by searching the Directory of Open Access Journals.

Variable	No.	%
Subject		
Clinical or translational sciences	1,984	58.2
Basic sciences	1,427	41.8
Included Web of Science subject categories		
Clinical or translational sciences	32	51.6
Basic sciences	30	48.4
Impact factor level (quartiles)		
<1	913	26.8
1-2	971	28.5
2-3	698	20.5
3>	829	24.3
Number of years in JCR		
2	403	11.8
3	355	10.4
4	175	5.1
5	157	4.6
6	156	4.6
7	2,165	63.5
Publishing status		
Open access journals	379	11.1
Subscription journals	3,032	88.9

Table I. Description of biomedical journals included for examining the variability of their citation measures reported in JCR during 2005-2011

Data processing and analysis

For the data analysis, we prepared a datasheet in Stata 11, extracting the citation profile of each journal and its respective indicators. When the same journal was listed in more than one subject category, we only took into account the first subject alphabetically. An expert librarian was asked to classify included journals into two major groups of basic and clinical/translation sciences.

In order to assess the trend of journals' IF over time, the linear and quadratic effects of year (1 for 2005 and 7 for 2011) were quantified using multilevel regression analysis.

For pooled analysis including all years, we calculated the mean, SD and CV (coefficient of variation: SD over mean multiplied by 100) of the above indices for each journal. CV is used to indicate the relative changes of journal citation measures.

In this study CV was the dependent variable while the mean values of journal citation measures were assumed as independent. The mean IF values were further divided into quartiles (from the lowest to the highest value) to determine the degree of the linear association between the CV values of citation measures and impact levels.

Multilevel regression analysis was applied to explore the associations, considering the possible clustering effects due to the dependency of journals' records with the same subject. The trends of variability measures in different citation measure levels were illustrated to indicate the direction of changes. The significance level was 0.05 for two-sided tests.

Findings

Descriptive statistics

Overall, the citation measures for 3,411 journals were extracted and examined. The results showed dissimilar frequencies of sampled journals according to subject and impact level groups. Clinical or translational journals had a greater share in biomedical journals. Moreover, nearly half of the journals had low impact values ($IF < 2$) (see Table I). The lowest IF was 0.005 while the highest IF was nearly 101.78.

Trends in variability of journal citation measures according to impact quartiles

Since 2005 the IF of the biomedical journals included in this analysis increased significantly ($r = 0.11$, $p < 0.001$). Therefore, it is possible to analyse these changes in biomedical journals across different impact levels and citation measures. Figure 1 shows the overall changes of citation measures across different impact levels in basic and clinical/translational journals. Moreover, open access or subscription journals were also compared according to their overall changes of citation measures. Looking at Figure 1, it is possible to verify that the overall changes in journal citation indicators follow similar trends in basic and clinical/translational journals and even open access and subscription journals, i.e. the relative variability of journal citation indicators is lower in journals with higher impact levels.

Furthermore, Figure 1 reveals that the relative changes in IIF were more obvious than other journal citation indicators in clinical (1) and non-clinical (2) journals according to the CV. IF, IF5 and Influence also had similar patterns but with a smaller range of changes compared to IIF. In this context CHL and Escore were nearly stable in raising impact levels except for very low impact ($IF < 1$) and open access journals.

Prediction of journal citation measures' variability according to the mean IF values

In order to estimate the variability of journal citation measures by the journals' IF values an adjusted regression analysis was performed. The results are summarised in

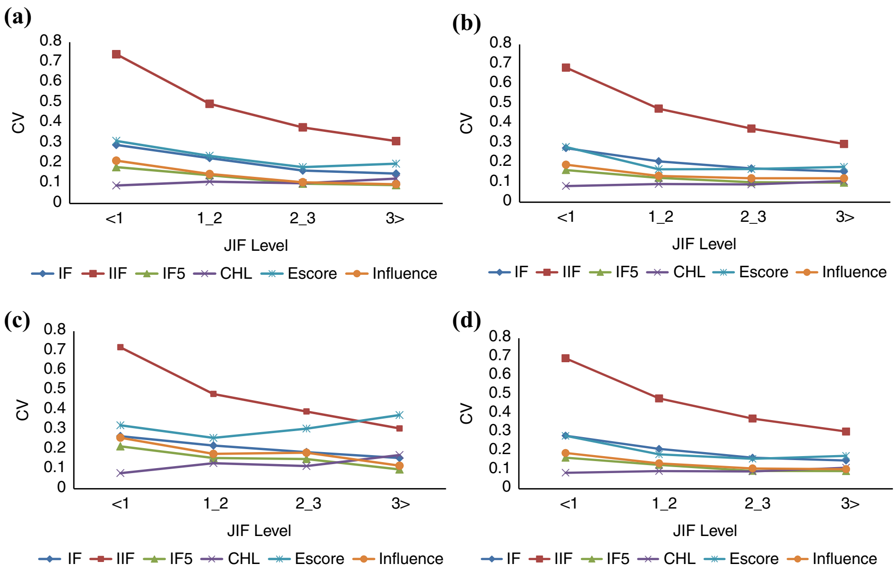

Figure 1.
Trends of CV values among journal citation measures and impact levels

Notes: In basic (a), clinical or translational (b), open access (c) or subscription journals (d)

Table II. According to CV as a measure of relative variability we found an overall negative but significant association between the mean values of journal citation measures and CV in basic and clinical/translational journals as well as open access or subscription journals. This data confirms the inverse association between the changes in citation measures and the mean IF values. It is possible to verify that the journals with higher impact levels have smaller changes in their citation measures.

It seems that the overall association between the CV and the mean impact was very similar in basic and clinical/translational journals except for IIF and Escore which had different coefficients. IIF had a higher negative association in basic science journals whereas CHL indicated higher coefficients in clinical or translational journals. Roughly, IIF showed the highest negative regression coefficient (−0.026; CI: −0.029, −0.022), while IF5 had the lowest (−0.003, CI: −0.004, −0.002). In terms of publishing status, subscription journals showed higher negative associations between changes in citations measures and their IF values.

Discussion

This study estimated the variability of different journal citation measures in biomedical journals between 2005 and 2011. Data from 3,411 journals were extracted and the pooled results yielded a broad estimate of the variability in biomedical journals so far. This approach also allowed us to explore whether the variability is more or less frequent according to the impact level of each journal, in different citation indicators and in different subject categories**.**

There is no globally accepted measure for evaluating the quality, performance and influence of biomedical journals. In recent decades significant achievements have been made in offering new citation measures to the scientific community. In this context ISI Thomson Reuters has proposed several journal citation attributes for evaluating the quality and influence of journals including total citations, IF, IIF, IF5, CHL, Escore and

Table II.
The association between the relative changes in journal citation measures and the mean IF values in basic, clinical/translational, open access and subscription journals

	Basic sciences		Clinical or translational sciences		Open access journals		Subscription journals		All	
Indicator	B	CI	B	CI	B	CI	B	CI	B	CI
IF	−0.008	−0.010, −0.006	0.008	−0.010, −0.006	−0.020	−0.029, −0.011	0.008	−0.009, −0.006	−0.008	−0.010, −0.007
IIF	−0.024	−0.028, −0.020	0.027	−0.031, −0.022	−0.077	−0.097, −0.057	0.024	−0.027, −0.020	−0.026	−0.029, −0.022
IF5	−0.003	−0.005, −0.002	0.003	−0.004, −0.001	−0.018	−0.027, −0.008	0.003	−0.004, 0.002	−0.003	−0.004, −0.002
CHL	0.003	0.002, 0.004	0.001	0.000, 0.002	0.018	0.013, 0.022	0.002	0.001, 0.003	0.002	0.002, 0.003
Escore	−0.006	−0.009, −0.003	0.006	−0.009, −0.003	0.009*	−0.006, 0.025	0.005	−0.007, −0.003	−0.005	−0.008, −0.003
Influence	−0.005	−0.006, −0.003	0.002	−0.004, −0.000	−0.022	−0.034, −0.010	0.003	−0.004, −0.002	−0.004	−0.005, −0.003

Notes: B, regression coefficient; CI, confidence interval. All of the regression coefficients were statistically significant ($p < 0.001$) except for Escore in open access journals (*)

Influence. Of these, the most prominent and widely used measure is the IF. While the new measures have become increasingly popular, the questions of which citation measures are most reliable, and "which aspects of journal performance for these measures are assumed to indicate" (Glänzel and Moed, 2002, p. 186) are challenging. It is therefore recommended to look closely at the reliability of the new measures and analyse citations more comprehensively.

The present study indicated that over the past five years IF values of biomedical journals have changed significantly. It is then possible to analyse the extent of these variations and explore the variability of journal citation measures in line with the IF fluctuations.

Roughly, the relative variability of the IF and other journal citation measures in basic and clinical/translational journals decreased while the quality and prestige of those journals developed. Interestingly, the more prestigious journals generally exhibited lower variability in their citation measures, while less prestigious journals with lower impact values had higher variability. Our findings also indicated that the variability of the citation indicators would be more crucial in the journals with lower impacts. Such journals have greater potential to experience dramatic changes in their citation measures, while high impact journals are more stable and their citation changes seem to follow a smoother curve. Further investigation of variability trends according to the journals' publishing status revealed that open access and subscription journals followed similar patterns.

The between-citation indicator comparison of variability indicated that IIF had the biggest reduction in the relative values of the variability against the growth of the impact. IF and IF5, while still indicating changes over impact level, presented a much smoother curve. These data indicate that IF and IF5 in particular can produce similar results. These data are consistent with the early investigations which showed that the distributions of IF5 were very similar to the distributions of the traditional IF (Campanario, 2010; Franceschet, 2010). It seems that expanding the size of the measurement window from one year of standard IIF to the five years of IF5 can mitigate some of the statistical variations. These data are also consistent with the findings of Amin and Mabe (2000) that expanding the size of the measurement window can reduce the variability of citation measures.

Escore in particular produced similar patterns with IF changes in basic, clinical/translational and subscription journals. Previous investigations indicated strong correlations between the Escore and IF values (Campanario, 2010; Rizkallah and Sin, 2010). Escore is a new citation measure which considers the quantity of citations as well as their quality by assigning weights to the sources of citations (Rizkallah and Sin, 2010). It seems that Escore addresses the shortcomings of the traditional IF by indicating the prestige, reputation and influence of biomedical journals through the prism of considering both the quality and quantity of citations to the journals' papers. These findings also indicate that improvements in IF, when the quality of citations is considered, tend to distribute similarly in biomedical journals. Changes in these improvements also tend to distribute similarly across different impact levels.

We also found that CHL was the measure with greater reliability than others. CHL was among the new measures added to JCR to overcome the IF limitations (Bornmann *et al.*, 2011; Krell, 2012). This finding led to suggestions to use CHL as a reliable journal citation indicator (Campanario, 2010; Yu *et al.*, 2010; Kuo and Rupe, 2007). CHL provides information on the length of time during which papers are used by the scientific community and continue to have an impact on science. CHL describes the number of years needed to reach 50 per cent of the total citations of a journal. In other words, it represents the time during which papers in the journal continue to receive citations (Bornmann *et al.*, 2011). Primary investigations indicated that the overall variations of CHL could be partly explained by the journal types and fields of science. Higher CHL values are expected in humanities and social sciences, where the rate of discoveries and novelty is low (Leydesdorff, 2008). Moreover, dramatic changes in CHL values might be relevant to the journal type as a primary research journal might have a longer CHL than a journal that provides rapid communication of current information (Ha *et al.*, 2006; Leydesdorff, 2008).

Our results also suggest that open access and subscription journals followed similar trends in terms of their impact measure variability. While open access journals have the potential to accelerate the access, dissemination and recognition of research findings (Eysenbach, 2006) our results indicated that open access and subscription journals follow similar variability trends in their impact measures. With the growing number of open access journals in the Web of Science database and the increasing interest of authors in publishing open access papers, emerging literature has explored the citation advantage of open access journals across different subject categories and geographic areas. Biomedical sciences account for nearly 55 per cent of open access journals and for 74 per cent of papers published across different subject categories (Walters and Linvill, 2010; Bjork and Solomon, 2012). Moreover, evidence shows that biomedical open access journals receive as many citations as subscription journals. Our findings extended this earlier finding that open access journals follow similar trends to subscription journals in biomedical sciences (Bjork and Solomon, 2012; Davis, 2009).

The most unexpected finding in this study was the failure to provide evidence on the effect of open access publishing on the overall changes in CHL and specifically Escore contrary to the trends indicated by other impact measures. The role CHL and Escore play in open access journals is not clear and further investigations are recommended to explore the overall changes of journal impact measures across open access and subscription journals in biomedical sciences.

In our study almost all calculated coefficients were not only statistically significant but they were also high enough to present substantive associations. However, there are some limitations which should be pointed out here. First, although the entire subject categories included in our study were representative of the subjects of their journals there might be some other categories which had few relevant journal titles that were not included. Second, we used the first subject for those journals placed under two or more subject categories which might be a source of selection bias in our study. However, the number of those journals was very small. Third, there are other citation measures for journal quality such as PageRank based measures and the SCImago Journal Rank indicator that were not considered in the present study. Fourth, we did not determine the reasons for the rise and fall of IF and other journal citation measures. However, previous studies suggested that the value of IF and other citation measures are affected by some social and statistical factors including subject and type of the journal, the average number of authors per papers, type of published papers, size of the journal and the size of citation window (Amin and Mabe, 2000; Ha *et al.*, 2006; Glänzel and Moed, 2002). As we have classified journals into two broad categories of basic and clinical/translational sciences and citation patterns of different journals differ even within a subject category, further investigations are recommended to explore the variability of scholarly journals within subject categories and also the focus of the current study could be shifted to technical journals.

In summary the present study indicates that journal citation measures can produce dissimilar variability trends and thus highlights the importance of using multiple measures in evaluating the performance and influence of biomedical journals. It is highly recommended to use IF in the context of other measures such as Escore, Influence and CHL in evaluating the impact of journals in biomedical fields. It is also suggested to perform a similar investigation for technical journals or other fields of science (e.g. humanities and social science journals) to explore the potential causes of variability in the journal citation measures.

Conclusion

This paper revealed that the variability of the journal citation indicators decreased with improvement in the prestige of the journals. It is therefore expected to observe dramatic changes in citation indicators in less prestigious and lower quality journals. It was indicated that the variability of the journal citation measures was dependent on the quality of a journal. As journal citation measures values fluctuate from year to year, it should be taken into consideration whether a journal has truly dropped or risen in quality in terms of changes in its IF values (Amin and Mabe, 2000). It is not recommended to use IF as a sole measure for journal quality. CHL and Escore were suggested as more reliable measures indicating a few changes in the study period and across different impact levels. These measures are also recommended to provide a more reliable and comparable indication of impact across different subject categories.

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Appendix

Table AI. Definition and explanation of journal citation indicators and statistical terms

	Definition/calculation
Journal citation indicator	
Impact factor (IF)	The classic two-year impact factor (IF) of an ISI journal is defined as "Total citations in a JCR year to papers published in an ISI journal in the previous 2 years/Total papers published in an ISI journal in the previous 2 years" (Chang *et al.*, 2011, p. 4). The IF is typically intended to measure how often on average authors cited papers from a particular journal
Immediacy index (IIF)	IIF, a zero-year impact factor of an ISI journal, is calculated annually, and is defined as "Total citations to papers published in a journal in the same year/Total papers published in a journal in the same year" (Chang *et al.*, 2011, p. 5)
Five-year impact factor (IF5)	The IF5 of an ISI journal is calculated annually, and is defined as "Total citations in a year to papers published in a journal in the previous 5 years/Total papers published in a journal in the previous 5 years" (Chang *et al.*, 2011, p. 5)
Cited half-life (CHL)	ISI defines CHL as: "The cited-half life is the number of publication years from the current year which account for 50 per cent of current citations received. This figure helps you evaluate the age of the majority of cited papers published in a journal. Each journal's cited-half life is shown in the Journal Rankings Window. Only those journals cited 100 or more times have a cited-half life." (Ladwig and Sommese, 2005, p. 528)
Eigenfactor score (Escore)	Escore is intended to consider both quantity and quality of citations and reflects the idea that citations from highly cited journals weigh more than those from less-cited journals. Its algorithm is similar to Google's PageRank (Bornmann *et al.*, 2011). The Escore is a modified IF5, and is calculated annually to capture the prestige of a journal. The Escore algorithm (see www.eigenfactor.org) effectively ranks journals according to citations and the length of time that researchers are logged on to a journal's web site (Chang *et al.*, 2011, p. 5)
Article Influence (Influence)	Article influence measures the relative importance of an ISI journal on a paper basis. "The Article Influence Score is calculated as a journal's Eigenfactor Score divided by the number of articles in that journal, normalized so that the average article in the Journal Citation Reports has an Article Influence Score of 1" (Chang *et al.*, 2011; West *et al.*, 2010, p. 238)
Statistical terms	
Coefficient of variation (CV)	CV is defined as the ratio of standard deviation to the mean. It is often presented in percentage form, e.g. 10 per cent. The CV for a particular variable describes the dispersion of the variable in a way that it does not depend on the variable's measurement unit. The higher the CV, the greater the dispersion in the variable. The CV is commonly used to compare the dispersion in different sets of data especially the data which differ in their means or in their units of measurement

(*continued*)

Table AI.

	Definition/calculation
Multilevel regression models	Multilevel models are typically used in research designs where data for participants are organised at more than one level (groups). For instance we may model visits to the doctor within groups of different hospitals. In this study, included journals are classified in several groups according to their subject and impact level, therefore making it possible to perform multilevel models in presenting statistical associations
Coefficient of regression	Regression models create an equation so that variables could be predicted by data. "When the regression line is linear ($y = ax + b$) the regression coefficient is the constant (a) that represents the rate of change of one variable (y) as a function of changes in the other (x); it is the slope of the regression line" (Farlex Inc., 2012)
Confidence interval	In addition to point estimate of (a), we may also obtain confidence interval estimates of these parameters. The width of these confidence intervals is a measure of the overall quality of the regression line. For example, 95 per cent confidence intervals on the slope (a) for each sample, then 95 per cent of those intervals will contain the true value of (b)

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