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Impact factor and electronic versions of biomedical scientific journals

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Background and Objectives. The development of electronic editions of scientific journals and the rapid spread of scientific information might modify the pattern the bibliographic citations, and thus the impact factor and *quality* of journals. We assessed changes in the impact factor over years of a number of journals and whether the presence of an electronic version of the journal was associated with the impact factor score.

Design and Methods. This is a retrospective longitudinal study. The availability of journals (table of contents (TOC), abstracts, full text and free full text) on Internet, in years 1995-2000, was assessed between December 2000 and January 2001. The first 20 top-journals from 8 subject categories were included. Changes in impact factor over time and association with Internet availability were modeled.

Results. Overall, 118/139 journals (85%) had their TOC on the Internet, of these 107 (77%) had abstracts, 97 (70%) had full text and 33 (24%) free full text. The median impact factor for all journals was 1.65, 2.08, 2.10, 2.21 and 2.35 for the years from 1995 to 1999, respectively. This increase was statistically significant, with differences among subject categories. The presence of TOC, abstracts and full text on the Internet was also significantly associated with higher impact factor, after accounting for time and subject category.

Interpretation and Conclusions. The impact factor has been used for assessing the quality of journals. We identified a new limitation of this indicator: the impact factor seems to be related to the amount of circulation of information through Internet. This could be a temporary limitation, associated with diffusion of journals on, and spread of Internet.

Key words: Internet, impact factor, scientific documentation.

In the last few years we have observed an astonishing increase in the electronic editions of scientific journals, hand in hand with the development and diffusion of the Internet and of a series of transmission and visualization standards for data and images (ftp, pdf, html, etc.). The impact factor is an indicator of a journal's quality and is based on the overall citations of the papers published in the journal over a certain time period. An impact factor score is attributed to the 4000 and more scientific journals indexed by the Science Citation Index©.[1,2] It is the *presentation card* of each scientific journal, an indicator of its quality, which is based on the acknowledgment of its value by the scientific community through citations. The development of electronic editions and the rapid spread of scientific information might modify the pattern of bibliographic citations in scientific papers. This in turn could influence the impact factor score and the *quality* of the journal. Here, we assess the changes in the impact factor over the last few years of a large number of journals. Furthermore, we examine whether the presence of an electronic version of a journal is associated with the value of the impact factor score.

Design and Methods

Study design

This was a retrospective longitudinal study.

Impact factor

The value of the impact factor was derived from the Journal Citation Report Science Edition (JCR©), a yearly publication of the ISI (Institute for Scientific Information, Philadelphia, USA). Each year an impact factor is calculated from the ratio of the number of citations of the journal over one year (e.g. in 1999) to the number of articles published by the same journal in the two preceding years (e.g. in 1997-1998). Impact factors for years 1995 to 1999 (last published) were considered. The journals included in the study were those ranking among the first

20 of each of the following subject categories in 1998: cardiac and cardiovascular system; medicine, general and internal; medicine, research and experimental; multidisciplinary sciences; otorhinolaryngology (orl); surgery; hematology and transplantation. There were only 12 journals in the transplantation category, thus a total of 152 journals were evaluated. Since some journals were included in more than one subject category, the actual number of journal titles was 139. For the purposes of this study, the 1998 classification of journals was used throughout the entire time span considered, independently of the actual inclusion of the journal.

The full list of journals considered here is available from the authors upon request.

Internet

The availability of the journal on the Internet in the different years considered (1995 to 2000) was assessed cross-sectionally between December 2000 and January 2001. The presence of table of contents (TOC), abstracts, full text and free full text were evaluated. It should be underlined that no information was usually recordable on Internet appearance time.

Google.com was utilized as a search engine, the rationale for this choice being its widespread use and good power. Both the title of the journal and ISSN were considered for the search strategy. Only journal sites with free access were included, i.e. those for which no subscription to the journal or package of full text journals was required.

Statistical analysis

Impact factor values are described, over years and according to subject categories, with median and quartiles in the tables and in the body of the text. Categorical variables are reported as absolute and relative frequencies.

Changes in the impact factor over the years were modeled by means of a linear regression model, with calculation of Huber-White robust standard errors to account for intra-journal correlation in time. First a univariate model was fitted, with the effect of time only; then a term for the subject category was included and thirdly the interaction of time and the latter was tested. Finally, the effect of time on the impact factor was assessed within each category, as this was demonstrated to be an effect modifier.

To test the association of the impact factor with the presence of the journal on the Internet in terms of TOC, abstracts, full text and free full text, other series of linear regression models were fitted. Huber-White robust standard errors were calculated. The role of the *journal on the Internet* was assessed in a univariate model. It was then controlled for time and area, these being potential confounders of the relationship between *journal on the Internet* and impact factor. The regression coefficient (β) and its standard error (se) are reported, to quantify the ratio between impact factor in the presence and in the absence of *journal on the Internet*.

Data on this association within each subject category are only described, but no inference is drawn because of the sample size, which is too small to account for both *journal on the Internet* and time within categories.

Computations were performed using Stata 7 software (StataCorp, College Station, TX, USA). Two-sided tests were used. A p value <0.05 was retained for statistical significance. The Bonferroni correction of reported p values was be applied for post-hoc comparisons to account for multiple test bias.

Results

Journals and Internet

Overall, 118/139 journals (85%) had their TOC available on the Internet. Of these 107 (77%) had the abstracts, 97 (70%) had the full text and 33 (24%) the free full text. This availability, as cross-evaluated early in 2001, is higher in more recent years, as shown in Figure 1, particularly for TOC, abstracts and full text. The availability of free full text shows a lesser increase.

Impact factor

The median impact factor for all the considered journals was 1.65 (0.84-2.80), 2.08 (1.00-3.51), 2.10 (1.20-3.44), 2.21 (1.63-3.65) and 2.35 (1.48-3.56) for the years from 1995 to 1999, respectively. The largest change of 26% was observed between 1995 and 1996. Regression analysis showed the changes to be statistically significant (p=0.0022; with 1995 vs. 1996 p=0.003 and 1996 vs. 1997 p=0.034; 1997 vs. 1998 and 1998 vs. 1999 $p>0.05$, for post-hoc comparisons). Subject category was demonstrated to be an independent predictor of the impact factor score. Moreover changes over years were different among categories (interaction present). Thus separate models for time were fitted within each subject category; this elicited significant changes ($p<0.05$) in all fields but for the multidisciplinary sciences category (Figure 2).

Internet and impact factor

The relationship of impact factor and the presence of TOC, abstracts, full text and free full text on the Internet is illustrated in Figure 3 for years 1995 to 1999. Higher impact factors were observed when the journal had an electronic version. The median IF values (collapsed over time) were 25% larger (2.25 vs

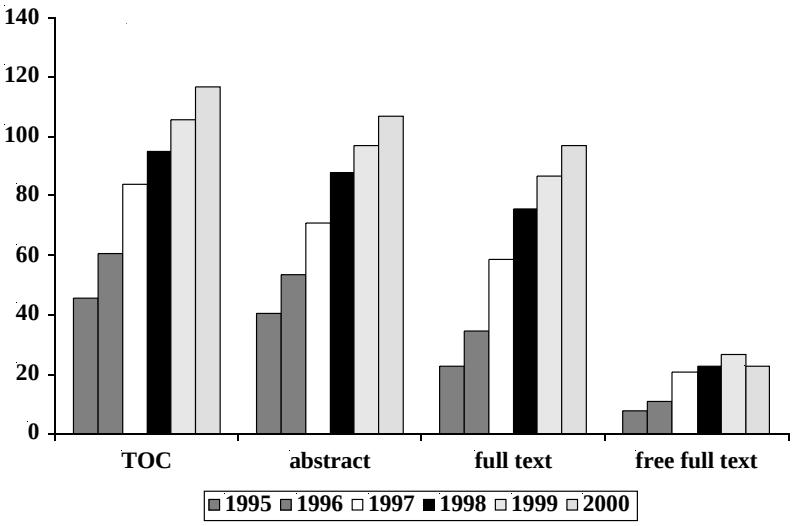

Figure 1. Distribution of the number of journals available on the Internet in terms of TOC, abstracts, full text and free full text in years 1995-2000 as assessed in December 2000-January 2001.

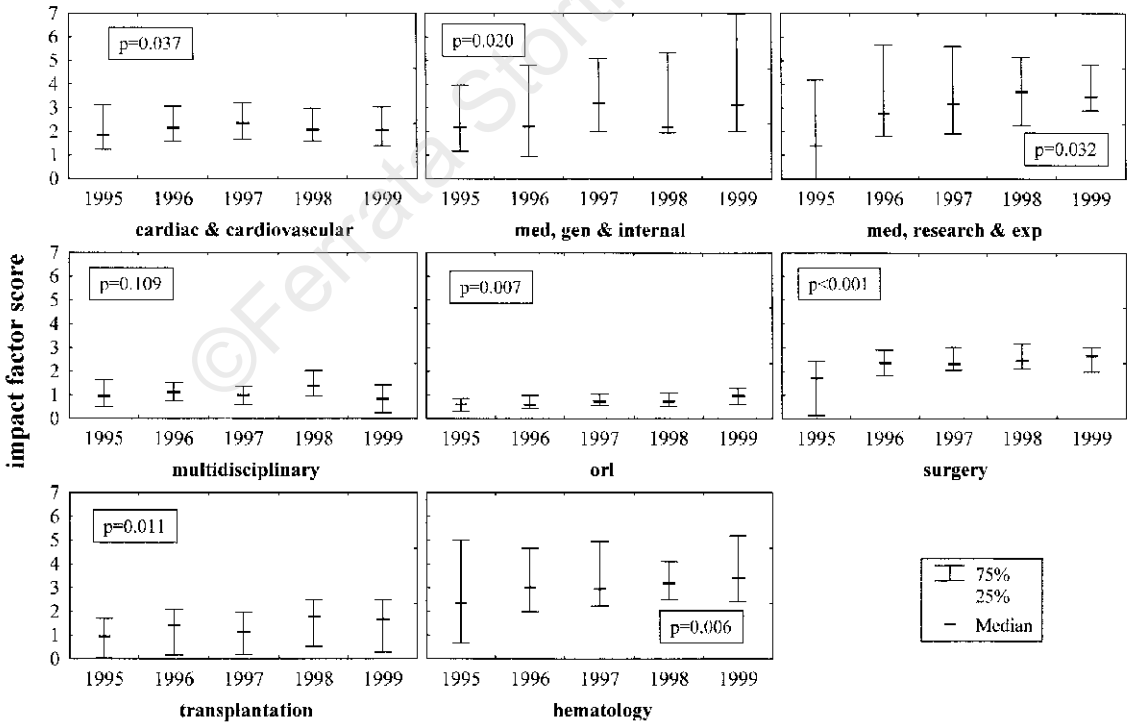

Figure 2. Median impact factor (and interquartile range), according to subject category over years. *p* values for change in time are reported for each subject category.

Table 1. Median impact factor (interquartile range) by subject categories over years, according to availability of full text on the Internet.

	Internet	*N*	*1995*	*N*	*1996*	*N*	*1997*	*N*	*1998*	*N*	*1999*
Cardiac and cardiovascular system	no	11	1.68 (0.92-2.10)	11	1.68 (0.98-2.40)	8	1.66 (1.14-2.39)	7	2.08 (1.69-2.85)	5	1.99 (1.66-2.11)
	yes	9	2.78 (2.24-4.34)	9	2.87 (2.37-3.47)	12	2.98 (2.20-5.14)	13	2.60 (2.14-3.00)	15	2.44 (2.02-3.23)
Medicine, general & internal	no	15	1.84 (1.17-3.64)	14	2.17 (1.46-3.86)	11	2.01 (1.69-4.78)	8	1.99 (1.95-2.85)	7	2.20 (1.85-3.38)
	yes	5	4.55 (3.75-9.92)	6	8.08 (3.83-17.95)	9	4.24 (2.24-12.05)	12	5.36 82.21-10.21)	13	5.14 (2.25-10.10)
Medicine, research & experimental	no	20	2.08 (0.00-4.18)	17	3.97 (2.15-5.93)	15	2.62 (1.82-5.03)	12	3.57 (2.24-4.45)	7	3.06 2.90-4.16)
	yes	0	–	3	1.89 (1.77-9.49)	5	6.00 (2.80-9.67)	8	4.57 (2.85-12.60)	13	4.19 (3.26-6.40)
Multidisciplinary sciences	no	18	0.99 (0.75-1.64)	16	1.05 (0.81-1.36)	10	1.10 (0.90-1.36)	10	1.45 (0.96-2.00)	10	0.76 (0.00-1.42)
	yes	2	5.90 (1.27-10.52)	4	1.47 (0.98-5.93)	10	1.27 (1.07-9.04)	10	1.15 (0.77-9.82)	10	1.56 (0.93-10.26)
Otorhinolaryngology	no	19	0.56 (0.28-0.86)	18	0.58 (0.44-0.98)	16	0.66 (0.50-1.05)	12	0.91 (0.58-1.09)	11	1.05 (0.65-1.27)
	yes	1	0.74 (0.74-0.74)	2	0.62 (0.35-0.89)	4	0.88 (0.71-1.05)	8	0.63 (0.46-1.23)	9	0.74 (0.49-1.31)
Surgery	no	14	1.71 (1.42-2.50)	10	2.46 (2.20-2.93)	8	2.37 (2.20-3.14)	6	2.48 (2.38-3.52)	5	2.81 (1.93-3.46)
	yes	6	2.15 (1.57-2.61)	10	2.29 (1.86-2.87)	12	2.18 (2.06-3.02)	14	2.46 (2.19-2.95)	15	2.73 (2.24-3.01)
Transplantation	no	12	1.28 (0.10-1.75)	12	1.44 (0.17-2.07)	10	0.89 (0.00-2.18)	9	1.51 (0.32-2.8)	7	1.25 (0.49-2.90)
	yes	0	–	0	–	2	1.45 (1.21-1.68)	3	1.87 (1.75-2.11)	5	1.75 (1.60-2.28)
Hematology	no	16	2.22 (1.26-3.88)	15	2.94 (2.21-4.27)	11	3.37 (2.28-3.91)	7	2.88 (2.41-3.47)	5	2.81 (2.00-4.93)
	yes	4	6.77 (3.76-8.41)	5	4.96 (2.53-7.62)	9	3.23 (2.34-8.44)	13	3.21 (2.68-4.26)	15	3.56 (2.54-5.41)

1.81) for TOC; 44% larger (2.34 vs 1.63) for abstracts; 53% larger (2.59 vs 1.69) for full text availability on the Internet. Regression models showed TOC to be significantly associated with the impact factor at univariate analysis (β=1.92 (se 0.54); p=0.0005). This association was also shown to be independent of time and subject category (β=1.76 (se=0.56); p=0.002). Similarly, abstract availability was associated with the impact factor score both at univariate (β=2.06 (se=0.54); p=0.0002) and at multivariate analysis (β=1.85 (se=0.58); p=0.002). Full text availability was also associated with the impact factor (β=2.32 (se=0.55); p<0.0001) and this association was independent from time and subject area (β=2.36 (se=0.60); p=0.001). Finally, a similar behavior was observed for free full text availability (β=2.63 (se=0.85); p=0.0025 and β=2.16 (se=0.90); p=0.02) at univariate and multivariate analysis, respectively.

Table 1 reports the median values of the impact factor for each subject category over years, according to the presence or absence of full text on the Internet. Findings in each category tend to reflect the general behavior illustrated above. They show higher values of the impact factors in the presence of full text on the Internet (except for surgery and otorhinolaryngology) and an increase of the number of available journals over years. The degree of variability observed could be attributed mainly to the small sample size obtained, when considering subgroups.

Discussion

In this paper we have shown an increase of the availability of journals on the Internet in terms of TOC, abstracts, full text and free full text. Whereas for the former two, PubMed (and some commercial databases) have already allowed Internet searches for literature, full text availability might represent a true change. In fact, PubMed was and is used to search by means of keywords, with a particular problem in mind. However, the electronic version of journals seems to be increasingly replacing the printed version in the continuous education of the medical researcher, during which a global approach to bibliographic information is used. Both ways of referring to literature complement each other.

As the availability of journals increased, the impact factor observed over these years climbed from 1.65 to 2.35. The main increase was noted between 1995 and 1996. One could wonder whether this represents a real variation or a random fluctuation of the values of the impact factor. We favor the former hypothesis: the greater amount of information available on the Internet, as elicited here, would induce more citations; the expansion of the Internet would further increase the number of users and thus the rate of citations. Consequently the impact factor would also grow. Furthermore the change observed followed the *25% increase* rule of thumb reported by Amin *et al.*[3] to distinguish real from random fluctuations of the

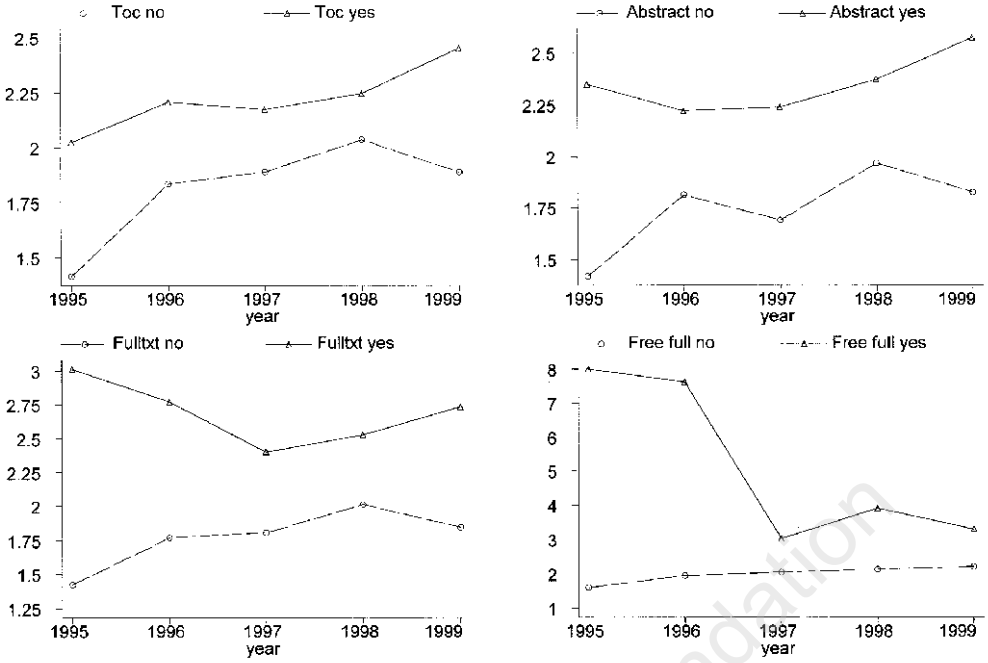

Figure 3. Time trend of median impact factor according to availability on the Internet of TOC (upper left), abstracts (upper right), full text (lower left) and free full text (lower right).

impact factor.

Interestingly, we show the impact factor increased differently according to the subject categories. This is to be related to the high variability of this index across subject fields as already noted,[3] and within subjects' fields as illustrated in Figure 2.

To our knowledge no previous reports have been published that deal with the association of the availability of bibliographic information on the Internet and the impact factor. In 1998 Tsay[4] showed a weak association (Spearman R=0.35, $p<0.05$) between frequency of use of 814 journals in a library and journals' impact factor, ranging from 0.27 to 0.54 according to 4 different areas. In 1996 Garfield denied the influence of circulation of information on impact factor.[5] Our data demonstrate higher values of the impact factor in the presence of the journal on the Internet. This is true for TOC, abstracts, full text and free full text, at univariate analysis and after controlling for the confounding effect of year and subject category.

The implications of free full text availability should be considered separately. Only a few journals offer this opportunity; some of them include it for free trial periods only, others allow free consultation of old back issues only. This can explain the considerable fluctuation observed in this group, as compared with changes associated with TOC, abstracts and full text (Figure 3). However, in the last years, access to full text has been made easier to researchers thanks to electronic campus subscriptions. As mentioned before, the greater availability of Internet resources and the higher number of users could explain the higher impact factor attained by those journals that have Internet full text. On the other hand, one could argue that mainly journals with a high impact factor are made available on the Internet. The shape of the impact factor curve over years in the presence of full text on the Internet (Figure 3) and the number of journals (Figure 1), suggests that this might have been true only at the very beginning of our observation period. The drop in the curve could coincide with the entry of journals with lower impact factors. No definite answer can be given right now, as we could only cross-sectionally assess the availability of journals on the Internet. However, at all times the curve for *Internet yes* stays above that for *Internet no*.

Study limitations

The main study limitation is related to the design that allowed longitudinal assessment of the impact factor through the JCR but only a cross-sectional assessment of the Internet availability: this particular information was not collected prospectively year by year. Moreover journal websites did not generally mention the time of Internet updates (particularly for back-issues). Therefore we were not able to establish a causal relationship formally: which comes

first, increase of Internet journals availability or increase of impact factor?

Conclusions

The impact factor has been used for years to evaluate a journal's quality. It has been used by librarians to identify journals to purchase and by researchers to identify journals to which to submit their articles.[6,7] In many research and academic settings, the impact factor is also used to fund research based on the evaluation of the quality of the several groups of researchers. Thus, it is particularly relevant to be aware of the appropriate use of the impact factor and to understand its limitations. The impact factor has been widely criticized for a series of pitfalls in its calculation, such as choice of articles included in the denominator;[8] choice of journals included in the source;[9] length of impact factor window;[3] choice of type of article included in the numerator;[10] use of negative citations.[11] Moreover the use and misuse of impact factors for evaluating a single researcher or group or comparing different specialties has been reported.[3,5,10-12] One possible and new limitation of this indicator is highlighted by our work, showing that impact factor values seem to be related to the amount of circulation of the information through the Internet. This could, perhaps, be a temporary limitation, that might disappear when all journals are able to offer an electronic version of their journal on a Website and when the Internet is available to all medical researchers. In that case we could expect levels of impact factors to undergo a general increase, related to the higher number of citations. Alternatively, we could witness a dichotomization of impact factor values, according to adherence or not to the National Institute of Health proposal for a public repository of free full text, as illustrated at *http://pubmedcentral.nih.gov* and other initiatives.[13,14]

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MC: conception and design, analysis and interpretation of data; drafting the article and revising, final approval of the version to be published; VP: conception and design, final approval of the version to be published; GG: conception and design, final approval of the version to be published; CK: conception and design, analysis and interpretation of data; drafting the article and revising, final approval of the version to be published.

Disclosures

Conflict of interest: none.

Redundant publications: no substantial overlapping with previous papers.

Manuscript processing

This manuscript was peer-reviewed by two external referees and by Professor Mario Cazzola, who took the final decision to accept this paper for publication. Manuscript received July 12, 2001; accepted September 12, 2001.

Potential implications for clinical practice

The availability of a journal on the Internet may have implications for research policy and may influence researchers to choose such journals for their papers, in order to allow their work to be read by the largest audience.

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