The h index as a research performance indicator

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Abstract In 2005, Jorge Hirsch introduced a new indicator for quantifying scientists' research output. His h index was proposed as an alternative to other bibliometric indicators such as citations per paper. It is based on a scientist's lifetime citedness, which incorporates productivity as well as citation impact (an all-in-one metric). This article gives an overview of different contexts of the h index application, its advantages and disadvantages, h index variants, its convergent validity, and future directions of research.

Key words Bibliometrics; impact factor; *h* index; science editing

The essence of scholarship is communication.[1] Scientists having important new research results publish them in the international journal literature.[2] Each new result is positioned with respect to the results published by others through the process of citing. As only valuable results are cited, the number of citations a paper receives reflects its usefulness to others.[3] Thus, scientific papers contain two quantities – "the increment of new science and the credit for its discovery".[4]

The most obvious tool available to measure quality in science is the publication list of a scientist – the number and the impact of his/her publications. Measuring quality of scientific research becomes even more important in a time when scientists increasingly compete for limited funding. In 2005, Hirsch introduced a new indicator for quantifying the research output of scientists.[5,6] This index was proposed as an alternative to other bibliometric indicators such as citations per paper and is defined as follows: "A scientist has index *h* if *h* of his or her N_p papers have at least *h* citations each and the other $(N_p–h)$ papers have ≤*h* citations each".[5] The *h* index can now be calculated automatically for any publication set in Web of Science (Thomson Reuters) and SciVerse/Scopus (by Elsevier). Abramo et al[7] offer subject-specific "benchmarks for those who wish to compare their individual performance to those of their colleagues in the same subject field". However, the *h* index differs, depending on what publications a database covers and analyzes.

Applying the *h* index

The *h* index is based on a scientist's lifetime citedness,[8] which incorporates productivity as well as citation impact (an all-in-one metric). All papers in a publication set which have at least *h* citations are called the "Hirsch core"[9]; publications in the core have the greatest impact.[10] The *h* index is approximately proportional to the square root of the total citation counts and linearly proportional to the total number of publications.[11] To get a higher *h* index, an individual needs at least 2*h*+1 extra citations.[12] For example, to increase the index from 4 to 5, at least 9 citations are needed. The higher the *h* index the more citations are needed to increase it.[11] It means that the difference between higher *h* index values (25 and 26, for example) is much greater than between lower values (4 and 5, for example).[13]

Currently the *h* index is used to measure research output not only of scientists but also research groups,[14] scientific facilities,[15] and countries.[16] The index can be calculated in the same way in all cases or based on successive *h* indices at higher aggregate levels[17]: "The institute has an index h_2 if h_2 of its *N* researchers have an h_1-index of at least h_2 each, and the other $(N–h_2)$ researchers have h_1-indices lower than h_2 each".[18] Braun et al[19] recommend using the *h* index to measure journals' output as an alternative to the impact factor provided by Thomson Reuters[20]: "Retrieving all source items of a given journal from a given year and sorting them by the number of times cited, it is easy to find the highest rank number which is still lower than the corresponding times cited value. This is exactly the *h*-index of the journal for the given year."

The considerable impact of the *h* index on both bibliometricians and on the global scientific community is due to its simplicity and intuitive meaning.[11] In recent years many studies analyzed different aspects of the indicator.[6,21-29] Up to the end of 2010, the paper by Hirsch[5] had been cited approximately 660 times, reflecting its popularity.

Disadvantages of the *h* index

There are some disadvantages of the *h* index. Combining publication and citation rates in one index is sometimes criticized.[30,31] "The problem is that Hirsch assumes equality between incommensurable quantities. An author's papers are listed in order of decreasing citations with paper *i* having *C*(*i*) citations. Hirsch's index is determined by the equality, *h*=*C*(*h*), which posits equality between two quantities with no evident logical connection".[30]

Other critical points are the following.[31]

- Like most pure citation measures the *h* index is field-dependent.
- It can be manipulated by self-citations.
- There is a problem of finding reference standards.
- There are many more versatile indicators for research evaluation.
- It is not easy to collect all data necessary for determination of the *h* index. Often a scientist's complete publication list is necessary to discriminate between scientists with the same names (a precision problem).

Some of the disadvantages[31] are more specifically related to the *h* index itself.

- The index disadvantages newcomers since their publication and citation rates are relatively low.
- It allows scientists to rest on their laurels since the number of citations received may increase even if no new paper is published.

• It is useful for comparing best scientists only. Its power for distinguishing amongst average scientists is not acceptable.
• It lacks sensitivity to performance changes: it can never decrease and is only weakly sensitive to the number of citations received.

Moreover, the *h* index does not take into account details of a citation record.[22,32] As the *h* index captures only a part of the record, scientists with substantially varying records can present with the same *h* index value: "Think of two scientists, each with 10 papers with 10 citations each, but one with additional 90 papers with 9 citations each; or suppose one has exactly 10 papers of 10 citations and the other exactly 10 papers of 100 each".[32] To overcome this limitation of the *h* index, Bornmann et al[33] introduced an approach providing additional information to the *h* index: h^2 lower, h^2 center, and h^2 upper allow quantifying three areas within a scientist's citation distribution: the low impact area (h^2 lower), the area captured by the *h* index (h^2 center) and the area of publications with the highest visibility (h^2 upper).

The *h* index variants

Numerous additions and variants of the *h* index have been proposed in recent years. Of these, the *g* index by Egghe[34] has received most attention, while many others, including the *e* index by Zhang[35] and the *n* index by Namazi and Fallahzadeh[36], still await validation. The *g* index is the highest number g of papers that together receive g^2 or more citations, meaning that $g \geq h$.[34] The *g* index weights highly cited papers more than the *h* index.[27] Hirsch himself proposed ħ ("hbar") as a *h* index variant defined as the number of papers of an individual with citations greater than or equal to the ħ of all co-authors of each paper, taking into account the effect of multiple co-authors.[37]

We determined the extent to which different variants of the *h* index add information not provided by the original index.[38-41] Though the proposed variants differ from the *h* index in many ways, they still correlate with the original index. Importantly, the results of the first meta-analysis on the *h* index and its variants yielded a strong correlation between the *h* index and its 37 variants (ranging between 0.8-0.9), suggesting that most of the proposed variants are redundant.[41] However, some variants are less strongly correlated with the *h* index. A good example is the *a* index measuring citation intensity in the *h* core (papers with at least *h* citations).[42] Also, based on factor analyses, we demonstrated that there are two independent types of the *h* index variants: those describing the number of papers in the most productive core*s* – *h* index or *g* index (output oriented indexes), and those that depict the impact of the papers in that core – *a* index or *m* index (citation impact oriented indexes).[38,40] These two index types complement each other.[43]

Convergent validity of the *h* index

When evaluating researchers, an important issue arises as to whether the results of bibliometric assessment by the *h* index are comparable to the assessment by peers, the so called convergent validity of the *h* index. We demonstrated that the average *h* index of accepted and rejected applicants for biomedical research fellowships differ statistically significantly.[28,44] Van Raan[14] found that the *h* index values are in agreement with peers' opinion in the field of chemistry. Also, the *h* index predicted academic promotion in urology.[45] Similar good correlation was found between the 2008 UK Research Assessment Exercises grade points and *h* index values.[46]

Future directions of *h* index research

Further studies are needed to examine the significance of the *h* index in different fields of application. According to Mingers,[47] some priorities for future related studies are:
• Validity of the *h* index in large and diverse groups of researchers
• Comparability of the *h* index across and within social sciences
• Validation of the *h* index by more sophisticated bibliographic analyses.

Using the *h* index wisely

The following points should always be considered when the *h* index is used for evaluating scientific output.
• Like other bibliometric measures, the *h* index depends on the length of an academic career, and it should be used for comparing researchers of similar age.
• The *h* index values are dependent on subject category and should be used within one discipline.
• Evaluating research performance on the basis of a single measure is not acceptable, and therefore the *h* index should not be viewed as an omnipotent measure. The number of highly cited and non-cited papers should be taken into account. In addition to bibliometric indicators, evaluations should provide a measure of concentration such as the Gini coefficient or the Herfindahl index, to assess the distribution of citations.[48]
• Bibliometric indicators should be used to support peer review.

Conclusion

The *h* index can act as an alternative to the journal impact factor, overcoming some of the latter's disadvantages, particularly its short citation time window. It can be used by science editors to compare research performance of individuals and institutions. Simplicity and promptness of the index make it particularly attractive, provided that limitations are kept in mind.

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Science editing for medical journals: two perspectives

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Abstract We examine several current issues of relevance to science editing for medical journals. We do so from the perspective of a former journal editor and from that of a current user, a physician responsible for training students to read critically. As Canadians, we bring a North American perspective to the discussion. Within this context, this paper addresses three topics that are likely to be viewed differently from our respective backgrounds. They are open access, peer review, and the role of publications in the context of knowledge transfer and the implementation of research findings. We believe these elements are interwoven and that the first two determine how well findings are implemented. This is equally true for clinicians as it is for researchers, and these relationships also appear to apply internationally.

Keywords Open access; peer review; knowledge transfer; clinical applications

Charles Pless, clinician teacher, writes:

My view is that of a typical clinical consumer of the medical literature. I work as a primary care physician at a university-affiliated clinic and in an emergency department. As well, I regularly supervise medical students and residents, and this involves journal clubs and case discussions. Our students have some training in epidemiology and biostatistics during their preclinical years, and during their residency they use computer-based modules to enable them to critically appraise medical articles. But it is the rare student who has a genuine interest in critiquing what appears in medical journals.

Part of the reason for this lack of interest relates to the fact that most of my own and my students' use of the literature is patient-driven. A patient has a particular problem and we search for an answer. Rarely will students search print journals; instead they head to the computer. The first destination is often the online textbook "UptoDate".[1] This is popular because it is easy to use, reliable, and has a solid reputation. For more in-depth research a Medline search may be conducted. Cochrane reviews are also popular, as are collections of guidelines.

What most of these have in common is that they are secondary sources; someone else has done the work of digesting the primary articles and judging their validity. They have synthesized a bottom-line answer to the basic question: "what should I do with this patient?" Where this opinion came from (and how) is rarely of interest to the busy medical student and future busy physician. That said, I assume authors of texts like UptoDate rely heavily on papers in well reviewed, highly reputable journals.

Occasionally, students are asked to choose a paper to present at a journal club or for a research project and will then have to evaluate it critically. I usually encourage students to choose from among well-known peer-reviewed frontline journals, explaining that a researcher with a good study will generally prefer to publish in the "best" journal. But more and more the lines between "good" and "bad" journals are blurred. Much questionable research is published in supposedly reputable journals, and occasionally we find good research appearing in apparently inferior publications. This leads me to question the importance of peer review and whether open access provides results comparable or superior to what appears in print journals.

Open access

On this topic I have mixed views. Students are among the intended beneficiaries of this publishing innovation that provides easy and free access to medical research. But in fact most medical students have ready access to journals online