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Measuring the impact factor of individual researchers in biomedical disciplines

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The authors propose an algorithm for calculating the cumulative personal impact factor of the publications of any researcher whose research activity involves reporting findings in scientific journals or books in the researcher's field of specialization. This algorithm takes into account the number of times that each published article or book is cited, self-citations, the position of the researcher's name in the authorship list of each article or book chapter, and the density of this cumulative impact in relation to the researcher's total production. In addition, it takes into account the type of article or book assessed (review or original research paper), and the length of time since the researcher's last publication.

This algorithm could be useful for the evaluation of the investigational quality of the subjects, in personnel selection processes in which the candidate's research performance comparisons of the personal scientific influence of various subjects and different research centers.

Key words: Personal impact factor, Citation, Measure, Scientific production, Bibliometry

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Evaluación del factor de impacto personal de cada investigador en disciplinas biomédicas

Los autores proponen un algoritmo para calcular el factor de impacto acumulado personal de las publicaciones de cualquier investigador cuya actividad exija informar de sus hallazgos en revistas científicas y en libros de su especialidad. Dicho algoritmo tiene en cuenta el número de citas que recibe cada artículo y libro publicado, las autocitas, el lugar que ocupa el investigador entre los firmantes de cada artículo o capítulo de libro, así como la densidad de ese impacto en su producción total. Además, tiene en cuenta el tipo de artículo o libro evaluado (revisiones o investigaciones originales), y el tiempo en el que el investigador ha permanecido inactivo.

Este algoritmo podría ser útil para la evaluación de la calidad investigadora de los sujetos, en los procesos de selección de personal donde se valore su capacidad investigadora, y permitiría comparar la influencia científica personal entre varios sujetos y la de diferentes centros de investigación.

Palabras-clave: Factor de impacto personal, Citación, medida, Producción científica, Bibliometría

BACKGROUND

Indicators to measurably and reliably assess different research activities in the field of medicine in general and other scientific disciplines are becoming increasingly more necessary every day.

Almost sixty years ago, Garfield (1955)[1] began work in this area by developing a simple method for assessing the *impact factor (IF)* of scientific journals. This method has been widely criticized,[2] although it has also proven useful.[3] One criticism is that Garfield's *IF* is not a direct measure of the quality of a journal, but rather of the frequency with which its articles are cited in one year.[4-9] First-rate science can be found in journals not included in the usual bibliographic databases.[10] Another criticism made is that the citation count does not distinguish between citations of research articles and citations of letters or editorials.[4,7,11-14] In addition, the *IF* does not allow different disciplines to be compared because each one has different citation criteria.[15] The *IF* also favors the most developed research areas, or those in which more researchers work, which originates large differences in *IF* between scientific disciplines that do not reflect differences in quality.[15]

Nonetheless, the main problem with the *IF,* aside from the conceptual problems described above, is the strong

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coverage bias of the source databases in favor of journals published in English, meaning that *IF* does not represent international scientific production. This creates a situation in which most of the citations used to calculate *IF* correspond to journals published in English, and articles published in languages other than English are cited less often.[11,12]

On the other hand, the *IF* does not adequately assess the impact, or potential personal influence, of individual researchers.

In addition, little correlation has been found between the number of citations that an article receives (which represents the personal impact of the researcher) and the *IF* of the journal where it was published. On the other hand, a researcher's most cited papers are not always published in journals with a high *IF*.[16]

If an indicator that could assess the personal influence, or impact factor, of scientists in general were available, differences could be established between subjects during recruitment processes, or in the scientific or academic accreditation of universities, health-care systems, research institutes and others. It would also be possible to compare groups of people and evaluate the overall excellence of research centers by adding the scientific performance scores of the individual researchers employed. This is particularly relevant when verifying institutional prestige and planning for investments.

There are several procedures for assessing the scientific performance of individual researchers:

i) *The total sum of published articles.* This figure indicates a researcher's productivity, but says nothing about the researcher's influence on peers. Publishing a lot does not guarantee that the articles will be read or cited.

ii) *The total sum of the impact factors of the journals in which articles are published.* This procedure attributes an impact to the subject that is not derived from the articles per se, but from the journals in which they were published. It is known that 50% of the citations received by a journal are due to only 15% of the articles published in the journal.[4] An author can be published in a journal with a high *IF* without being cited often.[16]

iii) *The total number of citations.* This evaluates an individual's influence. However, it gives no information on the degree of originality, level of coauthorship, or whether the citations correspond to part or of all of the researcher's work.

iv) *The number of citations received by a set of selected articles.* This figure provides information about which articles by a researcher are most frequently cited. Nonetheless, it leaves to the evaluator the arbitrary choice of selecting the number of citations that determine which articles are taken into account.

Some efforts have been made to develop a single indicator to gather information for assessing a given researcher's personal *IF*. Hirsch (2005)[14] proposed the *h*-index for that purpose. The h-index quantifies both the author's productivity and the impact of the literature. However, it ignores the articles cited below the *h*-index value, the degree of coauthorship of the articles, self-citation, and the type of article assessed. Despite its usefulness,[17,18] the *h*-index has been widely criticized.

OBJECTIVE

We propose an *indicator of the visibility,* impact, or personal influence of a researcher that takes into account certain qualitative factors. These factors may be, for example, the number of citations of a researcher's published articles and books, the position of the researcher's name among the authors, the density of the citations in relation to the researcher's total production, the type of article or book involved, self-citation and the time that the researcher has remained unpublished.

DEVELOPMENT

The total production of articles by an author (Pt) can be summarized as shown in Table 1.

A simple way of representing the personal influence of a researcher is the proportion of articles cited in relation to Pt:

$$[1] \quad RC_{\alpha} = \frac{\sum_{j=1}^{k} a_j}{Pt}$$

$\mathbf{RC}_{\alpha}$ represents the density of papers cited out of the individual's total production. Consequently, an $\mathbf{RC}_{\alpha}$ value close to 1.00 reveals that almost all of the articles produced by the researcher have been cited at some time.

This datum is undoubtedly important. However, $\mathbf{RC}_{\alpha}$ says nothing about the number of times an author is cited, which would represent the author's influence or impact more rigorously. In the same way that the Garfield *IF*[1] represents the relation between the number of citations received by a journal in a given time period and the total number of articles published in the same time period by the journal; the raw *personal impact factor* ($\mathbf{RC}_{\beta}$) of a researcher throughout his or her productive life is represented by the total number of citations received by the researcher's articles divided by the total number of published articles:

$$[2] \quad RC_{\beta} = \frac{\sum_{j=1}^{k} (a_j \cdot n_{cj})}{Pt}$$

Table 1	Bibliographic production of an author		
Articles published	In high-impact journal	In low-impact journal	Total
Cited	$a_1, a_2, a_3, a_4 \ldots$	$\ldots a_{k-2}, a_{k-1}, a_k$	$\sum_{j=1}^{k} a_j$
Not cited	$w_1, w_2, w_3, w_4 \ldots$	$\ldots w_{k-2}, w_{k-1}, w_k$	$\sum_{j=1}^{k} w_j$
			Pt

Where, for the purposes of calculation, a_j represents *one* article (and has a value of "1") and n_{cj} represents the number of times it is cited (see an example of the calculation in Table IV). Each external citation has a value of "1", whereas self-citations have a value of "0.73" (see below).

$\sum_{j=1}^{k} w_j$ is not represented in [2] because its value is zero.

Despite its evident utility, $\mathbf{RC}_{\beta}$ does not provide qualitative information about the type of article (e.g., original paper or review article), the position of the author in the authorship order, self-citation, etc. Thus, it has to be qualified with some correction factors.

Control of self-citation

Self-citations have caused problems for the evaluation of researchers because it can potentially be used to fraudulently increase the *IF* of a researcher.[19] However, there are data indicating that self-citation might reflect an element of continuity in the researcher's line of investigation.[20] An author necessarily cites his or her previous work if there are few external references or in order to justify a new investigation derived from previous research. It has been shown that the number of self-citations of an original article is highest immediately after publishing the article and descends gradually over time, in contrast with external citations of the same article, which increase with time.[21] Moreover, self-citations have little weight in the set of citations by other authors and involve fewer published articles,[21] so their specific weight among the indicators for evaluating articles is really small.[14,22]

However, the greatest risk of self-citation by an author or group of authors is that it accentuates the relevance of an article, thus falsely validating its content; if other researchers accept repeated citation without question, it limits the advance of scientific knowledge in the area.[23] At the individual level, self-citation confers on authors an impact that they may not have, since their influence is measured by the number of citations that their articles receive. Therefore, it seems to be necessary to control for self-citation by using an algorithm designed to assess the impact of an individual on peers; external citations therefore should have a different value compared to self-citations. Thus, n_{cj}, which represents each citation of an article, has a value of n_{cj} = 1.00 (*one* citation equal to "1") when referring to external citations, but a somewhat lower value, n_{cj} = 0.73, when it is a self-citation.

We obtained this figure using research by Costas et al (2010)[21] on 637 biomedical and material science scientists as the *gold standard*. Self-citations by this group of researchers and their coauthors reached a proportion of 27% of total citations. One way to counteract the effect of self-citation in our final algorithm would be to assign the value obtained by subtracting that proportion from the value of external citations. Thus, n_{cj} = (1 – 0.27) = 0.73.

However, if one does not wish to apply this correction factor because it takes too much effort to automatically obtain the information that a citation is actually a self-citation in the databases used, it suffices to assign all citations a unit value.

Type of article cited

One criticism of *IF* is that it provides no information about the quality of the content of the articles cited. Our algorithm does assess the quality of content.

Articles containing reviews are known to be more frequently cited than reports of the results of original research.[24] Reviews can offer useful information, with perspective, and can clarify confusing points on certain topics. However, review articles do not require as much effort as designing and conducting original research. Consequently, before introducing the citations in the algorithm, we applied a correction factor (Cp_j) to each article score according to whether it was identified in the database as a "review," "original research paper," "editorial" or " letter to the editor."

Thus, [2] would be:

$$[3] \qquad RC = \frac{\sum_{j=1}^{k} (a_j \cdot n_{cj} \cdot Cp_j)}{Pt}$$

Cp_j has unit value for original research papers and 0.76 for review articles. The value of 0.76 was reached in the following way.

The *IF* assigned to journals containing review articles is up to 3.5 times higher than the *IF* of journals publishing original research papers,[25] although there are more modest differences. We calculated the value Cp_j = 0.76 by adopting

the *IF* of two consecutive years of fourteen biomedical journals reviewed in two independent investigations as the *gold standard*.[26,27] We calculated the geometric mean ($\overline{X}_G$) of the values obtained by dividing the *IF* of the journals when they publish only review articles (IF_{rev}) by the *IF* of the same journals when they publish only original papers (IF_{orig}), as communicated in the cited review articles.[26,27]

$\overline{X}_G$ is the antilog of the arithmetic mean of the logarithms of each variable's value. Logarithmic transformation reduces the impact of outlier values, normalizes the curve and makes the arithmetic mean (logarithmic) more representative. $\overline{X}_G$ can also be calculated more simply[28]:

$$\overline{X}_G = \sqrt[n]{\frac{IF_{rev}}{IF_{orig}}_1 \cdot \frac{IF_{rev}}{IF_{orig}}_2 \cdot \frac{IF_{rev}}{IF_{orig}}_3 \ldots \frac{IF_{rev}}{IF_{orig}}_n}$$

(the nth root of the product of n $\frac{IF_{rev}}{IF_{orig}}$)

Thus, using the *IF* values published by Ketcham and Crawford[26] and Wolf and Williamson,[27] we obtained a value of:

$\overline{X}_G$ = 1,32 (d_n)

That is, the average IF_{rev} is 1.32 times greater than $IF_{orig.}$ By dividing the unit value by 1.32, we obtain the corrective constant that we assign to review articles.

$Cp_j = 1/d_n = 0{,}76$

because $\frac{IF_{rev}}{IF_{orig}} = d$ is equal to $IF_{rev} = d \times IF_{orig}$

or $IF_{orig} = \frac{IF_{rev}}{d}$

We have not found data that allow us to set a default value for "editorials" and "letters to the editor," which sometimes communicate worthwhile information. "Letters to the editor" are sometimes true *short reports* of original research. This is not the case of "editorials," which are usually commissioned by the journal to provide opinions or updates on the status of a topic of interest, but are not research per se. For lack of a better reference, we decided that the Cp_j value for "letters to the editor" is 0.24; we obtained it by subtracting the Cp_j value of "reviews" from that of "original research papers." If we subtract the same difference (0.24) from the value attributed to "letters to the editor," we obtain the value attributed to "editorials," or *zero* (Table 2).

Table 2 Value of type of article (Cp_j)

Original research papers	1.00
Reviews	0.76
Letters to the editor	0.24
Editorials	0.00

Authorship rank of each researcher

Signing an article as the first author is not the same as signing as the second, third, or other author. The first author has more visibility than the last author. In most sciences, the authorship order is decided by the amount of work that each author contributes to the article, rather than personal prestige or position in the department, unit or laboratory where the research was conducted. The author in the last authorship position often is the head of the unit, who lends his or her personal prestige or academic position to the article.[29-32] The exception to this rule is publications related to management, economics and, very recently, social sciences, in which alphabetical authorship order is preferred.[33] Alphabetical order is also observed in articles of high scientific relevance and articles signed by prominent academics.[34]

In recent times, medical and multidisciplinary journals are showing a tendency to assign the same degree of authorship to all the authors of an article.[35,36]

Since the tendency is to assume that the order of authorship is related more with the contribution of each author to the content of the research than to *senior* position in the group,[33] we think that authorship order (A_j) should be reflected in the sum of the dividend of our algorithm. Thus:

$$[4] \quad RC = \frac{\sum_{j=1}^{k} (a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)}{Pt}$$

Where A_j is the correction applied to the citation depending on whether the researcher is the first, second or other author.

What value should be assigned to authors for their position in the authorship order of the article? We thought that each author could be assigned a fraction related to the total number of authors. In this way, if there are five authors, the first author would be assigned 5/5 (five-fifths), the second 4/5 (four-fifths), the third 3/5, the fourth 2/5 and the fifth 1/5.

However, using this criterion, the value assigned varies from one article to another from the second author on in

Table 3	Weight attributed to each author of articles (based on Vancouver system)	
Author position	Standardizing Fraction	Weight A_j
1	7/7	1.00
2	6/7	0.86
3	5/7	0.71
4	4/7	0.57
5	3/7	0.43
6	2/7	0.29
≥7º (*et al.*)	1/7	0.14

accordance with the total number of authors. Thus, in the example above, the second author is assigned a value of 0.80 (4/5), whereas if there are only three authors, the second author is assigned 0.67 (2/3). For that reason, to ensure that all authors *always* receive the same value depending on their authorship rank, a standard reference should be used. We have adopted the Vancouver system[37] used by numerous journals to make bibliographic citations more homogeneous. This system assigns visibility to the first six authors; all the others, including the seventh, remain hidden under the term "et al" or "and others". Therefore, we decided that all authors of any article or book, regardless of the total number of authors, should always be assigned the same value based on the *gold standard* provided by the Vancouver system (Table III). An exception would be articles specifically stating that all authors have contributed equally to the content. In these cases, all authors should be assigned the same score as the first author. Consensus agreement should be reached about whether placing authors in alphabetical order means that they all have contributed equally to the article (regardless of whether they are positioned before or after); in this case, all authors would be assigned the same score as the first author.

The RC algorithm, as reflected in [4], yields a figure that indicates the personal influence factor or cumulative impact of a researcher. As can be seen in the example, this is more beneficial to the researcher with a short publication career, but a large number of citations (e.g., Subject A in Table 4), than to the researcher with a larger number of publications, but the same number of citations (e.g., Subject B in Table 4). The *h*-index does not do this.[38]

Time without publishing

Time without publications also affects the personal impact of a researcher because it reduces the researcher's visibility and influence, even though his or her work has not ceased to be interesting; this may occur when a researcher is engaged in management tasks, for example. Our algorithm introduces a correction factor for inactivity (Fci) that takes this into account. It penalizes new researchers more, although their RC according to [4] is very high, because one year represents more downtime in a subject who has been working three years than in one who has been active for thirty years. It is true that there are disciplines in which a year without publishing may be common given the nature of the discipline, but the fact that it also affects all the other researchers in the same discipline negates the differences. This element of our algorithm is useful for comparing subjects working in the same scientific field, but it is less useful for comparing, for example, a mathematician to a molecular biologist or a Latin philologist.

Fci is expressed as:

$$[5] \quad Fci = 1 - \frac{\sum y_i}{y_{ev} - y_{pr}}$$

Where $\sum y_i$ is the cumulative time without publishing (in years) from the year of the first publication (y_{pr}) to the year that the assessment is made (y_{ev}). The divisor reflects the difference between the year of the assessment and the year of the first publication, which represents the entire scientific career of the researcher.

Thus, our algorithm is expressed as follows:

$$[6] \quad RC = \frac{\sum_{j=1}^{k} (a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)}{Pt} \cdot (Fci)$$

In the example in Table IV, it is assumed that both subjects are evaluated in 2011, that each of them has had two years of inactivity, and that the first publication of Subject A was in 2008 and of Subject B in 1980. The value of Fci would be, according to [5], 0.33 for Subject A and 0.94 for Subject B, making their **RCs,** according to [6], 4.637 and 1.325, respectively. (Table 4)

Book citations

Books are another major source of citations for assessment and present their own problems.

Books are generally more or less extensive reviews that are frequently cited for the same reasons that review articles are cited.[24] This impedes assessing them in the same way as an article reporting the results of original research. However, books also require more effort to write than an article, even an original research article. Therefore, books cannot be evaluated in the same way as original research articles.

A book reflecting the authors' true original research cannot be considered the same as a comprehensive review

Table 4 Example of calculation for two hypothetical investigators (articles published).

10 articles cited a_j*		No. of times cited n_{cj}	Correction for type of article Cp_j	Position of author in authorship order A_j	$(a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)$
a1	1	1	1.00	1.00	1.000
a2	1	1	0.24	0.86	0.206
a3	1	2	1.00	0.86	1.720
a4	1	2	0.76	1.00	1.520
a5	1	2	1.00	0.86	1.720
a6	1	3	1.00	0.71	2.130
a7	1	16	1.00	1.00	16.000
a7 ϕ	1	1 × 0.73	1.00	1.00	0.730
a8	1	36	1.00	1.00	36.000
a9 ϕ	1	36	0.76	1.00	27.360
a9	1	2 × 0.73	0.76	1.00	1.110
a10	1	51	1.00	1.00	51.000
Total citations		153			
$\sum_{j=1}^{k}(a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)$					140.496
Subject A (Pt = 10)**: $\frac{\sum_{j=1}^{k}(a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)}{Pt}$					14.05
Subject B (Pt = 100)**: $\frac{\sum_{j=1}^{k}(a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)}{Pt}$					1.41

* a_j: one article (value always "1" for the equation); ** Pt: total number of articles published.
ϕ self-citations (1 for the article to a7 and 2 for article a9).

of the topic addressed, or a book in which one or more subjects direct a labor-intensive and voluminous review by numerous authors. These reviews are usually often cited because it is more convenient for the reader to read the review instead of the original sources.[24] Finally, none of this is the same as a book chapter, which is generally a review equivalent to a review article published in a journal (usually by commission). (Table 5)

In addition, as occurs with articles, the author's position in the authorship order must also be taken into account since it involves a different degree of involvement in the text.

Therefore, the second element of our algorithm, which refers to citations of books, is expressed as follows:

$$[7] \qquad \frac{\sum_{j=1}^{k}(b_j \cdot n_{cj} \cdot Cb_j \cdot A_j)}{Tb}$$

Where b_j = **one** book ("1" for the calculation, as in Table IV), n_{cj} = the number of citations of the book, A_j = the position of the author in the authorship order; Cb_j = correction for the type of book; Tb = total number of books published.

Table 5 Value of the type of book published

Type of book	Cb_j
Personal research, original	1.48
General review of a topic	1.24
Editor or coordinator	1.00
Book chapter	0.76

The value of the position in the authorship order, A_j, is the same as that shown in Table III for articles, based on the *gold standard* of the Vancouver system.[37] Similarly the value n_{cj} is the same as the value applied to journals. The correction factor Cb_j has the values shown in Table V according to the type of book in question ("original research," "review," "edited book," "chapter").

We have reached these figures using those calculated for Table III, by assigning a chapter in a book the same value as a review article (given their equivalence): 0.76. To this value, we added 0.24 (remember the difference between an original research article and a review) to obtain the value in the box immediately above it in Table V. Thus, editing or directing a book written by multiple authors is given the same score as publishing an original research article (1.00). This is a way of proceeding with some objectivity.

We do not use any correction factor for inactivity in the publication of books. Books generally require more preparation time, aside from the time occupied by the editorial process itself, so one cannot expect temporal regularity in book production and it would be unrealistic and unfair to penalize the author.

Thus, our algorithm is definitively defined as follows:

$$[8] \quad RC_\gamma = \left[\frac{\sum_{j=1}^{k}(a_j \cdot n_{cj} \cdot Cp_j \cdot A_j)}{Pt} \cdot (Fci)\right] + \frac{\sum_{j=1}^{k}(b_j \cdot n_{cj} \cdot Cb_j \cdot A_j)}{Tb}$$

Where a_j = **one** article (with a value of "1" in the calculation), n_{cj} = number of citations of the article (in the bracketed fraction), A_j = the position of the author in the authorship order of the article (in the bracketed fraction), Cp_j = correction for the type of article ("original," "review,"

Table 6 Example of calculation for two hypothetical investigators (books published)

	3 books cited b_j*	No. of times cited n_{cj}	Correction by type of book Cb_j	Author's position in authorship order A_j	$(b_j \cdot n_{cj} \cdot Cb_j \cdot A_j)$
Subject A (Tb** = 3):					
b1	1	5	0.76	0.86	3.268
b2	1	3	0.76	0.86	1.961
b2 ϕ	1	2 × 0.73	0.76	0.86	0.843
b3	1	5	0.76	0.86	3.268
$\frac{\sum_{j=1}^{k}(b_j \cdot n_{cj} \cdot Cb_j \cdot A_j)}{Tb}$					3.113
Subject B (Tb** = 3):					
b1	1	5	1.24	1.00	6.200
b2	1	3	1.24	1.00	3.720
b2 ϕ	1	2 × 0.73	1.24	1.00	1.810
b3	1	5	1.00	0.86	4.300
$\frac{\sum_{j=1}^{k}(b_j \cdot n_{cj} \cdot Cb_j \cdot A_j)}{Tb}$					5.343

* b_j: one book (value always "1" for the equation); ** Tb: total number of books published
ϕ self-citations

"letter to the editor," "editorial"), Fci = correction factor for inactivity, and Pt = total number of articles published. In this equation, b_j = **one** book (with a value of "1" in the calculation), n_{cj} = number of citations of the book (in the nonbracketed fraction), A_j = the position of the author in the authorship order (in the nonbracketed fraction); Cb_j = correction for the type of book ("original", "review", "edited book", "chapter"), and Tb = total number of books published.

Continuing with the previous example, Subject A has written three book chapters as the second author, each of which have been cited 5 times; Subject B has written 2 review books as the first author and edited another book as the second editor, all of which have also been cited 5 times each. In both cases there were two self-citations. The second element of our algorithm would yield a value of 3.113 for Subject A, and 5.343 for Subject B (Table VI). Consequently, the final assessment of the personal influence of each author (obtained by adding [6] and [7] as in [8]) would be **RC**γ = 7.750 for Subject A and **RC**γ = 6.668 for Subject B. (Table 6)

CONCLUSIONES

Our procedure provides three values, in addition to Pt and Tb, which allow the individual weight of a researcher to be assessed.

RC$_\alpha$ indicates the proportion of articles cited in relation to Pt (in the example shown in Table IV, **RC**$_\alpha$ = 1.00 for Subject A and **RC**$_\alpha$ = 0.10 for Subject B). The calculation for books can be made in a similar way.

RC$_\beta$ provides the raw *IF* of the individual with respect to Pt (**RC**$_\beta$ = 15.3 for Subject A and **RC**$_\beta$ = 1.53 for Subject B; see Table IV). The calculation can be made in the same way for books.

Finally, **RC**γ provides a better adjusted value for the personal impact factor of the researcher among peers, based on the content of each text and other qualitative elements (**RC**γ = 68.12 for Subject A and **RC**γ = 19.40 for Subject B; see above).

Accessible databases currently exist (Science Citation Index, Web of Knowledge [WOK], Embase, Scopus, PubMed) that, in combination, make it possible to determine the number of citations of a specific researcher's articles, the position in the authorship order, self-citations, the type of article in question and the dates of publication. For some time, Google has been testing a citation searching tool (including books) that could also be useful for these purposes (Google Scholar).

In the future, it might be useful to incorporate researchers' traditional curricula and the lists of citations received by their articles and books from these sources. That would enable evaluators to make an objective assessment. This would also mean that sources should make an extra effort to add journals not published in English[18,39] to their databases and unify the criteria for listing the names of indexed researchers. Researchers from Spain, for example, tend to have two or three name variations in such databases, which interfere with calculations of any indicator based on these data sources.[40] For this reason, authors and journals should unify the criteria for listing authors' names. While these databases are as complete as possible, the calculation of RC may have to be limited to the articles (and books) indexed in these sources, ignoring publications not found in them. Thus, only the indexed Pt and cited indexed articles will be used to for calculations. While it certainly is an unfair limitation with respect to real total production, it would affect all the researchers with a given specialty, thus nullifying its restrictive effects.

Limitations of the proposed algorithm

The main limitation of our algorithm, which is shared by other indicators, is their dependence on the incomplete databases described in the preceding paragraphs.

It also depends on decisions by the scientific community and the journals that publish the results of their research.

It is possible that the aspect of **RC**γ that arouses most doubts is how it assesses the contribution to authorship of the authors who sign each article.

The use of our algorithm requires general agreement among members of the scientific community and evaluators in order to unify the criteria for writing authors' names. Perhaps, journals should publish a uniform guidelines for authorship order of an article in their Instructions to Authors, as they have already done with the Vancouver rules of bibliographic references.[38] For example, they might decide that the investigator who has contributed most to the article *always* be the first author. Other systems have their drawbacks.

As noted above, there are specialties in which the most renowned or most highly ranked professional among the authors is the last author, as also occurs with laboratory managers,[34] although their contributions to the article in question are minimal or none. This practice exponentially increases the number of articles assigned to such professionals, which is disproportionate to their actual contribution after reaching the position.[29-33] Disciplines in which the custom is for authors to be ordered alphabetically[41] have their own problems. Economists have found that the practice of alphabetically ordering authorship results in authors with surnames closest to "A" attaining the most important academic positions, greater professional recognition and higher salaries.[42-44] This is undoubtedly due

to the increased visibility of bearing a surname like *Abad* as opposed to *Zamarro.*

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