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Commentary

Trends in research activity in toxicology and by toxicologists in seven European countries

Òscar Miró[a,*], Elisabet Montori[b], Xavier Ramos[c], Miguel Galicia[a], Santiago Nogué[b]

[a] Emergency Department, Hospital Clínic, Villarroel Street 170, 08036 Barcelona, Catalonia, Spain
[b] Toxicology Unit, Emergency Department, Hospital Clínic, Barcelona, Catalonia, Spain
[c] Emergency Department, Hospital de Barcelona (SCIAS), Barcelona, Catalonia, Spain

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The word "bibliometrics" was coined by Alan Pritchard in 1969 to design the application of mathematics and statistical methods to books and other media of communication (Pritchard, 1969). Philosophically, bibliometrics contributes to a better understanding of the information universe because it studies how humans in general, and scientists in particular, relate to information. In practice, the management of scientific literature through analytical and quantitative methods allows knowing trends of publication volume, authors' activity and research fields and, in a more general aspect, the evolution of knowledge in the mechanisms and processes of science. Bibliometrics has gained importance because it constitutes one of the key tools in objectively evaluating the scientific production of a researcher, a research group or a scientific community but, especially, because it is frequently applied to allocate research funding and resources (Gervás et al., 1990; Hendrix, 2008; Nicol et al., 2007).

During the last years, several specialities have measured and analyzed the outcome of their scientific production from either, a national (Insall, 2003; Camí, 2007; Gómez and Sanz, 1990; Ramos Rincón et al., 2001; Miró et al., 2007a,b) or an international (Swaminathan et al., 2007; Clarke et al., 2007; García Río et al., 2000; López-Muñoz et al., 2008; Ramos et al., in press) perspective. In contrast, the evolution of scientific production in the field of toxicology has been poorly explored to date and mainly focused on articles or authors (Guimarães and Carlini, 2004; Jones, 2004; Bird, 2008; Bolt and Hengstler, 2008) rather than on an overall point of view. The fact that toxicology is a transversal discipline, without a formal speciality in most European countries, has probably contributed to this lack of information.

We have evaluated, from a quantitative approach, the scientific production in toxicology and by toxicologists during the last 15 years (1991–2005) in seven European countries: Spain, Germany, Italy, France, Holland, Belgium and England. We utilized the Web of Knowledge® (version 3.0) from the Institute for Science Information (ISI) as a bibliometric tool for the search, and the Science Citation Index (SCI)-Expanded as the database. The search was performed during September 2006. The period of analysis consisted in 15 consecutive years, from 1991 to 2005. The European countries analyzed we took England as a subrogate of United Kingdom, because the SCI codifies the documents produced in United Kingdom separately as England, Wales, Scotland and North Ireland in origin, and more than 80% correspond to the first. Using the proper descriptors, we utilized a double strategy in order to distinguish documents signed by toxicologists (investigators that sign their manuscripts as pertaining to a Toxicological Unit) and documents produced in the field of toxicology (documents indexed by SCI under the subheading "Toxicology"). From the documents initially identified, we excluded those corresponding to meeting communications (identified as *Meeting Abstract* by the SCI).

The absolute scientific production produced "by toxicologists" and referring "to toxicology" was corrected by the total amount of documents produced in each country (relative production), as well as by the population (number of citizens, data from 2002) and by economic development (gross domestic product, GDP, referring to

* Corresponding author. Tel.: +34 93 227 98 33; fax: +34 93 227 56 93.
E-mail address: omiro@clinic.ub.es (Ò. Miró).

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2002). To make the annual rate of change in scientific production of the different selected countries comparable independently of the total amount of documents produced by each one, we performed a logarithmical transformation of the data before applying statistical analysis.

During the 15-year period, we identified 26,414 documents signed by toxicologists and 25,070 documents identified by the SCI as fitting in the field of toxicology, which implied a figure of 0.75% and 0.77%, respectively, when compared with the 3,254,871 documents published in these seven countries. Only 21.7% of documents signed by researches identifying themselves as toxicologists fell into the category of toxicology by the SCI, while only 7.4% of documents pertaining to the toxicology category of the SCI were signed by toxicologists. Bibliometric descriptors for documents published by toxicologists and in toxicology are presented in Tables 1 and 2, respectively. As it can be seen, the behaviour of every country was different: absolute production by toxicologists and in toxicology was led by Germany and England, respectively, while relative production in both aspects and taking into account all considered parameters (total scientific production, population and GDP of each country) was led by Holland. All countries experienced increases in the absolute number of documents produced by toxicologists and in the field of toxicology over time (in most cases statistically significant), corresponding to Belgium the greatest annual increase rates. By contrast, we observed a progressive decrease in the contribution of toxicologists and in toxicology compared to the evolution of overall national scientific production (Fig. 1). Actually, only Belgian and German toxicologists significantly increased their contribution during the 1991–2005 period with respect to the total research production in their countries, with all the other toxicologists decreasing (Table 1). On considering the scientific production in the field of toxicology, with the exception of Belgium, in all the remaining countries this discipline lost significant weight with respect to the overall national scientific production (Table 2). For both categories (by toxicologists and in toxicology), Spain showed the greatest loss of weight in the national scientific production.

Toxicology and toxicologist productivity have followed the general explosion in scientific productivity observed in the last decades and, specially, in last years (Andersen et al., 2006; Ramos-Rincón et al., 2004). Indeed, published documents indexed by SCI surpassed 100,000 documents in 2008 and this database only covers around 6000 out of more than 30,000 scientific journals edited worldwide (López-Illescas et al., 2008). Our quantitative study showed that there are some countries, such as Holland and Belgium, where the total toxicologist productivity and toxicology production during this 15-year period have been clearly higher than in the remaining countries irrespective of whether they were expressed per population, richness or overall scientific activity of the country. The rhythm of growth has been specially marked in Belgium. However,

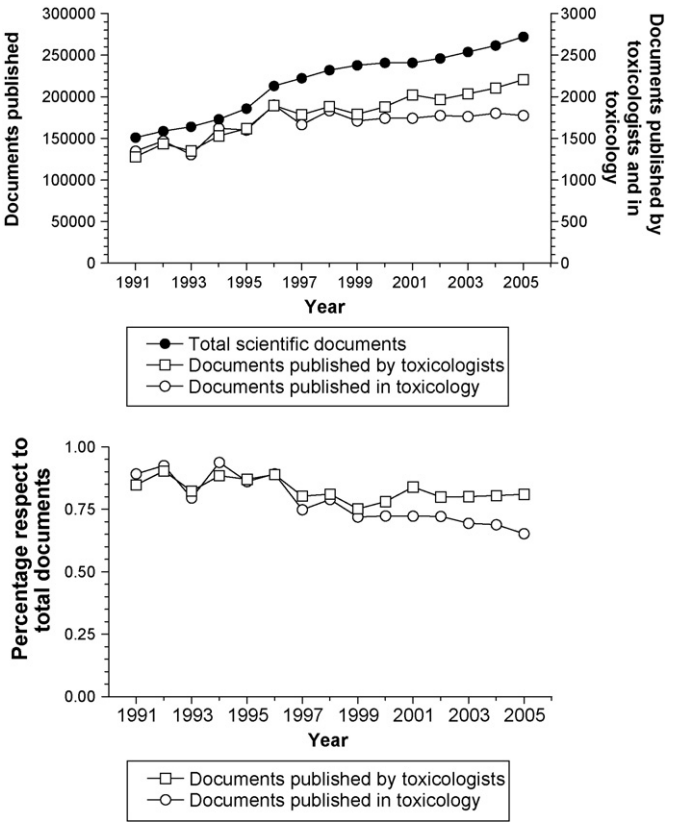

Fig. 1. Annual evolution of documents published by the seven studied countries between 1991 and 2005 in absolute (upper graphic) and relative (lower graphic) values.

Bradford's law states that most articles are produced by few sources following the basis of the 80/20 rule: 80% of items used come from 20% of sources (Diodato, 2004). Therefore, it would have been more interesting to know how the toxicology growth was in quality rather than in quantity. In this sense, it could have helped to identify the most highly cited articles, the most prolific authors and/or the most highly cited authors for each country for better insight into the comparison. Nonetheless, quantity and quality could be, to some extent, paired. For example, Jones AW analyzed the top 10 countries (which included 6 out of the 7 studied here) publishing articles in a particular toxicology journal between 1981 and 2003 (Jones, 2004) and Holland occupied both, the first position in number of papers per 100,000 inhabitants and in number of citations per article.

The contribution of toxicologists has gone down alarmingly regarding the overall scientific production except in Belgium and

Table 1
Bibliometric data for documents published by toxicologists between 1991 and 2005.

	Doc. published in the country	Doc. published by toxicologists (absolute production)	% doc. by toxicologists respect of doc. of the country (relative production)	Doc. published by toxicologists per million of inhabitants	Doc. published by toxicologists per billion of euros	Year rate of change in absolute production	Year rate of change in relative production respect of doc. of the country
Germany	842,526 (1)	7375 (1)	0.87 (3)	6.2 (3)	0.24 (4)	+2.3% (2)***	+0.5% (2)*
England	718,861 (2)	3893 (4)	0.54 (7)	5.2 (4)	0.16 (6)	+0.2% (7)	−1.1% (6)**
France	627,994 (3)	4468 (2)	0.71 (5)	4.9 (5)	0.20 (5)	+0.7% (6)***	−0.8% (4)**
Italy	414,564 (4)	2684 (5)	0.65 (6)	3.0 (7)	0.15 (7)	+1.6% (4)***	−0.8% (4)**
Spain	279,724 (5)	2310 (6)	0.83 (4)	3.6 (6)	0.27 (3)	+1.9% (3)***	−1.4% (7)**
Holland	242,432 (6)	3902 (3)	1.61 (1)	15.9 (1)	0.67 (1)	+1.0% (5)***	−0.6% (3)**
Belgium	128,226 (7)	1782 (7)	1.39 (2)	11.3 (2)	0.45 (2)	+3.7% (1)***	+1.4% (1)**

Numbers within parenthesis denote the ordinal position of that particular country among the seven studied countries.
* $p < 0.05$ (calculated using lineal regression coefficients).
** $p < 0.01$ (calculated using lineal regression coefficients).
*** $p < 0.001$ (calculated using lineal regression coefficients).

Table 2
Bibliometric data for documents published in toxicology between 1991 and 2005.

	Doc. published in the country	Doc. published in toxicology (absolute production)	% doc. in toxicology respect of doc. of the country (relative production)	Doc. published in toxicologists per million of inhabitants	Doc. published in toxicologists per billion of euros	Year rate of change in absolute production	Year rate of change in relative production respect of doc. of the country
Germany	842,526 (1)	5691 (2)	0.68 (6)	4.8 (4)	0.15 (7)	+1.0% (2)*	−0.7% (2)*
England	718,861 (2)	5801 (1)	0.81 (4)	7.7 (2)	0.24 (4)	+0.3% (6)	−1.1% (4)*
France	627,994 (3)	3871 (3)	0.62 (7)	4.2 (5)	0.17 (6)	+0.8% (5)	−0.7% (2)
Italy	414,564 (4)	3405 (4)	0.82 (3)	3.8 (6)	0.19 (5)	+1.0% (2)**	−1.4% (6)**
Spain	279,724 (5)	2211 (6)	0.79 (5)	3.4 (7)	0.26 (3)	+1.0% (2)**	−2.3% (7)**
Holland	242,432 (6)	2930 (5)	1.21 (1)	9.7 (1)	0.50 (1)	+0.3% (6)	−1.3% (5)**
Belgium	128,226 (7)	1161 (7)	0.91 (2)	7.4 (3)	0.29 (2)	+2.3% (1)**	0.0% (1)

Numbers within parenthesis denote the ordinal position of that particular country among the seven studied countries.
* $p < 0.01$ (calculated using lineal regression coefficients).
** $p < 0.001$ (calculated using lineal regression coefficients).

Germany. Similarly, toxicological documents have lost weight with respect to the overall scientific production in nearly all countries (Belgium is again an exception). These data suggest a regression in the weight of European toxicologists and toxicology in scientific productivity (Fig. 1). The present study was not designed to investigate the causes of this because it was projected in a descriptive basis. However, taking into account that Spain occupied the last position in the ranking, with annual decrements of between 1% and 2% and that all the authors of the present study are Spanish, some hypotheses can be postulated from our own national experience. Toxicology research is sometimes moved by catastrophes that may determine changes in productivity. For example, the "toxic oil syndrome" that affected thousand of Spaniards during the 1980s pushed the Spanish government to allocate specific research funding to investigate this syndrome, thereby promoting toxicological research activity (Tabuenca, 1981; Fournier et al., 1982; Pestaña and Muñoz, 1982; Kilbourne et al., 1983). However, in the last decade this interest has decayed which has consequently been mirrored by the decline in toxicological productivity: Spanish papers published on the toxic oil syndrome decreased 40% between the 1991–1995 and 2001–2005 (consulted through SCI-Expanded using "toxic oil syndrome" as topic and "Spain" as address). The lack of a medical speciality superimposes a clear additional limitation to toxicologists and it is a disadvantage with respect to other fields with recognised specialities, especially if the speciality has been recognised during the period of the study (Ettlin et al., 2008; De Rosa et al., 2003; Abbritti et al., 2005). Moreover, causes outside toxicology itself may have influenced this decline. For instance, if a larger number of journals in fields other than toxicology had been incorporated into the SCI-expanded repository during the study period, then the falling productivity by toxicologists and, specially, in toxicology could be partly explained by this fact.

Some limitations of the present study merit comment. As general limitations, the methodology followed was especially designed for this study and was not based on any routine of the SCI program. Therefore, the model could have included generic flaws. However, we used a similar strategy to describe the activity of Spanish emergency physicians (Miró et al., 2007a,b), which (similar to toxicology) is, as yet, not recognised in Spain as specialty a medical, and it rendered valuable results that mirror data obtained using other more conventional strategies (Camí, 2007). Accordingly, and even recognising the possibility of some imprecision in the measurements, the bias was the same for all countries. Finally, it is widely recognised that the SCI has a positive bias with journals written in English and, thus, some toxicologists and toxicological documents from countries with different languages other than English may be omitted from the SCI database because they are published in non-indexed journals. With respect to toxicologist productivity, sometimes their affiliations do not correspond to an explicitly named toxicological unit. On the other hand, some branches of toxicological sciences may use other alternative words to name their units or departments not including the word toxicology. Finally, with respect to toxicology production, it is important to note that the assignation of a document is done manually by the SCI and, thus, criteria can be intentionally or unintentionally shifted. Nonetheless, we believe that this is the first study to establish general trends in toxicologist productivity and toxicology production in Europe and may open a more general debate and further investigation to study, in depth, the root causes of our findings.

Conflict of interest

All the authors explicitly declare that there are no conflicts of interest.

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