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Original Article

Virology research in a Latin American developing country: a bibliometric analysis of virology in Colombia (2000–2013)

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Abstract

Introduction: Bibliometric analysis demonstrates that the virology research in Latin America has increased. For this reason, the objective of this study was to evaluate Colombian publications on viruses and viral diseases in indexed journals during the period from 2000 to 2013.
Methodology: The bibliographic data were collected from MedLine, SciELO, LILACS and Scopus databases. The database was constructed in Excel descriptive statistics. The SCImago Journal Rank (SJR) was evaluated using the SCImago Journal & Country Rank in 2013 and was used as an indicator of the quality of the journals used by the Colombian researchers.
Results: The total number of papers published was 711, of which 40.4% were published in local journals, and 59.6% were published in foreign journals. Most (89.2%) were original papers. Moreover, 34.2% of the papers were published in collaboration with international researchers, with the United States being the most represented. Of the journals used, 85.6% had an SJR, and 14.4% did not. The median SJR of the papers was 0.789, and the median of the papers with international collaborators was higher compared to the SJR of the papers without international collaboration. Papers were most frequently published in journals whose categories were medicine (miscellaneous), virology, and infectious diseases. The viruses that appeared in the papers more frequently were HIV, dengue, and papillomavirus.
Conclusions: This study provides data for use in research, health planning, and policy analysis as it relates to virology in Colombia and other developing Latin American countries.

Key words: bibliometric; Colombia; developing country; virology; virus.

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Introduction

Virology is a field of microbiology that studies a broad group of viral diseases that are the cause of considerable morbidity and mortality worldwide in different human, animal, and plant populations. Virology research ranges from the clinical findings, the etiology, pathogenesis, epidemiology, prevention and treatment of viral diseases, to the molecular therapeutic for cancer and other viral and non-viral diseases [1].

According to International Committee on Taxonomy of Viruses (ICTV), viruses comprise seven orders, 87 families, 19 subfamilies, 349 genera, and 2,284 viruses and viroid species [2,3], and are becoming the most diverse microorganisms on earth.

Several investigators have conducted bibliometric analyses of research productivity of different regions of the world, focused mainly on biomedical fields [4,5,6]. These bibliometric analyses have shown that research in microbiology [7] and research in virology [8] are concentrated in developed areas (United States and Western Europe), which have produced the majority of the world's virology research in terms of both quantity and quality of information. Specifically, these two world regions have produced 77.7% of the published articles in this field [8].

From previous bibliometric analyses, is interesting to note that between the years 1995 and 2003, virology research in Latin America exhibited a tendency to a relative increase of production in published articles indexed in the Journal Citation Reports database of the Institute for Scientific Information (ISI) [8]. Similarly, a recent analysis in Colombia evaluating publications on infectious disease publications in Colombian journals showed a similar increase between 2000 and

2009 and noted that there is an imbalance between different areas of the country [9].

According to previous analysis, there is an urgent need for virology researchers from developed regions to enhance their research cooperation with developing areas to perform the most accurate science and to have more equity in these developing regions [8]. However, it is important to highlight that Falagas *et al*. only evaluated articles belonging to the virology category [8], and it is clear that due to wide importance of virology, this approach creates a gap in the knowledge, because many articles regarding viral diseases are published in journals of other categories such as *medicine, general and internal*; *medicine, research and experimental*; *infectious diseases*; *veterinary (miscellaneous)*; *agronomy and crop science*, and others.

It is important to highlight that cooperation between countries in Latin America has been proposed as an alternative way to obtain equity in these developing regions. Regional initiatives, such as the Brazilian/Argentinean Center for Biotechnology (CABBIO), have increased the cooperation and the publication index between those countries and others from the region through the implementation of training courses in biotechnology and grant funding mainly in the Mercosur area [10,11]. The CYTED initiative (from the Spanish Programa Iberoamericano de Cooperación en Ciencia y Tecnología para el Desarrollo: Ibero-American Cooperation for Scientific and Technological Development Programme) founded by Latin American and Caribbean countries, Portugal, and Spain to enable further cooperation among research terms, has led to important advances in increasing scientific cooperation and development [12,13]. However, only one initiative in virology has been placed in the virology area in all Ibero-America, the Virored-Cyted network (Red Temática en Virosis Emergentes: Thematic Network on Emerging Viruses), which was created in 2010 and, unfortunately, has been inactive since 2013 [14].

In recent years, no one has quantified the real balance of virology-related research by Colombian researchers in indexed journals. It is necessary to evaluate if scientific production in virology has continued to increase during the last decade and if the indicators show a real potential for Colombia in basic science and clinical aspects of viral diseases. This paper evaluates Colombian publications on viruses and viral diseases in indexed journals covering several areas of virology and published in many different journal categories to provide basic data for use in research, health planning, and policy analysis regarding virology in Colombia and other developing Latin American countries, as has been proposed in other Latin American bibliometric initiatives [15].

Methodology

Data collection

This retrospective and documental study was conducted using printed and Epub ahead-of-print online articles published from January 2000 to December 2013. The bibliographic data were collected from the databases of the National Library of Medicine on the web (MedLine) (http://www.ncbi.nlm.nih.gov/pubmed), the Scientific Electronic Library Online (SciELO) (http://www.scielo.org), LILACS, the Pan-American Health Organization's supported database on Latin American and the Caribbean Literature in Health Sciences (http://lilacs.bvsalud.org/en/), and Scopus database from Elsevier (http://www.scopus.com/). The data were exported to Excel, and the database was constructed with the title, author, address, source, year, type of publication, journal title, language of publication, virus, journal category, and SCImago Journal Rank (SJR) of the journal. The SJRs were obtained from SCImago Journal & Country Rank and were arbitrarily adopted to estimate the visibility of the papers and the quality of the journals [15,16]. The SJR was used as an indicator of the quality of the journals used by the Colombian researchers. As reported by others, when using the descriptive statistics of SJR for research documents, those with no SJR were given a score of zero [17]. To clarify international cooperation, the collaborating country was included in the database search, and the absolute country counting method was adopted [18]. The citation analyses were retrieved only from the Scopus database and obtained as a table with numbers of cited articles for individual years, as well as the total number of cited references for all years [19]. Notes, letters, editorials, news, and meeting abstracts were excluded.

Search strategy

For each search in the PubMed database, a sentence consisting of different parts joined together by Boolean operators, *i.e.*, AND, OR, and NOT was used in the search field. By making use of the *Limits* function that is incorporated in the search engines, each search was limited to specific years. Manual detection was used to exclude publication types, such as notes, letters, editorials, news, and meeting abstracts. The words *Colombia* AND *virus* were

selected as medical subject heading (MeSH) terms. Despite this meticulous search, some articles were missed because the full address was not registered. In order to include these articles, the words that could help to find several important viral diseases that specifically affect Colombia were included, such as *dengue*, *HIV*, *Solanum tuberosum*, and *plant* in [MeSH Terms] and [All Fields]. An example of the main search the following text was used: ("viruses"[MeSH Terms] OR "viruses"[All Fields] OR "virus"[All Fields]) OR ("virology"[Subheading] OR "virology"[All Fields] OR "viruses"[All Fields] OR "viruses"[MeSH Terms]) OR ("dengue"[MeSH Terms] OR "dengue"[All Fields]) OR ("hiv"[MeSH Terms] OR "hiv"[All Fields]) OR ("rabies"[MeSH Terms] OR "rabies"[All Fields]) OR HPV[All Fields] AND ("colombia"[MeSH Terms] OR "colombia"[All Fields]) AND ("2000/01/01"[PDAT]: "2013/12/30"[PDAT]).

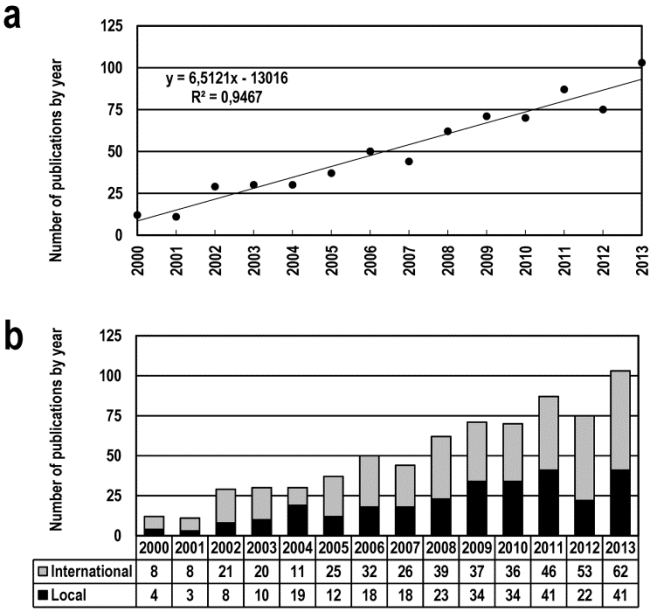
The search in Scopus was performed using the basic search system and the date range to delimitate the search. A mix of words joined together by Boolean operators were used in the basic search system (article title, abstract, key words). An example of the terms used in the main search follows: virus OR viruses OR dengue OR HIV OR rabies OR HPV AND Colombia.

The SciELO and LILACS databases were accessed through the databases' websites and the review was operationalized through electronic search of articles indexed in the subject index [20] based on the key words *Colombia* and *virus*, and using date limits. Finally, the Excel database was filtered to eliminate repeated records from different primary databases. To strengthen the methodological validity of this study, two independent authors conducted the data collection and filtered the results, as previously reported [21]. In case of disagreement between the two investigators, the results were discussed in research group meetings.

Statistical analyses

Descriptive statistics were used in all cases to evaluate the results (*i.e.*, the frequency in count and percentage). To measure the tendency in total number of published papers by year, lineal regression (R^2) was used as a measure of lineal association with a p value of < 0.05. The Shapiro-Wilk test was used to evaluate normality, and differences in SJR between papers with and without international cooperation were evaluated using the Mann-Whitney test. A p value < 0.05 was regarded as statistically significant (two-tailed). Statistical analyses were performed using GraphPad Prism version 6 for Windows.

Figure 1. Temporal evolution of the number of Colombian virology publications (2000–2013)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
International	8	8	21	20	11	25	32	26	39	37	36	46	53	62
Local	4	3	8	10	19	12	18	18	23	34	34	41	22	41

A. Number of publications in each year of the evaluated period. **B.** Number of papers published in international or national (local) journals in each year of the evaluated period.

Results

There were a total of 711 papers published by Colombian researchers in different areas of virology that were included in the present study. Figure 1 presents the actual number of articles produced each year during the study period. It is clear that the total number of papers increased progressively during the period ($r^2 = 0.9467$; $p < 0.001$). There was a more than eightfold increase in the number of papers from 2000 (12) to 2013 (103), with the highest number of published papers in 2013 (Figure 1A).

Taking into account that databases included local indexed journals (Colombian journals), the number of papers published in foreign (international) or national (local) journals was evaluated. During almost all the years studied, papers in foreign international journals accounted for the majority of publications, ranging from 37% (2004) to 73% (2001) with an average of 59.6% of international publications from 2000 to 2013 (Figure 1B). There was no statistically significant correlation between the number of articles appearing each year and the percentage of articles published in international journals.

Because only primary research, which includes mainly original papers, short communications, short papers and reviews/assays was included, the percentage of original research of Colombian

researchers and the total number of reviews or essays as possible indicators of top research in different areas of virology was sought. Of the published papers, 89.2% were original papers and only 10.8% percent were reviews and/or essays.

An important finding was that the publication language followed the same pattern as the international publications, with 52.9% of the papers written in English, 46.8% in Spanish, and only 0.3% written in Portuguese. No paper appeared in another language.

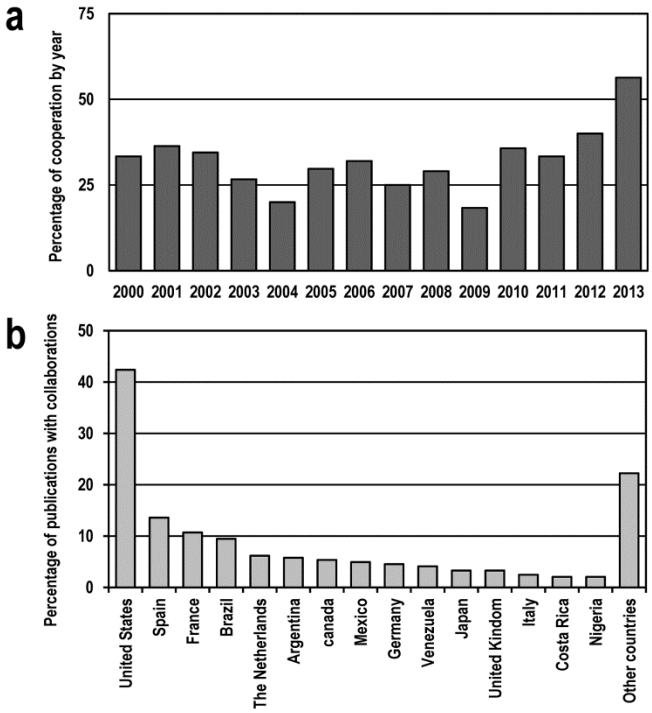
Furthermore, 94.9% of the publications were co-authored. The median number of authors was 5.3 (range, 1 to 38). On average, articles with 10 or more authors appeared in journals with higher SJRs than did those with fewer than four authors. Table 1 presents the total distribution of the number of authors per publication.

There is an urgent need for Latin American researchers to enhance their cooperation with developed countries to enhance their research capacity. With this in mind, foreign collaboration with Colombian researchers was evaluated. A total of 34.2% (243) of the papers published during the study period included foreign international collaboration, as indicated by the authors in the papers (rank between 20.0% in 2004 and 41.7% in 2000); in some of them, the researchers collaborated with more than one country or international institution. The tendency can be observed in Figure 2A.

The main collaborating countries were the United States, Spain, and France (42.4%, 13.6%, and 10.7%, respectively), which account for more than a half of the studies with international cooperation. However, Colombian researchers collaborated with 45 different countries, including some important Latin American productivity leaders such as Brazil, Argentina, and Mexico, which are in the fourth, sixth, and eighth positions in the collaboration list, respectively, as seen in Figure 2B.

The SJR of the journals in which the papers were published was evaluated as a common indicator of the quality of the journals used. Of all the journals, 85.6% had an SJR and 14.4% did not have an SJR. The median SJR of the papers was 0.789 (rank, 0.000–11.563). The role of foreign international collaboration in publishing in journals with higher SJRs was also evaluated. As can be seen in Figure 3, the SJR was significantly higher ($p < 0.0001$) in papers that included foreign international collaboration than in papers that did not. The median SJR in the collaborative papers was 1.372 (rank, 0.000–11.563), compared to the SJR of papers without such cooperation (median, 0.486) (rank, 0.000–5.720).

Figure 2. International collaboration in Colombian papers



A. Tendency of the percentage of papers published in collaboration with other countries in the evaluated period. **B.** Percentage of papers published based on the international collaborating countries. Note: Percentages may not add up to 100% because some papers included more than one collaborating country.

Table 1. Distribution of the number of authors per publication

No. of authors	No. of publications	Percentage
1	36	5.1
2	60	8.4
3	145	20.4
4–5	209	29.4
6–10	224	31.5
10–15	27	3.8
> 15	10	1.4
Total	**711**	**100%**

Table 2. Main journal categories of Colombian papers

SCR[a]	Subject category of journal	Frequency	Percentage	SCImago Journal Rank[b]
1	Medicine (miscellaneous)	185	26.0	0.520
2	Virology	100	14.1	1.295
3	Infectious diseases	86	12.1	1.390
4	Public, environmental, and occupational health	73	10.3	0.319
5	Veterinary (miscellaneous)	35	4.9	0.201
6	Agronomy and crop science	29	4.1	0.583
7	Cancer research	21	3.0	1.488
8	Obstetrics and gynecology	15	2.1	0.247
9	Microbiology	13	1.8	0.970
10	Multidisciplinary	13	1.8	0.041
11	Biochemistry	12	1.7	1.326
12	Immunology	12	1.7	1.919
13	Biochemistry	9	1.3	0.000
14	Agricultural and biological sciences (miscellaneous)	8	1.1	0.162
15	Gastroenterology	8	1.1	0.361
16	Health (social science)	8	1.1	0.907
17	Neuroscience (miscellaneous)	8	1.1	0.364
18	Epidemiology	6	0.8	1.811
19	Health policy	5	0.7	0.112
20	Applied microbiology and biotechnology	4	0.6	1.019
21	Aquatic science	4	0.6	0.876
22	Dermatology	4	0.6	0.556
23	Drug discovery	4	0.6	1.395
24	Ecology, evolution, behavior, and systematics	4	0.6	1.493
25	Insect science	4	0.6	0.292
26	Nursing (miscellaneous)	4	0.6	0.103
27	Otorhinolaryngology	4	0.6	0.570
28	Pediatrics, perinatology, and child health	4	0.6	0.759
29	Hematology	3	0.4	0.825
30	Hepatology	3	0.4	1.232
31	Earth and planetary sciences (miscellaneous)	2	0.3	0.079
32	Horticulture	2	0.3	0.193
33	Pathology and forensic medicine	2	0.3	1.968
34	Periodontics	2	0.3	0.962
35	Pharmaceutical science	2	0.3	0.637
36	Plant science	2	0.3	1.932
37	Transplantation	2	0.3	0.581
38	Urology	2	0.3	0.361
39	Cell biology	1	0.1	0.228
40	Cellular and molecular neuroscience	1	0.1	5.720
41	Dentistry	1	0.1	0.000
42	Environmental engineering	1	0.1	0.600
43	Molecular biology	1	0.1	0.242
44	Psychiatry and mental health	1	0.1	0.320
45	Radiology, nuclear medicine, and imaging	1	0.1	0.325

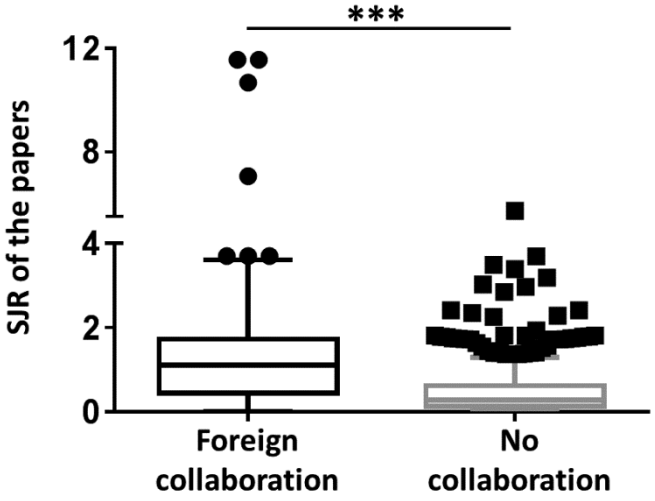
[a] Standard Competition Ranking according to the number of papers published papers published during the period studied (2000-2013); [b] The SJR value in the table is the average of the SJR of each one of the journals belonging to each category, according to the SCImago Journal & Country Rank in 2013.

Table 3. Main virology journal used by Colombian researchers

SCR[a]	Journal name	Frequency	Percentage	SJR[b]
1	Virology Journal	10	10.4	1.023
2	AIDS Research and Human Retroviruses	9	9.4	1.122
3	Archives of Virology	7	7.3	1.002
4	Journal of Clinical Virology	7	7.3	1.812
5	Virology	6	6.3	1.784
6	Virus Research	5	5.2	1.291
7	Advances in Virus Research	4	4.2	1.749
8	Intervirology	4	4.2	0.956
9	Journal of Virological Methods	4	4.2	0.860
10	Journal of Virology	4	4.2	3.492
11	AIDS	3	3.1	3.701
12	Current HIV Research	3	3.1	1.034
13	Journal of General Virology	3	3.1	1.751
14	Journal of Neurovirology	3	3.1	1.367
15	The Open Virology Journal	3	3.1	NA
16	Viral Immunology	3	3.1	0.934
17	AIDS Care	3	3.1	1.307
18	Acta Virologica	2	2.1	0.352
19	Journal of Medical Virology	2	2.1	1.058
20	Virologica Sinica	2	2.1	0.353
21	Journal of AIDS	2	2.1	2.850
22	Antiviral Research	1	1.0	1.512
23	Current Opinion in Virology	1	1.0	3.195
24	Future Virology	1	1.0	0.476
25	Retrovirology	1	1.0	2.121
26	Virus Genes	1	1.0	0.839
27	AIDS Reviews	1	1.0	1.685
28	Viruses	1	1.0	1.631

[a] Standard Competition Ranking according to the number of papers published during the period studied (2000-2013). [b] The SJR was reported according to the SCImago Journal & Country Rank in 2013.

Figure 3. Distribution of the impact factor according to the international collaboration.



The Tukey boxplot shows the median SJR of published papers published with the inclusion of international collaboration. The asterisks indicate statistically significant differences (***p < 0.0001).

Table 4. Principal virus studied in the Colombian papers published

SCR[a]	Virus name	Frequency	Percentage	SJR[b]
1	Human immunodeficiency virus-1	152	21.4	0.682
2	Dengue virus	112	15.8	0.581
3	Papillomaviruses	90	12.7	1.391
4	Plant viruses	59	8.3	0.619
5	Veterinary viruses	49	6.9	0.347
6	Rotavirus and others	41	5.8	1.513
7	Hepatitis viruses	38	5.3	0.639
8	Influenza virus	34	4.8	0.832
9	Rabies	33	4.6	0.759
10	Herpesviruses	28	3.9	0.895
11	Emerging viruses	16	2.3	1.037
12	Human T-lymphotropic virus	16	2.3	0.353
13	Yellow fever virus	8	1.1	0.333
14	Venezuelan equine encephalitis virus	7	1.0	0.963
15	Pest control	6	0.8	0.995
16	General virology	6	0.8	0.657
17	Viral vectors	5	0.7	0.781
18	Rubella virus	5	0.7	0.286
19	Phagues	2	0.3	0.991
20	Human respiratory syncytial virus	2	0.3	0.361
21	Poliovirus	2	0.3	0.313

[a] Standard Competition Ranking according to the number of papers published during the period studied (2000-2013); [b] The SJR value in the table is the average of the SJR of each one of the journals belonging to each category, according to the SCImago Journal & Country Rank in 2013.

Table 5. Top 10 institutions with the highest numbers of papers published

SCR[a]	Institution	No. of papers published	Percentage
1st	Universidad de Antioquia	142	20.0
2nd	Universidad Nacional de Colombia	65	9.1
3rd	Pontificia Universidad Javeriana	58	8.2
4th	Instituto Nacional de Salud	55	7.7
5th	Universidad Industrial de Santander	44	6.2
6th	Universidad del Valle	40	5.6
7th	Instituto Nacional de Cancerología	38	5.3
8th	Fundación Instituto de Inmunología	19	2.7
9th	Centro Internacional de Agricultura Tropical	18	2.5
10th	Universidad de Córdoba	17	2.4

[a] Standard Competition Ranking according to the number of papers published during the period studied (2000-2013).

Table 6. Top 10 most prolific authors with their affiliations

SCR[a]	Name	No. of documents	Affiliations
1st	Rugeles, M.T.	35	Grupo Inmunovirología, Universidad de Antioquia. Medellín, Colombia.
2nd	Villar, L.A.	26	Centro de Investigaciones Epidemiológicas, Universidad Industrial de Santander. Bucaramanga, Colombia.
3rd	Gutierrez, M.F.	18	Grupo de Enfermedades Infecciosas, Pontificia Universidad Javeriana. Bogotá, Colombia.
4th	Muñoz, N.	18	Instituto Nacional de Cancerología. Bogotá, Colombia.
5th	Patarroyo, M.E.	18	Fundación Instituto de Inmunología de Colombia-FIDIC. Bogotá, Colombia.
6th	Franco, M.	16	Instituto de Genética Humana, Pontificia Universidad Javeriana. Bogotá, Colombia.
7th	Rey, G.	16	Laboratorio de Virología, Instituto Nacional de Salud. Bogotá, Colombia.
8th	Angel, J.	14	Instituto de Genética Humana, Pontificia Universidad Javeriana. Bogotá, Colombia.
9th	Morales, F.	13	Centro Internacional de Agricultura Tropical-CIAT. Cali, Colombia.
10th	Mattar, S.	13	Instituto de Investigaciones Biológicas del Trópico, Universidad de Córdoba. Montería, Colombia.

[a] Standard Competition Ranking according to the number of papers published during the period studied (2000-2013).

Table 7. Top 10 Colombian publications most cited [40-49]

SCR[a]	Title	Affiliation	Time cited	Reference	SJR[b]
1st	Worldwide distribution of human papillomavirus types in cytologically normal women in the International Agency for Research on Cancer HPV prevalence surveys: a pooled analysis	Instituto Nacional de Cancerología	542	Lancet (2005) 366: 991-998	11.563
2nd	Safety, immunogenicity, and efficacy of quadrivalent human papillomavirus (types 6, 11, 16, 18) recombinant vaccine in women aged 24-45 years: a randomised, double-blind trial	Instituto Nacional de Cancerología	217	Lancet (2009) 373: 1949-1957	11.563
3rd	Variations in the age-specific curves of human papillomavirus prevalence in women worldwide	Instituto Nacional de Cancerología	197	Int J Cancer (2006) 119: 2677-2684	2.967
4th	Incidence, duration, and determinants of cervical human papillomavirus infection in a cohort of Colombian women with normal cytological results	Instituto Nacional de Cancerología	183	J Infect Dis (2004) 190: 2077-2087	3.607
5th	Prevalence and determinants of HPV infection among Colombian women with normal cytology	Instituto Nacional de Cancerología	161	Br J Cancer (2002) 87: 324-333	2.707
6th	Determinants of clearance of human papillomavirus infections in Colombian women with normal cytology: a population-based, 5-year follow-up study	Instituto Nacional de Cancerología	149	Am J Epidemiol (2003) 158: 486-494	2.971
7th	Cervical coinfection with human papillomavirus (HPV) types and possible implications for the prevention of cervical cancer by HPV vaccines	Instituto Nacional de Cancerología	83	J Infect Dis (2005) 192: 1158-1165	3.607
8th	Cytotoxic and antiviral activities of Colombian medicinal plant extracts of the Euphorbia genus	Universidad de Antioquia	58	Mem Inst Oswaldo Cruz (2002) 97: 541-546	0.735
9th	West Nile virus antibodies in Colombian horses	Universidad de Cordoba	49	Emerg Infect Dis (2005) 11: 1497-1498	3.182
10th	Serologic response to human oncogenic papillomavirus types 16, 18, 31, 33, 39, 58 and 59 virus-like particles in Colombian women with invasive cervical cancer	Instituto Nacional de Cancerología	47	Int J Cancer (2002) 97: 796-803	2.967

[a] Standard Competition Ranking according to the number of citation of each paper published during the period studied (2000-2013); [b] The SJR was reported according to the SCImago Journal & Country Rank in 2013.

The main category for each journal was determined by taking into account the SCImago Journal & Country Rank in 2013 subject categories. Colombian virology papers were published in journals belonging to 45 different subject categories. The five main journal categories included *medicine (miscellaneous)* (26.0%); *virology* (14.1%); *infectious diseases* (12.1%); *public, environmental, and occupational health* (10.3%); and *veterinary (miscellaneous)* (4.6%). Those five categories covered more than 65% of the total scientific production. Table 2 shows the selected journal categories used.

The main virology journal used by Colombian researchers was also investigated. As seen in Table 3, Colombian papers were published in 28 of the world's virology journals. The five journals most frequently used by the Colombian researchers were *Virology Journal* (10.4%), *AIDS Research and Human Retroviruses* (9.4%), *Archives of Virology* (7.3%), *Journal of Clinical Virology* (7.3%), and *Virology* (6.3%). However, it is important to highlight that virology journals were only the second category of journals used.

According to the scope of the SJR, virology is one of the widest areas of research. It includes all aspects of viral organisms and host-virus interactions and covers the molecular, biochemical, and cellular studies of bacterial-, archaea-, plant-, animal-, and human-specific viruses, as well as materials on medical virology and pathogenesis and treatment of viral diseases. In Colombia, various researchers work on viral diseases and viruses. The numbers of papers dealing with each virus or group of viruses according to similar characteristics were analyzed. The major viruses or diseases that appeared in databases were HIV/AIDS, dengue, and papillomavirus (21.4%, 15.8%, and 12.7% of the total productivity, respectively). Plant viruses and some veterinary viruses appeared as the fourth and fifth groups of viruses studied (8.3% and 6.9%, respectively). As can be seen in Table 4, some categories included more than one viral agent. It is important to highlight that research on human viral infections accounts for the vast majority of the papers produced in Colombia (84.5%).

Table 5 shows the top 10 institutions with the highest number of published papers in virology. Almost 70.0% of the papers (496) were published by those ten institutions. The institutions were as follows: Universidad de Antioquia (142 papers; 20.0%), Universidad Nacional de Colombia (65; 9.1%), Pontificia Universidad Javeriana (58; 8.2%), Instituto Nacional de Salud (55; 7.7.%), Universidad Industrial de Santander (44; 6.2%), Universidad del Valle (40; 5,6%), Instituto Nacional de Cancerología (38; 5.3%), Fundación Instituto de Inmunología (19; 2.7%), Centro Internacional de Agricultura Tropical (18; 2.5%), and Universidad de Córdoba (17; 2.4%).

Table 6 shows the top 10 most prolific authors with their affiliations, taking in account the standard competition ranking. These 10 authors accounted for 26.3% of the virology-related published papers in the studied period, and all of them belonged to some of the top 10 institutions (Table 5). A list of the top 10 most-cited Colombian virology papers is presented in Table 7. It is important to highlight that the most-cited papers (8 of 10) focused on HPV, included at least one of the most prolific authors (N. Muñoz), and belonged to one of the most prolific institutions of the country (Instituto Nacional de Cancerología), although none of those top virology papers were published in virology subject journals.

Discussion

This study shows an interesting analysis of Colombian's research publications on viruses and viral diseases between 2000 and 2013. The main results show a continuous increase and important growing trends in the number of publications from Colombia on the subject of virology (Figure 1, Table 1). This is consistent with data from the only previous Colombian bibliometric study [9] that showed an increasing trend in the number of publications on infectious diseases in the main Colombian journals from 2000 to 2009. Using a similar approach, a growing pattern has been shown for Colombia's academic production in the field of biotechnology for the period 2001–2012 [22]. However, in contrast to this work, our study analyzed publications from the four main databases and the main international journals to have a better view of the current situation of research on viruses in Colombia. As has been reported previously [23], there are some areas in which a literature search in one or two databases alone leads to incomplete information retrieval about the region, due mainly to the wide scope of the research topic; this issue occurs also for virology. Our data set collected major virology's Colombian papers indexed in the most important regional (SciELO and LILACS) and international (Scopus and PubMed) databases.

Falagas *et al*., in 2005, showed that developing areas of the world (such as Colombia) urgently need more help from developed regions to enhance their research infrastructure in the field of virology [8]. This

study found that Colombian researchers are increasingly producing internationally co-authored papers with an increasing number of collaborations (Figure 2A), and the vast majority of these with developed countries such as the United States, Spain, and France (Figure 2B). These first-world countries have had a significant growing share in the virology field in the last decade [4,24], which can be very useful for developing countries such as Colombia in terms in terms of reduction of transactional cost of technology transfer, communication, and quality of research. Important Latin American countries such as Brazil and Mexico are included in the top 10 collaborators, and those countries have been shown to be the most important producers of regional literature in public health registered in Scopus and to act as proxies in the network of intra-regional collaboration in different areas [25,12,11].

One of the most the most important findings of our analysis is that developing countries (in our case, Colombia) could obtain better visibility of their research by developing international projects and internationally co-authored publications (Figure 3). Our results and previous studies [26,27] found that articles with international collaboration appeared in journals with higher SJRs and were likely to be more frequently cited [16]. It has been suggested that this may be due to the fact that research involving international cooperation could include topics of broader interest and be suitable for journals with higher SJRs, that only the strongest researchers will have the resources and motivation to overcome the difficulties of collaboration over a distance, and that the biggest- and highest-profile projects are more likely to be international [16]. In fact, countries with the lowest scientific productivity (such as Colombia) have a higher tendency to collaborate than do the countries with the highest leadership. Advanced scientific development and leadership may mean greater autonomy and a lesser need to collaborate [28].

Our results and the results of others [29,24,7] have shown that it is important to take into account the fact that many articles concerning viruses and viral diseases are published in journals of other SJR categories and not just in the virology category. This study shows that, for Colombia, the main categories included *medicine (miscellaneous), virology, infectious diseases,* and *public health, environmental and occupational health* (Table 2). This could be due to the strategic, tropical, and geographic location of Colombia and the possibility of conducting research on important tropical pathogens such as the dengue virus (Table 3). It should also be stressed that research in virology and/or viral diseases actually interests physicians of several medical specialties and researchers from other biomedical areas such as veterinarians, biologists, agricultural engineers, and others [8,1].

Although Richardson recently (2014) proposed that global bibliometric analysis in virology including only the journals that are categorized in Scopus within the virology subject captures the great majority of relevant research [30], our results shows that Colombian researchers published virology papers most frequently in journals of *medicine (miscellaneous)* (26%) than in journals of *virology* (14.1%), showing that it is very important to evaluate different databases [23] and different categories to have a full panorama of what is been published in an area of research. This idea has also been supported by recent studies showing that the global research on yellow fever virus is published mainly in the *public, environmental, and occupational health* category in the database [31], whereas research on human papillomavirus (HPV) is published in journals in which oncology is the main category [32]; in both cases, virology was the fourth subject in order of importance, confirming our hypothesis that not all virology knowledge is published in journals of the same subject.

Another important finding is the fact that HIV/AIDS, dengue, and papillomavirus research account for almost half of the Colombian articles published. This is very important because those viruses are well known as major pandemic and emerging viruses worldwide [33,34,35], and developing countries need to be ready to fight these and other viral threats. Such results could indicate that Colombian researchers are prepared to face various viral threats as previously encountered in the 2009 influenza A(H1N1) pandemic [36].

One of the most controversial issues in bibliometric evaluation is the use of the SJR to qualify authors' work; one of the limitations of using the SJR is that it is greatly dependent on the category of the subject [37]. Our analyses combining SJR allowed us to summarize the SJR of the papers belonging from a same journal categories (Table 2) or a virus studied (table 4) as an arbitrary measure of the visibility of the research in that category and/or virus. In the case of Colombian productivity in research on HPV, although most of the published papers came from HIV studies, the highest median SJR of the publications came from HPV research (Table 4), indicating that the classical view of the number of papers is not the only important

factor in categorizing research. This could be useful in establishing points of reference and facilitating decision making regarding research policies related to virology studies and also animal, human, and plant health, as has been proposed by others [38].

Potential limitations of the present study are related to the databases used to retrieve articles. The databases analyzed do not represent all scientific and biomedical journals published [39]. However, this probably does not add any systematic bias in the analysis of the data, and the fact that we used four different international databases diminishes bias. Also, despite the meticulous search methodology, some articles were missed because the full address of the authors was not registered or the address was misspelled. Other limitations include the multiple citations of the subject category in the journals examined that were generally used in SCImago Journal and Country Rank. One journal with its articles might be indexed with several subject categories. However, this fact probably does not add any systematic bias to the analysis of the data because we selected the most accurate subject to the virology knowledge.

Conclusions

This work has revealed a progressive increase in the scientific productivity, visibility, and impact of published research on the subject of virology in Colombia. This is due to the growing presence of publications in foreign journals and increasing international collaboration with developed countries, both of which have allowed better publications in quality journals and better visibility of the virology studies carried out in Colombia.

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