

The scientific production in health and biological sciences of the top 20 Brazilian universities

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Abstract

Brazilian scientific output exhibited a 4-fold increase in the last two decades because of the stability of the investment in research and development activities and of changes in the policies of the main funding agencies. Most of this production is concentrated in public universities and research institutes located in the richest part of the country. Among all areas of knowledge, the most productive are Health and Biological Sciences. During the 1998-2002 period these areas presented heterogeneous growth ranging from 4.5% (Pharmacology) to 191% (Psychiatry), with a median growth rate of 47.2%. In order to identify and rank the 20 most prolific institutions in these areas, searches were made in three databases (DataCAPES, ISI and MEDLINE) which permitted the identification of 109,507 original articles produced by the 592 Graduate Programs in Health and Biological Sciences offered by 118 public universities and research institutes. The 20 most productive centers, ranked according to the total number of ISI-indexed articles published during the 1998-2003 period, produced 78.7% of the papers in these areas and are strongly concentrated in the Southern part of the country, mainly in São Paulo State.

Key words

- Health sciences
- Scientific publications
- Information science
- Scientometrics
- Bibliometric analysis

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Introduction

Brazilian scientific production determined on the basis of articles indexed by the Science Citation Index has increased 4-fold (from 0.44 to 1.7% of total world articles) since the beginning of the 1980's. This improvement in the scientific output ranks Brazil as the 17th most productive country in the world, and the most productive one among the Latin American nations, with a production corresponding to 1.7% of the world articles in 2004 (1-3).

One of the reasons for this improvement is the stability of domestic investments in research and development activities during recent years, attaining 1% of the Brazilian Gross Domestic Product (GDP) or approximately US\$13.5 billion in 2004 (1,4). Two other probable factors that contributed to this increase are the modernization of research institutions and changes in funding policies adopted by national funding agencies, such as the National Council for Scientific and Technological Development (CNPq) and the Coordination for the Enhancement

of Higher Education Personnel (CAPES), both responsible for investments in research and in graduate programs in all of the 27 Brazilian states.

Despite this accelerated growth observed in all fields of knowledge, Health and Biological Sciences were the most productive areas, as reported by Leta and De Meis (5) and Guimarães (6). These areas generated 44.2% of the 64,475 original Brazilian articles registered in the Science Citation Index Expanded database from 1998 to 2002 (7,8). Medicine exhibited one of the most expressive growth rates (85.6%) during this period and alone produced one-fourth of all those papers, with less traditional areas such as Psychiatry and Psychology also presenting increased production (9). The increase in national production in these areas ranked Brazil as the only Latin American country among the 20 most productive nations in Health Sciences during the last decade (10).

Almost all of this scientific production - approximately 90% of the ISI articles - comes from a small group of public universities and research institutes that offer the most advanced Graduate Programs in Brazil (11,12). Another distinguishing trait of the Brazilian scientific system is that these institutions are concentrated in the southern part of Brazil, specifically in São Paulo State, where the most important state research funding agency is also located: the State of São Paulo Research Foundation (FAPESP) that invests in scientific research projects and fellowships for Master's, Doctoral students and post-Doctoral students in the State of São Paulo. The budget of FAPESP is the second largest one among funding agencies in the country. In 2002 FAPESP invested US\$148 million in research and development, CNPq US\$170 million and CAPES US\$146 million (13,14).

This paper analyzes Brazilian scientific production in Health and Biological Sciences in order to identify and rank the 20 most productive institutions in these areas, based on the estimated number of ISI origi-

nal articles published from 2001 to 2003.

Material and Methods

A sample of 592 Brazilian Graduate Programs (GPs) offered by 118 universities and research institutes from 1998 to 2003 were selected from the CAPES database (DataCAPES). Five hundred and ninety of the 592 GPs selected belong to Health and Biological Sciences, an area comprising 11 fields: Biological Sciences I, Biological Sciences II, Biological Sciences III, Physical Education, Nursing, Pharmacy, Medicine I, Medicine II, Medicine III, Dentistry, and Public Health. Two other programs classified under Psychology, an area of Human Sciences, were also included in this analysis because their scientific production is closely related to that of Health and Biological Sciences (15).

Journal Citation Reports (JCR) was consulted in order to identify the original Brazilian articles in Health and Biological Sciences published in ISI-indexed journals. MEDLINE was consulted in order to identify the Brazilian manuscripts published in MEDLINE-indexed journals during this period.

DataCAPES is a database developed by CAPES, an agency of the Ministry of Education responsible for the Brazilian graduate training system. Since 1996, DataCAPES collects detailed information from all the national GPs. The available data for each program include the institution's name and location, field of knowledge it belongs to, number of scientific advisors, number of Master's and Doctoral students, mean time needed to conclude the program, and number of original articles published in journals indexed by various databases (MEDLINE, ISI, Lilacs, and SciELO) published by the program members (professors and graduate students) each year. DataCAPES was used to access the scientific production of each of the 592 programs from 1998 to 2003. Only

original articles from the ISI and MEDLINE databases were considered in this analysis.

Results

Extensive searches in DataCAPES allowed the identification of 109,507 original articles produced by the 592 GPs offered by 118 Brazilian universities and research institutes. The source of 98,884 articles published from 1998 to 2003 was retrieved through a comparison of the International Standard Serial Number (ISSN) of each article and the ISSN of journals indexed in the JCR-ISI and in MEDLINE databases. It was not possible to identify the source of 10,623 articles, which were excluded from the analysis. First, the ISI and MEDLINE articles were grouped by GP and subsequently by institution. Universities and research institutes that have two or more GPs in one area were considered to be independent institutions, as they generally have different sources of investment and other specificities. As CAPES carries out a complete assessment of each GP every three years, we ranked the 20 most productive universities and research institutes according to the total number of ISI-indexed articles published during the latest triennium (2001-2003) evaluated by CAPES. In a further analysis, the scientific output of the first triennium (1998-2000) was compared to that of the second (2001-2003). A frequency analysis for each triennium was then performed separately in the ISI and MEDLINE databases using Microsoft Access. Since many journals indexed by ISI are also indexed by the MEDLINE database and, to a lesser extent, MEDLINE journals are registered in ISI database, it was not possible to sum ISI and MEDLINE papers, since some articles would be counted twice. It was not possible to eliminate duplication in the counting of articles written by co-authors from different GPs.

The 20 most productive Brazilian institutions in Health and Biological Sciences of-

fered 377 GPs and published 86,132 articles indexed by ISI and MEDLINE (corresponding to 78.7% of the national papers produced in these areas) during the period 1998-2003. The 20 most productive universities and research institutes were ranked according to the total number of ISI-indexed articles published during the 2001-2003 triennium (Table 1). Among the top 20, the most productive was the University of São Paulo, which offered 69 GPs and published 5,696 papers indexed by ISI during that period.

The scientific production in this area is concentrated in 11 of the 27 Brazilian provinces or counties, most of them located in the Southeastern and Southern part of the country. Eight research centers that produced about 80% of the articles published in each triennium are located in only four States: São Paulo, Minas Gerais, and Rio de Janeiro, in the southeastern part of the country, and in Rio Grande do Sul, in the South. Four of these institutions are in São Paulo: University of São Paulo (USP), Federal University of São Paulo (UNIFESP), State University of Campinas (UNICAMP), and University of São Paulo in Ribeirão Preto (USP-Ribeirão Preto).

Almost all the institutions registered significant increase in the absolute number of articles published between the first and second triennium. There was a similar growth in ISI- and MEDLINE-indexed articles (Table 2). The growth rate of ISI articles ranged from 22% (UFRJ) to 222% (UNICAMP-Piracicaba) and the growth rate of MEDLINE articles ranged from 22% (UFRJ) to 232% (UNICAMP-Piracicaba).

It was possible to divide the top 20 into two distinct groups. The first included the 8 most productive universities and institutes with a more homogeneous growth rate, ranging from 21.5 to 60%, and the second included the 12 remaining institutions, with the increment ranging from 17 to 232%.

There were some interesting changes concerning human resources in these top 20

institutions. The average number of students obtaining a PhD increased, while the average number of advisors decreased. Despite this change, every institution registered a growth in the mean number of ISI-articles published by graduate student research advisors (Table 3).

Discussion

The scientific output of the 20 most productive Brazilian institutions in Health and Biological Sciences presented significant increase from the first to the second triennium, as analyzed in the present study. The sole

exception was Unesp-Botucatu whose production decreased. However, these data must be interpreted carefully because there may be duplication in the counting of articles indexed by both ISI and MEDLINE and a double counting of papers written by co-authors from different GPs. The absolute number of articles published by each institution augmented at similar rates, both in the ISI and in MEDLINE databases. Since both databases cover the most important scientific journals in the world, this increase indicates an improvement in the general quality of articles published by Brazilian institutions.

Table 1. The 20 most productive Brazilian institutions in Health and Biological Sciences (1998-2003).

Rank	Institution	Graduate programs	Number of articles indexed in:			
			MEDLINE ^a (1998-2000)	MEDLINE ^a (2001-2003)	ISI ^b (1998-2000)	ISI ^b (2001-2003)
1st	USP	69	4,491	6,368	4,025	5,696
2nd	UFRJ	36	1,908	2,318	2,037	2,476
3rd	UNIFESP	45	1,826	2,687	1,504	2,290
4th	USP-Ribeirão Preto	29	1,606	2,290	1,477	2,129
5th	UNICAMP	20	1,362	2,039	1,384	2,031
6th	UFRGS	21	1,095	1,762	1,090	1,695
7th	FIOCRUZ	5	1,245	1,711	1,095	1,425
8th	UFMG	26	1,043	1,553	1,020	1,451
9th	UFPR	14	328	652	400	735
10th	UNESP-Botucatu	13	551	457	557	520
11th	UFPE	21	331	452	433	599
12th	UERJ	12	320	705	306	634
13th	UnB	8	295	340	285	437
14th	UFSC	11	265	422	241	405
15th	UFBA	8	323	522	259	369
16th	UFC	11	215	348	192	323
17th	UNESP-Rio Claro	4	72	118	171	280
18th	UNICAMP-Piracicaba	10	135	448	102	328
19th	UNESP-Araraquara	9	131	268	148	280
20th	UFPA	5	147	225	168	258
Total			17,689	25,685	16,894	24,361

Source: DataCAPES (<http://ged.capes.gov.br/AgDw/silverstream/pages/frPesquisaColeta.html>).

USP (University of São Paulo); UFRJ (Federal University of Rio de Janeiro); UNIFESP (Federal University of São Paulo); USP-Ribeirão Preto (University of São Paulo, Ribeirão Preto); UNICAMP (State University of Campinas); UFRGS (Federal University of Rio Grande do Sul); FIOCRUZ (Oswaldo Cruz Institute Foundation); UFMG (Federal University of Minas Gerais); UFPR (Federal University of Paraná); UNESP-Botucatu (São Paulo State University, Botucatu); UFPE (Federal University of Pernambuco); UERJ (Rio de Janeiro State University); UnB (University of Brasília); UFSC (Federal University of Santa Catarina); UFBA (Federal University of Bahia); UFC (Federal University of Ceará); UNESP-Rio Claro (São Paulo State University, Rio Claro); UNICAMP-Piracicaba (State University of Campinas, Piracicaba); UNESP-Araraquara (São Paulo State University, Araraquara); UFPA (Federal University of Pará). ^a2,242 journals; ^b2,747 journals.

Despite this general performance, scientific production in these areas is mainly sustained by institutions classified in the eight first positions of the ranking (USP, UFRJ, UNIFESP, USP-Ribeirão, UNICAMP, UFRGS, FIOCRUZ, and UFMG). Generally, they presented a lower relative growth rate than that of the other twelve centers. The absolute number of articles published by these top eight institutions was quantitatively much superior: altogether they produced about 80% of the articles indexed by MEDLINE and ISI in the first and second triennia.

This performance can be explained by the concentration of GPs in those eight institutions, which offered 251 (66.6%) of the 377 programs in Health and Biological Sciences offered by the 20 centers ranked in the present paper. Another potential reason is that these eight most prolific centers are centered geographically in the two Brazilian

Table 2. Improvement in Brazilian scientific production measured in terms of number of articles indexed in MEDLINE and ISI.

Institution	Growth from 1998-2000 to 2001-2003	
	MEDLINE papers	ISI papers
USP	41.8%	41.5%
UFRJ	21.5%	21.6%
UNIFESP	47.2%	52.3%
USP-Ribeirão Preto	42.6%	44.1%
UNICAMP	49.7%	46.8%
UFRGS	60.9%	55.5%
FIOCRUZ	37.4%	30.1%
UFMG	48.9%	42.3%
UFPR	98.8%	83.8%
UNESP-Botucatu	-17.1%	-6.6%
UFPE	36.6%	38.3%
UERJ	120.3%	107.2%
UnB	15.3%	53.3%
UFSC	59.3%	68.1%
UFBA	61.6%	42.5%
UFC	61.9%	68.2%
UNESP-Rio Claro	63.9%	63.7%
UNICAMP-Piracicaba	231.9%	221.6%
UNESP-Araraquara	104.6%	89.2%
UFPA	53.1%	53.6%

Source: DataCAPES (<http://ged.capes.gov.br/AgDw/silverstream/pages/frPesquisaColeta.html>). For abbreviations, see legend to Table 1.

Table 3. Comparison of the outcome of the top universities regarding the number of graduates and scientific production in the two periods of assessment (1998-2003).

Institution	Doctorate students graduated		Average number of advisors		PhD students graduated per advisor		ISI-indexed articles per advisor	
	1998-2000	2001-2003	1998-2000	2001-2003	1998-2000	2001-2003	1998-2000	2001-2003
USP	1,340	1,860	1,904	1,627	0.70	1.14	2.11	3.50
UFRJ	445	514	733	640	0.61	0.80	2.78	3.87
UNIFESP	563	638	540	582	1.04	1.10	2.79	3.94
USP-Ribeirão Preto	340	499	576	524	0.59	0.95	2.57	4.07
UNICAMP	297	446	561	446	0.53	1.00	2.47	4.56
UFRGS	200	257	421	422	0.48	0.61	2.59	4.02
FIOCRUZ	162	224	400	323	0.41	0.69	2.74	4.41
UFMG	153	224	331	429	0.46	0.52	3.08	3.38
UFPR	101	144	246	227	0.41	0.63	1.63	3.23
UNESP-Botucatu	135	192	346	236	0.39	0.81	1.61	2.20
UFPE	39	104	280	271	0.14	0.38	1.55	2.21
UERJ	46	134	236	203	0.19	0.66	1.30	3.12
UnB	32	73	121	138	0.26	0.53	2.35	3.17
UFSC	37	65	225	187	0.16	0.35	1.07	2.16
UFBA	25	59	164	136	0.15	0.43	1.58	2.71
UFC	26	113	112	162	0.23	0.70	1.72	1.99
UNESP-Rio Claro	59	91	129	106	0.46	0.86	1.33	2.64
UNICAMP-Piracicaba	99	169	130	121	0.76	1.39	0.79	2.70
UNESP-Araraquara	58	94	118	119	0.49	0.79	1.25	2.35
UFPA	21	31	84	117	0.25	0.27	2.01	2.21

Source: DataCAPES (<http://ged.capes.gov.br/AgDw/silverstream/pages/frPesquisaColeta.html>). For abbreviations, see legend to Table 1.

regions with the highest budgets applied to research and development. Seven institutions are located in the States of Rio de Janeiro, São Paulo and Minas Gerais, in the Southeastern region of the country, and one is in Rio Grande do Sul, in the South. It was not possible to identify the total amount each region of the country invested in research and development activities, but from 1990 to 2003 the governments of the four Southeastern States and the three Southern States invested about 1% of the regional GDP (ranging from 0.6 to 1.5) in research and development activities (1).

More detailed data are available for São Paulo, the richest State in the country, contributing 34% of the national GDP. In 2000, the public and private sectors in the State of São Paulo, where half of the eight top institutions are located, applied US\$4.5 billion to research and development activities, almost 40% of national investments in research and development. From 1998 to 2002, FAPESP alone invested approximately US\$40 million per year in medical research (16). This amount corresponds to approximately 35% of investments made by six public funding agencies in this area (17). The continuous investment in research and development made by São Paulo for the last decades may explain the concentration of the Brazilian scientific production in this State, as reported by Leta and De Meis (5), and the presence of three State universities (USP, UNICAMP, and UNESP) among the top 500 universities in the world. UFRJ in Rio de Janeiro is the fourth Brazilian university classified in the Shanghai Jiao Tong University's ranking that attributes considerable weight to this academic production (18,19).

The evolution of Brazilian scientific output is also due to the consolidation and expansion of GPs in the country. Inaugurated in 1951 by CAPES, these programs were conceived to carry out research and prepare investigators to obtain their Master's and

Doctoral degrees. Some evaluations show that one third of these programs can be considered to be up to international standards: they include most of the researchers, producing most of the scientific material and publications coming out of Brazilian institutions (20). In 1996, CAPES registered 1,209 GPs in nine fields. Five years later, Brazilian universities and institutions had 1,551 GPs (21).

The absolute number of Doctoral degree recipients from Brazilian GPs increased 5-fold in the last decade: 1,206 students earned a degree in 1990 in comparison to 6,042 in 2001 (22). This means a significant mean growth rate of 14.5% a year, making it possible for Brazilian universities and institutes to graduate 3.50 students with a Doctoral degree per 100,000 inhabitants in 2001 (Germany graduates 30 students per 100,000 inhabitants; France, Russia and the United States 15 per 100,000; Japan and South Korea 12 per 100,000). A recent estimate indicates that by 2010 Brazil will graduate 18.8 per 100,000 inhabitants, exceeding the estimated rates of the United States and Japan (23). Unless this expansion is followed by a real increase in funding, the national graduate system may have to deal with an unfavorable scenario of competition and job stress that may lead to a decline of Brazilian science (24).

Once more the most productive areas in Brazil are Health and Biological Sciences, giving graduate degrees to almost one fourth of the doctorate students. Concentration in this field is more evident in São Paulo State, alone responsible for half of the national scientific production (25). Federal and State funding agencies made an important contribution to this performance. From 1990 to 2001, there was a continuous growth in the graduate fellowships offered by CAPES and CNPq, both Federal agencies. The absolute number of fellowships grew from 6,000 to 14,822 within this period (22). However, this system has recently experienced a small

decrease in the fellowships granted by state funding agencies such as FAPESP (25).

This growth in the number of GPs offered by Brazilian institutions was followed by a general increasing trend in the number of Doctoral students graduating in the top 20 universities and research institutes in Health and Biological Sciences. From the first to the second triennium, the number of students obtaining Doctoral degrees expanded at rates ranging from 13 to 335%. Among the top eight, this increase was remarkable in UNICAMP (50%), USP-Ribeirão (47%), and UFMG (46%).

This growth was followed by a decrease in the average number of advisors in fourteen of the twenty institutions, ranging from 3% (UFPE) to 32% (Unesp-Botucatu). Despite this reduction, a general improvement in the mean production of the advisors can be observed. The number of ISI-indexed articles published by advisors increased from 10% (UFMG) to 241% (UNICAMP-Piracicaba). Although it may seem paradoxical, this increase in productivity may be explained by changes in the evaluation of the GPs. During the last decade, CAPES implemented a more stringent evaluation process that may have stimulated universities and research institutes to adopt new patterns of productivity, replacing the less productive advisors. Moreover, advisors became more aware of their role and have increased individual productivity. In 1998, CAPES adopted the international standard as a guide to analyze the performance of each GP, classifying each GP with scores ranging from 1 (lowest) to 7 (highest). A score of 5 is considered to indicate a good program, and scores of 6 and 7 are considered to indicate programs that are equivalent to international standards in dif-

ferent areas of knowledge (8). CAPES also developed a scoring system for scientific production based on the journals in which the papers were published, and the actual involvement of graduate students in the authorship of the articles.

The performance of these top 20 research institutions reveals a concentration trend in scientific output in Health and Biological Sciences in the richest regions of Brazil. It is a concentration at the national level, similar to that observed by Paraje et al. (10) on the international scene. National efforts, such as the enhancement of academic training and stimuli to the activity of state funding agencies should be made to reduce this gap and to better comply with the needs of poorer regions of the country. King (3) stated that the strengthening of Science has additional benefits for every nation, and for the world as a whole, because of the sorts of threats faced nowadays. This assertion could probably be translated to a more regional level: Brazil as a whole would benefit from the strengthening of scientific production in the most varied regions of the country, regions so diverse economically, socially and culturally that they could be considered as independent countries inside the larger country.

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