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Scientific production and most researched diseases in the Biological Sciences postgraduate programs in Brazil

Produção científica e doenças mais pesquisadas nos programas de pós-graduação em Ciências Biológicas no Brasil

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Abstract

This macro-level scientometrics study aimed to analyze the similarities and differences in the scientific communication patterns of the Brazilian postgraduate programs (BPPs) belonging to the Biological Sciences II field (BS2), as defined by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Also, it was identified the most researched diseases and it was discussed their relationship with the needs of Brazilian public health considering the burden of disease (Disability-Adjusted Life Year - DALY, Brazil) estimated by the World Health Organization (WHO). Thus, the scientific production of the BS2's sub-areas Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology was evaluated from 2013 to 2016, through considering the citation impact, Impact Factor (*Journal Citation Reports*), and scientific collaboration. Data collected included formal information provided to CAPES by all BPPs through the Plataforma Sucupira as well as metadata from Web of Science documents. In addition, were employed the standardized Medical Subject Headings (PubMed) for the analysis of researched diseases. We concluded that the patterns of scientific communication in Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology were predominantly different. Thus, there is a need to consider specificities among the five sub-areas in the evaluation process performed by CAPES. Different approaches are revealed by identifying the most frequently researched diseases and explaining the contributions of each sub-area for Brazilian public health.

Keywords: Scientific production; Researched diseases; World Health Organization; Postgraduate programs evaluation system in Brazil; Biological Sciences field.

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Resumo

Este estudo cientométrico de nível macro teve como objetivo analisar as semelhanças e as diferenças nos padrões de comunicação científica dos programas de pós-graduação brasileiros (PPGs) da área de Ciências Biológicas II, avaliados pela Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). Além disso, foram identificadas as doenças mais pesquisadas e foi discutido sua relação com as necessidades de saúde pública brasileira, considerando a carga de doenças (Disability-Adjusted Life Year - DALY, Brasil) estimada pela Organização Mundial da Saúde (OMS). Assim, a produção científica das subáreas Biofísica, Bioquímica, Farmacologia, Fisiologia e Morfologia da área de Ciências Biológicas II foi avaliada de 2013 a 2016, considerando o impacto de citações, o Fator de Impacto (*Journal Citation Reports*) e a colaboração científica. Os dados coletados incluíram informações declaradas à CAPES por todos os PPGs por meio da Plataforma Sucupira, bem como metadados de documentos da Web of Science. Além disso, foram utilizados os cabeçalhos de Medical Subject Headings (PubMed) para a análise das doenças pesquisadas. Concluímos que os padrões de comunicação científica entre as subáreas Biofísica, Bioquímica, Farmacologia, Fisiologia e Morfologia foram predominantemente diferentes. Assim, é necessário considerar as especificidades entre as cinco subáreas no processo de avaliação realizado pela CAPES. Diferentes abordagens são reveladas a partir da identificação das doenças mais pesquisadas e da explicação das contribuições de cada subárea para a saúde pública brasileira.

Palavras-chave: Produção científica; Doenças pesquisadas; Organização Mundial da Saúde; Sistema de avaliação de programas de pós-graduação no Brasil; Campo das Ciências Biológicas.

Introduction

The higher education system in Brazil is widely diversified and has an enormous territorial scope with various types of institutions, both public and private, involved on teaching, researching, and extension programs. To ensure the quality of education, control public spending, and remain accountable to the citizenry, undergraduate and postgraduate programs are assessed by government institutions and financing agencies according to specific norms and schedules. Maintaining a single evaluation process has become difficult and requires a specific standard of implementation of additional approaches and indicators to address this system's significant size, complexity, and diversity.[1]

Public Brazilian postgraduate programs (BPPs) are mainly responsible for the country's scientific production, and the private institutions' contribution is not relevant.[2-4] Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) is an agency linked to the Ministry of Education that annually evaluates the quality of BPPs and renews the accreditation of Master's and Doctoral programs in the Sistema Nacional de Pós-Graduação (SNPG) – the National Postgraduate Program System – every four years. Each postgraduate program is evaluated in its activity field and then scored from one to seven, where three is the minimum necessary grade to retain accreditation. The results of these evaluations serve as a guideline for formulating the public policy and for distributing scholarships and research resources for graduate studies.[5]

The CAPES evaluation system contributes to an institutional evaluation that assesses the postgraduate programs quality, based on their performance in the following aspects: 1- Program proposal (objectives, actions to train students, and promotion of students integration to society); 2- Professors/researchers (profile of researchers and distribution of teaching and researching activities); 3- Student scientific qualification, theses and dissertations (number of concluded theses and dissertations, published results, and training time); 4- Intellectual Production (scientific production evaluated by its impact on academic journals and the distribution of scientific productions by the researchers); 5- Social Insertion (impact on society, measured by the number of master and PhD incorporated in Higher Education and Basic Education Institutions); and 6- Internationalization (an attribute that considers the participation of foreign researchers in the scientific production, the

scientific production published in foreign journals and/or publications that are indexed in international databases.[6,7]

On aspects 2 and 4, CAPES uses bibliometrics and scientometrics indicators such as scientific productivity, journal visibility, and internationalization of BPPs. The evaluation of Brazilian science based on quantitative indicators complements the qualitative evaluation conducted by peers. This method is common around the world and subjects the scientific community to an intense evaluation process that is important for defining scientific and technological policies/parameters for establishing research funding.[8-10]

The principles and guidelines of the CAPES evaluation system are used to compare and to qualify the 49 fields of knowledge.[11] Among them, it is included the Biological Science II field (BS2), which is composed by five sub-areas: Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology.

Similar to the world scenario of science assessment,[12] the CAPES evaluation system has assigned greater value to the professor/researcher productivity and the journal visibility, which corresponds to almost 70% of the grade attributed to BPPs.[13] It is of the utmost importance to mention that BPP science community is diverse and publishes part of its research in journals that are not indexed in international databases and/or have no impact indicators (such as *Journal Citation Reports* - JCR – and *SCImago Journal & Country Rank* - SJR, from Scopus/Elsevier). Also, different fields employ different publishing strategies. The Natural Sciences and the Earth and Exact Sciences fields, for example, have a broader international exposure than Social Sciences or Humanities, which don't have impact factor.[14] In fact, CAPES has adopted a unique evaluation system for classifying the publication source of scientific production of BPPs: the Qualis ranking. In order of prominence, journals are currently ranked A1, A2, B1, B2, B3, B4, B5, and C.

All fields, including BS2, have autonomy on establishing their classification guidelines in the journal rankings[15] and examine aspects such as the regular publication schedules, the diversity of authors, the participation of foreign authors and whether journal is indexed in national and/or international databases and has impact indicators (JCR and SJR). For the BS2 field, focus of this article, Qualis evaluation is constituted from the equivalence of the Impact Factor (IF) values[16] and the SJR indicators. The reference indexes of IF and SJR for determining Qualis ranking in the last assessment, the 2017 Quadrennial (from 2013 to 2016), were: A1 ≥4.60; A2 ≥3.531 and <4.60; B1 ≥2.481 and <3.531; B2 ≥1.65 and <2.481; B3 ≥1.096 and <1.65; B4 ≥0.728 and <1.096; B5 <0.728. In the BS2 field, it was determined that rank C is assigned for scientific production in journals that do not have an IF or SJR value (CAPES 2016c). In certain cases, journals are ranked higher than C even though they do not have IF or SJR values due to their significance in their field.[15,17] Moreover, the quality of BS2 scientific production is fundamentally measured by impact indicators of journals that are indexed in the Web of Science (WoS) and Scopus.[6,11]

Thus, focusing on the period from 2013 to 2016, this study seeks to identify similarities and differences in the patterns of scientific communication among the BS2 sub-areas Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology. In addition, it identifies the researched diseases in each sub-area and discusses their relationships with the burden of disease of the local population as provided by the World Health Organization (WHO), according to the method applied by Ràfols and Yegros,[18] Confraria and Wang[19] and Yegros *et al*.[20] Finally, this study seeks to understand how the analysis of multiple indicators can contribute to the improvement of the BPP evaluation. From our hypothesis, there are important differences among the scientific production of aforementioned sub-areas. Thus, these specificities are relevant in the processes of evaluating institutional performance.

The present research constitutes a macro-level scientometrics/bibliometrics study[21] intended to contribute to the understanding of patterns and specificities of scientific communication and

research priorities. By adopting a set of indicators that were not previously used in the CAPES Evaluation System, this article expands the possibilities to analyze the performance of BPPs and offer new perspectives for a more accurate evaluation about diversity and the contribution of BS2 postgraduate programs to Brazilian scientific production and its social impact. The present approach can provide grants to support the improvement of the CAPES Evaluation System.

Previous studies on the scientific communication and researched diseases

The CAPES evaluation system is constantly refined. Despite advances achieved with diversified indicators, certain gaps remain concerning the identification of particular features of each field and also to assess the social impact of the research. In this sense, Barata,[13] the former director of the CAPES evaluation system, argues that changes in the evaluation of postgraduate programs in Brazil are necessary, as essential issues such as training, self-evaluation, economic and social impact are absent or undervalued in the evaluation processes. Thus, filling the gaps left by the system is an important task to expand perceptions about the contributions of BPPs to science and society.

The CAPES Evaluation System has been a subject of research in Brazil using various approaches. Marenco[22] analyzed the postgraduate program evaluation processes and their influence on the development of the Political Science field. This influence can be seen especially in the increase in scientific production, in the orientation and concentration of such production towards more academically prestigious periodicals. Miranda and Mugnaini[23] assessed the influence of CAPES evaluation criteria on the publication profile in the field of Tourism. The authors concluded that small changes in the criteria – such as requiring only indexation on specific bases, rather than minimum JCR Impact Factor or h-index in Scopus – could favor the Tourism sub-area. Gheno *et al*.[24] evaluated the feasibility of a CAPES policy that limited the number of students per professor/researcher and mapped the social insertion of a Biochemistry Postgraduate Program with data based on its PhD in the labor market. The authors concluded that the number of students per professor does not affect the scientific production per student and that the social insertion was 88%. In her analysis, Voguel[25] identified that the hardest criticism to the CAPES Evaluation System is related to aspect 4- Scientific Production, due to the high value attributed to researchers' and students' productivity, and also because the criteria adopted to measure "quality" are based on the scientific production itself and the visibility of journals.

The Qualis ranking serves as the basis for the evaluation of scientific production and is also the subject of criticism and controversial debate, which indicates the need to deepen discussions on the participation of researchers in relation to the perspectives of science for various scientific areas of research in Brazil.[13,15,26]

Comparative studies are important to understanding scientific communication patterns of fields and disciplines, especially in the context of large scientific fields. Bordons and Zulueta[27] evaluated, for example, the publishing activity and the main differences between the fields of Cardiovascular Science and Pharmacy & Pharmacology in Spain, based on their different clinical/basic charater. Despite the similarities in productivity and international co-authorship, the study identified differences in publication strategies, interdisciplinarity, and citation impact, and other aspects. Oppenheim[28] analyzed the correlation between number of citations and the research assessment exercise ratings for British research in Genetics, Anatomy and Archaeology. The study identified that in all three cases, there is a statistically significant correlation between the number of citations and the research exercise score. It also indicated that citation counting provides a robust and reliable indicator for the research performance in different disciplines.

Vaughan and Shaw[29] studied the impact of citations on the fields of Biology, Genetics, Medicine, and Multidisciplinary Research and indicated that there is a significant correlation between the number of citations in different disciplines and

databases. They also proposed that the web-evident impact, with citations of different sources, might provide a balance to the geographic or cultural biases of main databases. Thelwall and Nevill[30] evaluated gender differences and the impact of American articles on the fields of Biochemistry, Genetics, and Molecular Biology and identified that, despite the lower presence of women, there is no evidence in the research contributions and citation of a bias determinant of gender disparities in these disciplines in United States, although there is a small male first author citation advantage in more fields than the opposite. Kamdem *et al*.[31] studied the productivity of Brazilian researchers in the fields of Biochemistry, Pharmacology, Biophysics, and Physiology. They found that scientific performance is not homogeneous, that is, there are great variability in the scientific productivity and citation in all subfields of Biological Sciences, with better performance of researchers from Pharmacology, followed by researchers from Biochemistry.

Analyzing the most frequently researched diseases is relevant for understanding health research trends. Bender *et al*.[32] analyzed Germany's participation in articles and collaboration networks regarding Neglected Tropical Diseases (NTD). They found that the share of publications with German affiliations in this discipline is approximately half of their share in other fields of medical research, and underlined the need to identify barriers and expand Germany's otherwise strong research activities towards NTDs, particularly with partner abroad in low- and middle-income countries. Peykari *et al*.[33] analyzed publication trends and collaboration networks regarding research into noncommunicable diseases in Iran. They identified a steady increasing trend in the country's publications, but not in all diseases. While cancer, diabetes, and cardiovascular diseases are well represented, there is need for more effort in chronic respiratory diseases researches and stronger collaboration with regional countries.

Some studies compared the research efforts/research priorities with WHO estimates of health burden of disease (Disability-Adjusted Life Year - DALY). Ràfols and Yegros[18] compared research and development (R&D) data at the international level and in Spain with data from the estimates provided by WHO/DALY. The results revealed that in both contexts, there is misalignment between R&D and the health needs. The authors suggest that some diseases that affect low- and middle-income countries, such as malaria and tuberculosis, should receive more attention in R&D because of the high burden of disease. Confraria and Wang[19] investigate the relations between research priorities and medical field investments with the burden of disease in the context of African countries. These authors identified that, despite the low capacity of research and investment from foreign countries, medical research in Africa is generally associated with its burden of disease. Yegros *et al*.[20] highlight that the high-income countries concentrate higher percentages of research, and this scientific production focuses their needs in terms of health. Furthermore, the pharmaceutical industry and the public sector tend to make more effort to research diseases most prevalent in high-income countries.

In this context, this article expands the possibilities to analyze the scientific production of Brazilian professors/researchers and offers new perspectives for a more accurate evaluation of BPPs including the contribution of research in areas related to the needs of Brazilian public health. In this way, we compared the performance of five sub-areas evaluated by CAPES with the same criteria.

Materials and Methods

This macro-level scientometrics study examines complementary aspects related to scientific production, citation impact, IF, scientific collaboration (co-authorship), and the most frequently researched diseases, as well as human resources (number of researchers) in the 73 BPPs of the BS2 field (Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology sub-areas) spread across the country.

The scientific production data (document titles and Qualis results) and the list of researchers/professor in the BS2 field were obtained from the

Plataforma Sucupira, an online management tool for BPPs[34] that records information officially declared by the BPGs to CAPES. All this information was compiled in the 2017 Quadrennial assessment (2013-2016) and was made available by CAPES.[7] The standardization of sub-areas for each postgraduate program and their respective performance rankings were based on the classification by CAPES.[35] In the absence of complete information about scientific production on Plataforma Sucupira, it was necessary to extract complete data sets at WoS and JCR.

Data from the scientific production of the BS2 field during this period were collected from WoS, making it possible to access each document's Data Object Identifier (DOI), and the co-authorship and affiliation data. The data were collected in June 2019 using the Advanced Search option in the WoS Core Collection, the field tag "CU" referring to the country, the search term (Brazil OR Brasil), and the time period 2013-2016. Data were downloaded in tab-separated format in sets of 500 records, compiled into a single file and cross-referenced with the documents titles in Plataforma Sucupira using *R* programming language.

To assess differences and similarities in IF distribution by sub-area, the non-parametric Kruskal-Wallis one-way analysis of variance (ANOVA) was applied, followed by Dunn's test to correct for multiple comparisons (Benjamini-Hochberg). The journal's IF refers to the 2015 JCR. The choice of this evaluation period is justified by the fact that BS2 rankings used 2015 IF data to compile the Qualis rankings for the 2017 Quadrennial, as stated in the CAPES Evaluation Report.[36] All statistical tests were performed using GraphPad Prism 6 (San Diego, CA, USA).

To identify the most frequently researched diseases, bibliographic data were collected in PubMed with the Medical Subject Headings (MeSH), the standardized terms available in the MeSH terms (MH) field. Data were collected from the basic PubMed search field using DOIs and the field tag "DOI". Data from documents without digital identifiers were collected by document title searches with the field tag Title (TI). PubMed data were downloaded in MEDLINE format and associated with the data set using *R* language. In the case of documents that did not have MeSH terms (2,329, representing 15.8%), the author's keywords were used, which were available in the Author Keywords (DE) field on WoS and were standardized to conform with the MeSH terms. Thus, the MeSH terms were attributed to 1,820 documents (12.3%). The 509 documents (3.5%) without MeSH terms and without the author's keywords were not included in the analysis of the diseases.

MeSH terms referring to diseases were identified by specialists on Biological Sciences, Pharmacy, and Medicine who, individually and blindly, selected two groups of terms which after review, resulted in a final list of 945 diseases. From these, 16 categories that grouped all diseases-referring terms with the corresponding frequency of documents for each sub-area were extracted – Cancer/Tumor; Cardiovascular/Immunologic System Diseases; Digestive System Diseases; Genetic-Associated Diseases; Infection-or Vector-related Diseases; Locomotor System Diseases (Bone, Muscle, and Joint); Metabolic and Hormonal Diseases; Nervous System Diseases; Ophthalmic Diseases; Pregnancy-related and Fetal Diseases; Renal System Diseases; Reproductive System Disorders; Respiratory System Diseases; Skin Diseases; Sleeping Diseases; and Not Categorized. All diseases-referring words were categorized considering the Human Anatomical Systems, as proposed by experts from the Federative International Programme on Anatomical Terminologies. Specific categories were created for diseases that could reach all body systems, such as Cancer and Genetic-associated diseases.

To assess whether research priorities meet Brazilian public health needs, we correlated the number and percentage of documents by disease with burden of disease DALY 2016, Brazil (WHO 2016), methods adopted by Ràfols and Yegros[18] and Confraria and Wang.[19] According to Ràfols and Yegros[18] "DALY is a measure that estimates the loss of one year of healthy life to disease, taking into consideration mortality as well as disability caused by a health condition". WHO estimates

a "DALYs for a disease or health condition are calculated as the sum of Years of Life Lost (YLL) due to premature mortality in the population and Years Lost due to Disability (YLD) for people living with the health condition or its consequences.".[37]

The *corpus* of research was formed by 14,733 documents published in journals evaluated by Qualis, JCR, and indexed in WoS (2,364 documents in journals that were not evaluated by JCR and/or that were not indexed on WoS were not taken into account), a majority were published by researchers from more than one BS2 field and may therefore have involved authors with different or multiple affiliations in relation to sub-areas and/or institutions. The research used the bibliometrics method of full counting, by which each postgraduate program and sub-area was credited with a document without data fractionation – an option widely used in bibliometrics studies.[21,38,39] Thus, some documents analyzed in the research may have been attributed to more than one sub-area or postgraduate program, and therefore the total count of various indicators does not correspond to the total number of documents.

Results and Discussion

Geographic distribution and performance of postgraduate programs by sub-area in the BS2 *field*

In the 2017 Quadrennial Evaluation (2013-2016), CAPES evaluated 73 postgraduate programs linked to the BS2 field: 3 in Biophysics, 19 in Biochemistry, 16 in Pharmacology, 29 in Physiology, and 6 in Morphology. Most programs are linked to federal universities (56) and state universities (13), and only four belong to private universities and institutes (Figure 1, ID's 4, 9, 47, and 71). This is relevant in the context of Brazilian research since public universities have a greater number of postgraduate programs (Master's and Doctoral) and are responsible for almost 90% of the country's scientific production[3,40] and the PhDs.[41] The contribution of the BS2 field to the production of knowledge in this period was 14,733 documents in journals evaluated by Qualis and JCR and indexed on WoS, which corresponds to 86% of documents listed in Plataforma Sucupira.

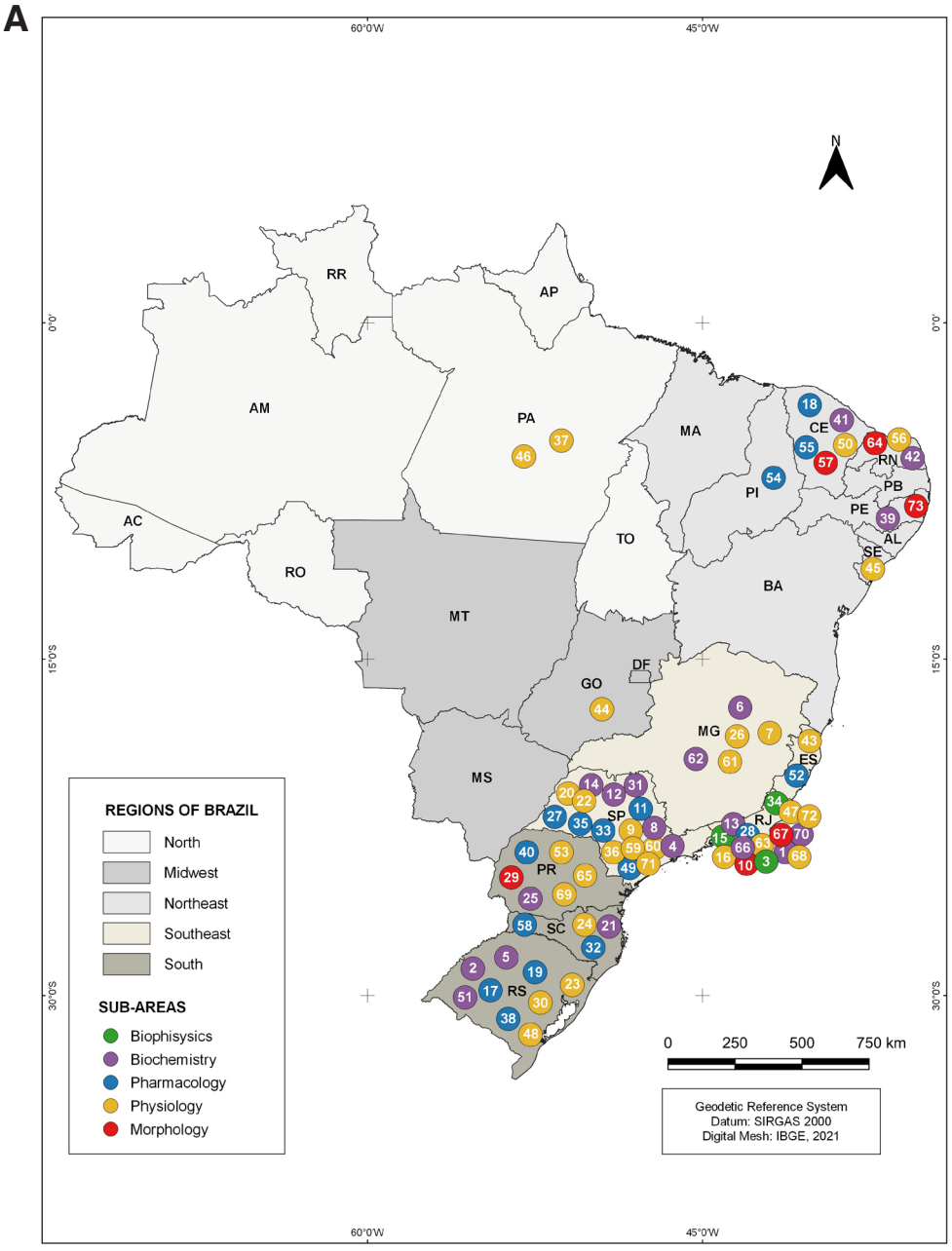
Brazil is divided into 27 federative units: 26 states plus the Federal District. Postgraduate programs in the BS2 field are distributed among 14 of these federative units (Figure 1); 39 (53.5%) are located in the Southeast region, which includes the states of São Paulo (SP), Rio de Janeiro (RJ), Espírito Santo (ES), and Minas Gerais (MG); and 19 (26.0%) are located in the South region, which includes Rio Grande do Sul (RS), Santa Catarina (SC), and Paraná (PR). The Northeastern region, which includes the states of Ceará (CE), Pernambuco (PE), Piauí (PI), Rio Grande do Norte (RN), and Sergipe (SE), the Northern region, which includes the state of Pará (PA), and the Central-Western region, which includes state of Goiás (GO), relatively have few programs, counting the remaining 12 (16.5%), 2 (2.5%), and 1 (1.5%), respectively.

Regarding the classification of postgraduate programs in the CAPES Evaluation System, 29 (40.0%) were ranked Four; 15 (21.0%) were ranked Five; 13 (18.0%) were ranked Seven; 9 (12.0%) were ranked Three; and 7 (10.0%) were ranked Six. The 20 (27.0%) postgraduate programs evaluated with the highest rankings, Six and Seven, are located in the Southeast and South region, with the exception of one program in the Northeast, in Ceará (CE). In addition to being evaluated as high performing, these programs concentrated the greatest number of documents (46.2%), international collaborations (from 19.9% to 42.3%), and average number of documents by researchers (from 5.3 to 22.3).

Regions with the greatest concentration of postgraduate programs were also the most productive. The Southeastern region was responsible for 60.1% of scientific production, followed by the Southern (26.4%), Northeastern (10.4%), Northern (2.1%), and Central-Western regions (1.0%). The five postgraduate programs that presented the higher number of scientific production were: *Biologia Celular e Molecular* at the Fundação Oswaldo Cruz - Fiocruz (958 documents); *Ciências Biológicas* (*Bioquímica Toxicológica*) at the Universidade

Federal de Santa Maria - UFSM (703); *Ciências Biológicas* (*Biofísica*) at the Universidade Federal do Rio de Janeiro - UFRJ (687); *Multicêntrico em Bioquímica e Biologia Molecular* at the Sociedade Brasileira de Bioquímica e Biologia Molecular - SBBQ (683), and *Ciências Biológicas* (*Bioquímica*) at the Universidade Federal do Rio Grande do Sul - UFRGS (610). Notably, of these, only one is maintained by a public research institute (Fiocruz), and all others are linked to public universities. The greatest production average by researcher came from UFSM (18.5) and UFRGS (12.4), however, these did not coincide with the highest percentage of documents with foreign co-authors. The Fiocruz (33.5), UFRJ (32.8), and SBBQ (32.2) programs had the greatest index of international co-authorship.

Figure 1 - AB - Geographic distribution and characteristics of postgraduate programs in the Biological Sciences II field in Brazil (2013-2016).



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ID	Organization	Postgraduate Program	Evaluation Grade (Quadrienal 2017)	Number of Documents	% International Collaboration	Number of Researcher	Documents by researcher
1	Fundação Oswaldo Cruz	Biologia Celular e Molecular	7	958	33.5	108	8.9
2	Universidade Federal de Santa Maria	Ciências Biológicas (Bioquímica Toxicológica)	6	703	20.3	38	18.5
3	Universidade Federal do Rio de Janeiro	Ciências Biológicas (Biofísica)	7	687	32.8	95	7.2
4	Sociedade Brasileira de Bioquímica e Biologia Molecular	Multicêntrico em Bioquímica e Biologia Molecular	4	683	32.2	160	4.3
5	Universidade Federal do Rio Grande do Sul	Ciências Biológicas (Bioquímica)	7	610	24.3	49	12.4
6	Universidade Federal de Minas Gerais	Bioquímica e Imunologia	7	599	42.1	112	5.3
7	Universidade Federal de Minas Gerais	Ciências Biológicas (Fisiologia e Farmacologia)	7	589	33.3	54	10.9
8	Universidade Estadual de Campinas	Biologia Funcional e Molecular	6	577	27.6	52	11.1
9	Sociedade Brasileira de Fisiologia	Multicêntrico em Ciências Fisiológicas	4	572	20.1	95	6.0
10	Universidade Federal do Rio de Janeiro	Ciências Morfológicas	7	553	40.9	52	10.6
11	Universidade de São Paulo/ Ribeirão Preto	Ciências Biológicas (Farmacologia)	7	513	25.1	23	22.3
12	Universidade Federal de São Paulo	Ciências Biológicas (Biologia Molecular)	7	501	29.1	55	9.1
13	Universidade Federal do Rio de Janeiro	Química Biológica	7	500	34.2	67	7.5
14	Universidade de São Paulo	Ciências Biológicas (Bioquímica)	7	456	42.3	57	8.0
15	Universidade Federal do Rio de Janeiro	Formação para a Pesquisa Biomédica*	4	446	33.9	76	5.9
16	Universidade Federal do Rio de Janeiro	Ciências Biológicas (Fisiologia)	7	432	36.3	51	8.5
17	Universidade Federal de Santa Maria	Farmacologia	5	404	18.6	38	10.6
18	Universidade Federal do Ceará	Farmacologia	6	398	24.4	34	11.7
19	Universidade Federal do Rio Grande do Sul	Ciências Biológicas: Farmacologia e Terapêutica	4	395	29.6	27	14.6
20	Universidade de São Paulo/ Ribeirão Preto	Fisiologia	7	354	25.7	23	15.4
21	Universidade Federal de Santa Catarina	Bioquímica	5	336	31.5	19	17.7
22	Universidade de São Paulo	Ciências (Fisiologia Humana)	6	335	29.6	36	9.3
23	Universidade Federal do Rio Grande do Sul	Ciências Biológicas (Neurociências)	5	331	24.2	30	11.0
24	Universidade Federal de Santa Catarina	Neurociências	5	329	28.6	28	11.8
25	Universidade Federal do Paraná	Ciências (Bioquímica)	7	323	27.6	34	9.5
26	Universidade Federal de Minas Gerais	Inovação Tecnológica e Propriedade Intelectual*	5	315	38.4	36	8.8
27	Universidade de São Paulo	Farmacologia	5	307	33.2	31	9.9
28	Universidade Federal do Rio de Janeiro	Ciências Biológicas (Farmacologia e Química Medicinal)	5	303	41.6	31	9.8
29	Universidade Federal do Paraná	Biologia Celular e Molecular	5	298	28.9	42	7.1
30	Universidade Federal do Rio Grande do Sul	Ciências Biológicas (Fisiologia)	5	297	29.3	31	9.6
31	Universidade de São Paulo/ Ribeirão Preto	Bioquímica	6	287	29.6	26	11.0
32	Universidade Federal de Santa Catarina	Farmacologia	6	277	28.9	21	13.2
33	Universidade Federal de São Paulo	Farmacologia	6	266	19.9	29	9.2
34	Universidade Federal do Rio de Janeiro	Formação Científica para Professores de Biologia*	4	262	29.8	50	5.2
35	Universidade Estadual de Campinas	Farmacologia	4	262	22.5	26	10.1
36	Universidade Federal de São Carlos	Ciências Fisiológicas	4	257	25.3	30	8.6
37	Universidade Federal do Pará	Neurociências e Biologia Celular	4	257	33.1	36	7.1
38	Universidade Federal de Pelotas	Bioquímica e Bioprospecção	4	255	12.5	25	10.2
39	Universidade Federal de Pernambuco	Bioquímica e Fisiologia	4	254	21.3	30	8.5
40	Universidade Federal do Paraná	Farmacologia	5	251	21.1	22	11.4
41	Universidade Federal do Ceará	Bioquímica	5	239	15.9	22	10.9
42	Universidade Federal do Rio Grande do Norte	Bioquímica	4	226	24.3	29	7.8
43	Universidade Federal do Espírito Santo	Ciências Fisiológicas	5	217	29.0	21	10.3
44	Universidade Federal de Goiás	Ciências Biológicas	5	206	20.9	33	6.2
45	Fundação Universidade Federal de Sergipe	Ciências Fisiológicas	4	204	9.8	24	8.5
46	Universidade Federal do Oeste do Pará	Biociências	3	204	29.4	29	7.0
47	Universidade do Grande Rio - Prof Jose de Souza Herdy	Biomedicina Translacional	4	202	37.1	32	6.3
48	Universidade Federal do Rio Grande	Ciências Fisiológicas	4	199	24.1	30	6.6
49	Universidade Est.Paulista Júlio de Mesquita Filho/Botucatu	Farmacologia e Biotecnologia	4	187	12.3	21	8.9
50	Universidade Estadual do Ceará	Ciências Fisiológicas	4	183	25.7	29	6.3
51	Fundação Universidade Federal do Pampa	Bioquímica	4	180	20.6	23	7.8
52	Universidade Federal do Espírito Santo	Bioquímica e Farmacologia	3	178	18.0	23	7.7
53	Universidade Federal do Paraná	Fisiologia	4	156	18.6	21	7.4
54	Fundação Universidade Federal do Piauí	Farmacologia	4	153	16.3	17	9.0
55	Universidade Federal do Ceará	Farmacologia*	5	152	24.3	22	6.9
56	Universidade Federal do Rio Grande do Norte	Neurociências	4	152	46.1	23	6.6
57	Universidade do Ceará	Ciências Morfofuncionais	4	144	32.6	17	8.5
58	Universidade Federal de Santa Catarina	Farmacologia*	4	143	31.5	20	7.2
59	Universidade Federal do ABC	Biossistemas	4	141	27.7	25	5.6
60	Universidade de São Paulo	Ciências (Fisiologia Geral)	4	136	31.6	25	5.4
61	Universidade Federal de Minas Gerais	Inovação Tecnológica e Biofarmacêutica	5	131	34.4	34	3.9
62	Universidade Federal do Triângulo Mineiro	Ciências Fisiológicas	3	127	26.0	23	5.5
63	Universidade Federal Fluminense	Ciências Biomédicas (Fisiologia e Farmacologia)	4	121	28.9	19	6.4
64	Universidade Federal do Rio Grande do Norte	Biologia Estrutural e Funcional	3	113	20.4	19	5.9
65	Universidade Estadual de Maringá	Ciências Fisiológicas	3	99	29.3	15	6.6
66	Universidade Federal do Rio de Janeiro	Química Biológica*	3	94	41.5	33	2.8
67	Instituto Nacional de Traumatologia e Ortopedia	Ciências Aplicadas ao Sistema Musculoesquelético*	4	91	47.3	30	3.0
68	Universidade Federal Fluminense	Neuroimunologia	4	80	30.0	25	3.2
69	Universidade Estadual de Ponta Grossa	Ciências Biomédicas	3	74	27.0	16	4.6
70	Fundação Oswaldo Cruz	Tecnologia de Imunobiológicos*	4	63	30.2	56	1.1
71	Centro Universitário Herminio Ometto	Ciências Biomédicas	3	61	11.5	20	3.1
72	Universidade Federal Rural do Rio de Janeiro	Ciências Fisiológicas	4	45	17.8	13	3.5
73	Universidade Federal de Pernambuco	Morfotecnologia	3	11	0.0	16	0.7

Caption: the location of each postgraduate programs on the map is indicated by the identification (ID) number.
* Indicates professional postgraduate programs. The others are academic.
Source: the authors.

The concentration of postgraduate programs in the BS2 field and their scientific production in the Southeastern and Southern regions stimulate an analysis on the reasons why certain states and cities participate more in the production of scientific knowledge. In Brazil, regional and state asymmetries regarding scientific production in various fields of knowledge are discussed by many researchers precisely because they demonstrate that the country's scientific production is concentrated

in only a few states and regions.[42-45] Although they are accentuated in this context, asymmetries among Brazilian regions in funding and human resources and the resulting scientific production is not limited to Brazil. The competition for research funding, facilities, and talent is common worldwide, and makes regions and cities, instead of countries, increasingly relevant to the activity of research.[43]

Three states in the Southeast of Brazil, São Paulo, Rio de Janeiro, and Minas Gerais, have historically stood out politically and economically, and in the production of scientific knowledge. In political terms, from the Proclamation of the Republic until the end of the Old Republic (1889-1930), presidential candidates from São Paulo and Minas Gerais were always elected with only one exception.[46] For Schwartzman,[47] the concentration of political power in these states occurred precisely because at that time they were the centers of the coffee industry (São Paulo) and the livestock industry (Minas Gerais). Today, the Southeast's contribution to the country's Gross Domestic Product (GDP) is 52.9%,[48] indicating the continued status of these states as major national producers of goods and services.

Scientific traditions in Southeastern Brazil date back to the 18th century, although the systematic research only began in the 19th century. During this period, several cultural and scientific institutions were created, including Museu Real (today, the National Museum), Horto Real (today, the Botanical Garden of Rio de Janeiro), the National Library, and the School of Medicine and Surgery of Rio de Janeiro, among other institutions. These have become important centers in the production and dissemination of knowledge in Anthropology, Health Sciences, and Natural Sciences, attracting scientists from the world.[47]

Research institutions in the Southeast region are ranked among the top of the country's scientific production scale. São Paulo was among the top 20 publishing cities in the world between 2004 and 2008, reflecting the rapid growth of Brazilian scientific production in recent decades and the city's role as the capital of the state that maintains the strongest scientific tradition in Brazil.[43] Research financial provided by the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), a state agency that is among the main agencies funding scientific and technological research in the country, plays a key role in the progress of science in the region with an annual budget, provided for by the law, corresponding to 1% of the state's total tax revenue.[49] In other state research support foundations throughout the country, the budget percentage is not defined, and grants may vary according to the legislation and the taxation of each state.[50]

The concentration of research in the Southeastern states is evidence of the inequality in the distribution of support and the resulting research in Brazil, which is most serious in the North, Central West, and Northeast region. In a study on the scientific production in the Biomedical Sciences, Hoppen, Santin, Correa, and Vanz[45] demonstrated the concentration of documents in certain states in the South and Southeast, with São Paulo leading the number of the scientific production (47.7%), followed by Rio de Janeiro (17.0%), Minas Gerais (13.9%), Rio Grande do Sul (12.5%), Paraná (7.5%), and Santa Catarina (4.7%). The states in the Southern region have a high profile in terms of scientific production from its institutions and postgraduate programs, and are second only to São Paulo, Rio de Janeiro, and Minas Gerais. This is particularly true of the Universidade Federal do Rio Grande do Sul – fifth among the most productive institutions.[40]

Distribution of Qualis and impact factor among sub-areas in the BS2 *field*

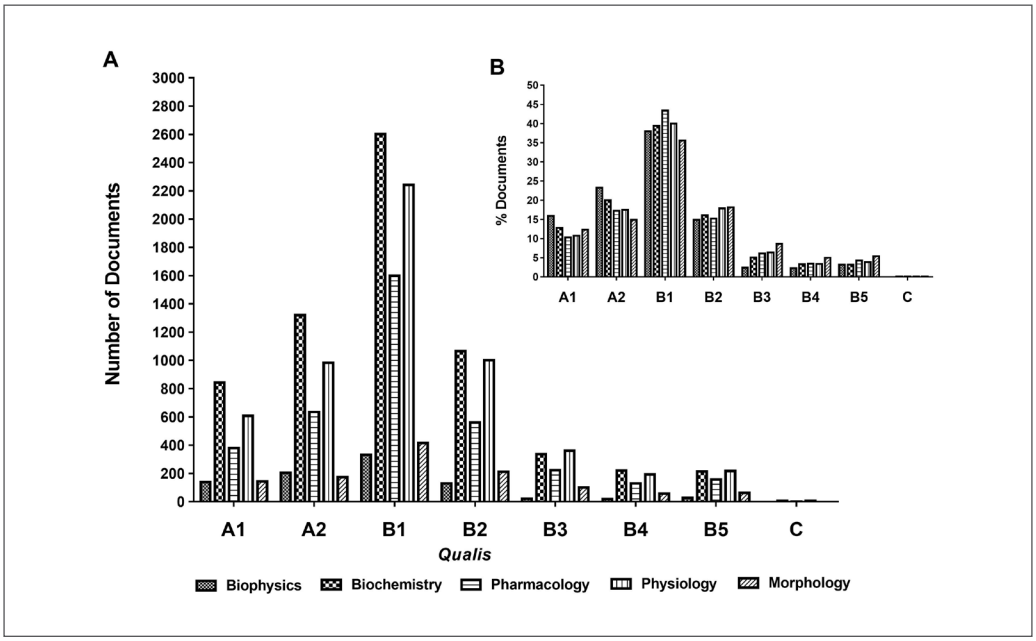
We compared the performance achieved by the five noted academic sub-areas in relation to the visibility of their scientific production as measured by their journals' Qualis ranking in absolute numbers (Figure 2A) and in percentages (Figure 2B). Compared to the others, Biochemistry sub-area

performs better in terms of number of documents in almost all Qualis rankings (6,609 documents), followed by Physiology (5,614), Pharmacology (3,687), Morphology (1,169), and Biophysics (874) sub-areas.

These results reflect the larger volume of documents from Biochemistry, Physiology, and Pharmacology, which follow the distribution of the number of researchers and postgraduate programs shown in Figure 1. The number of researchers per sub-area is as follows: Biophysics (161), Biochemistry (902), Pharmacology (373), Physiology (786), and Morphology (173). Also, it was found that Pharmacology present the higher average number of documents by researchers (9.9) than what was found in the other sub-areas, followed by Biochemistry (7.3), Physiology (7.1), Morphology (6.8), and Biophysics (5.4).

In absolute numbers (Figure 2A), the sub-areas that presented the highest scientific production in almost all strata were Biochemistry and Physiology; and this fact highlight an asymmetry if comparing to the other sub-areas. However, in percentage terms (Figure 2B), this asymmetry is less evident and the five sub-areas show similarities in the distribution of documents in the Qualis rankings. For example, in ranking A1 (equivalent to IF $\geq$ 4.60), the sub-areas were distributed in the following percentages: Biophysics (15.9%), Biochemistry (12.8%), Pharmacology (10.3%), Physiology (10.8%), and Morphology (12.3%). In addition, it is possible to verify that the BS2 field sub-areas have a tendency to publish their results in journals with a B1 ranking, which is equivalent to an IF ≥2.481 and <3.531, with a shift to A2 (≥3.531 and <4.60), and A1 (≥ 4.60).

Figure 2 - (A) Numeric and (B) percentage distribution of scientific production by sub-areas of the BS2 field according to Qualis rankings (2013-2016).

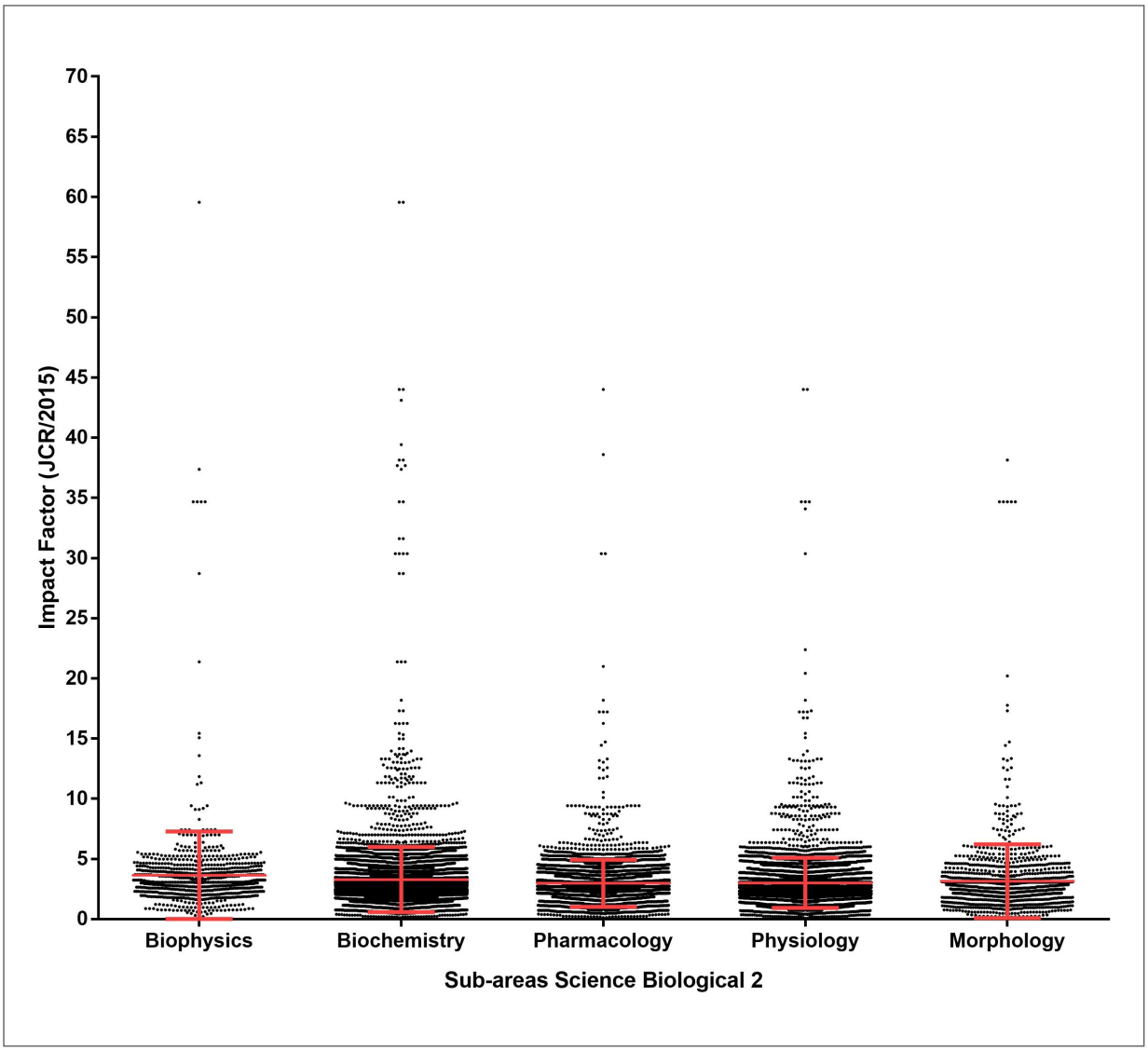


Caption: A1 corresponded to an index of IF or SJR of ≥4.60; A2: ≥3.531 and <4.60; B1: ≥2.481 and <3.531; B2: ≥1.65 and <2.481; B3: ≥1.096 and <1.65; B4: ≥0.728 and <1.096; B5: <0.728.
Source: the authors.

Only these results such as presented in Figure 2AB are presented and discussed by CAPES. Thus, we firstly evaluated the IF distribution of sub-areas belonging to BS2 field since this indicator is important to classify journals in the Qualis ranking.

From non-parametric ANOVA test, a significative difference ($p < 0,0001$) was found among the sub-areas' IF index (Figure 3). The Kruskal-Wallis *post-hoc* revealed that the results of Pharmacology (Mean: 2.978; Standard Deviation: 1.952), Physiology (3.004; 2.085), and Morphology (3.144; 3.071) were similar to each other but lower than the means of Biochemistry (3.275; 2.704) and Biophysics (3.638; 3.63), being this last significantly higher than all. Considering the median values, the results were: Biophysics (3.057), Biochemistry (2.972), Pharmacology (2.73), Physiology (2.73), and Morphology (2.685). Finally, the sub-areas that present no significative differences were: Pharmacology *vs*. Physiology (ns), Pharmacology *vs*. Morphology (ns), and Physiology *vs*. Morphology (ns).

Figure 3 - Distribution of the Impact Factor of the journals used by the Brazilian scientific community in the Biological Sciences II field in the sub-areas Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology (2013-2016).



Caption: significance among sub-areas: Biophysics *vs*. Biochemistry (****), Biophysics *vs*. Pharmacology (****), Biophysics *vs*. Physiology (****), Biophysics *vs*. Morphology (****), Biochemistry *vs*. Pharmacology (****), Biochemistry *vs*. Physiology (****), Biochemistry *vs*. Morphology (****), Pharmacology *vs*. Physiology (ns), Pharmacology *vs*. Morphology (ns) and Physiology *vs*. Morphology (ns).
Source: the authors.

Considering that CAPES uses Qualis to qualify scientific production, the differences observed through the distribution by IF do not reveal themselves in the evaluation processes and, therefore, are not addressed within the scope of the CAPES Evaluation System. In relation to the IF, neither the BS2 Assessment Report,[36] the principal document examining the performance of postgraduate programs, nor the spreadsheet of scientific production data collected on Plataforma Sucupira provide IF values. They only provide Qualis rankings, which compromises the understanding and discussion of these values.

In addition, there is a range of IF values equivalent to the Qualis ranking A1 (IF ≥4.60). As this is the highest Qualis ranking, in this classification there is a minimum value (4.60) but no maximum IF value. This range of values within the same A1 ranking can lead to a distortion in the evaluation processes. Therefore, the CAPES evaluation parameters for the BS2 field could benefit from being more specific and including the distinct aspects of each field.

To broaden the view of communication patterns found in these sub-areas, there was a need to analyze scientific production based on additional indicators (not applied by CAPES), such as the impact of citations, international collaboration, and particular research approaches of each field (in this study it was the most frequently researched diseases). An analysis from this perspective could contribute to the formulation of national public health policies, and, more importantly, reflect on the *modus operandi* of the CAPES Evaluation System in its prioritizing of the performance of postgraduate programs by analyzing their impact on journals.

According to "The Leiden Manifesto for research metrics (LM)"[12] and the "San Francisco Declaration on Research Assessment (DORA)",[51] there is a need for the application and adequate interpretation of quantitative indicators by funding agencies, as well as by researchers, editors, and research institutions. DORA proposes, for example, the elimination of the exclusive use of metrics such as IF in financing decisions, the appointment of researchers, and giving promotions and performance awards to support institutions in evaluating research on its own merits instead of solely on journals where research is published.

Considering that these indicators impact research systems by way of the incentives that are established by funding institutions,[12] IF and/or SJR together with Qualis must be used with caution. In the case of Brazil, the distribution of resources based on evaluation criteria that do not account for distinct contextual aspects may end up increasing existing asymmetries between postgraduate programs, and would therefore contradict the premises of the 2011-2020 National Postgraduate Plan,[52] which seeks to reduce differences among the country's various regions.

Citation and international collaboration

Table 1 shows the number of citations, number authors per document, and number of documents with national and international collaborations in each sub-area. The results reflect the generally large volume of documents in Biochemistry, Physiology, and Pharmacology, which is also seen in the distribution of researchers and postgraduate programs.

The total number of citations, citations per document, and percentage of documents not cited was calculated. The total number of citations in a sub-area is directly related to the sub-area's size according to the scientific production. Therefore, it was necessary to calculate the average number of citations per document. In this case, the sub-area with the lowest scientific production (Biophysics) represents the highest value of citations per document (15.3), followed by Morphology (13.7). As for the percentage of documents not cited, Biophysics is the best performing discipline because only 3.8% of its documents were not cited in contrast to more than 6.1% in Morphology.

Table 1 - Number of documents with national/international co-authorship and number of citations per document.

Sub-areas	Number of documents	Collaboration between authors			Citations			Documents without and with international collaboration *versus* citation							
		Number of authors	Co-authorship index	Rate of collaboration	Total number of citations	Citation impact	% not cited	Number of documents without international collaboration	%	Number of citations	Average citations	Number of documents with international collaboration	%	Number of citations	Average citations
Biophysics	874	6,316	7.2	90.3	13,389	15.3	3.8	550	62.9	6,427	11.7	324	37.1	6,962	21.5
Biochemistry	6,609	45,443	6.9	88.6	84,393	12.8	4.5	4,668	70.6	51,068	10.9	1,941	29.4	33,325	17.2
Pharmacology	3,687	26,848	7.3	90.4	42,835	11.6	4.6	2,772	75.2	28,694	10.4	915	24.8	14,141	15.5
Physiology	5,614	37,076	6.6	88.2	62,931	11.2	5.1	4,022	71.6	39,334	9.8	1,592	28.4	23,597	14.8
Morphology	1,169	8,781	7.5	94.2	16,069	13.7	6.1	764	65.4	9,486	12.4	405	34.6	6,583	16.3

Source: the authors.

One commonly used indicator to measure collaboration in scientific production is the co-authorship index. In the present study, the results reveal similarities in patterns of collaboration through the average number of authors involved in the documents that ranged among the sub-areas from 6.6 to 7.5. Another indicator is the degree of collaboration or proportion of works with more than one author. In this case, it was found that Morphology had a 94.2% degree of collaboration – far greater than the other BS2 sub-areas.

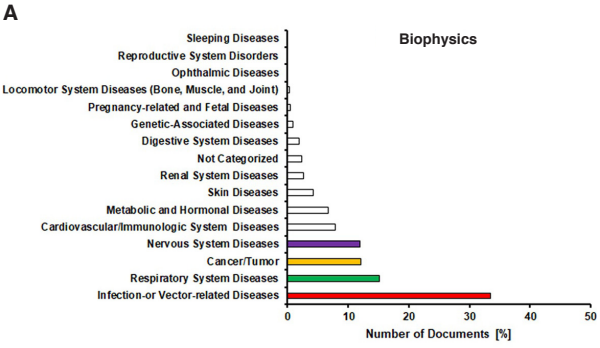
Regarding international collaboration, the Biophysics and Morphology sub-areas presented the highest percentages of documents with international co-authorship, 37.1% and 34.6%, respectively. The other three sub-areas ranged from 24.8% to 29.4%. The average of citations for documents with international collaboration was higher for all sub-areas compared to documents without international co-authorship, although there is not a direct correlation between the variables.

Researched diseases and their relationship with the needs of Brazilian public health

The analysis of the most frequently researched diseases was motivated by the content of the three documents found in journals with the greatest IF (Figure 3), two of which are on Biochemistry and one on Biophysics, all in the *New England Journal of Medicine*, with an IF of 59.558. The two documents on Biochemistry, for example, refer to research on the Zika virus – a flavivirus transmitted by *Aedes aegypti* that has recently become a relevant topic in Brazilian science since it was associated with epidemiological conditions such as microcephaly, which compromise the central nervous system.[53] The Biophysics document refers to a study on Chagas Disease, which is an old theme in Brazilian science, but also has great epidemiological impact on the country.

Figure 4 (A, B, C, D, and E) presents the most frequently researched diseases in the sub-areas Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology. We sought to relate these results with the current needs of public health research in Brazil.

Figure 4 - Categories of most frequently researched diseases in the sub-areas Biophysics (A), Biochemistry (B), Pharmacology (C), Physiology (D), and Morphology (E).



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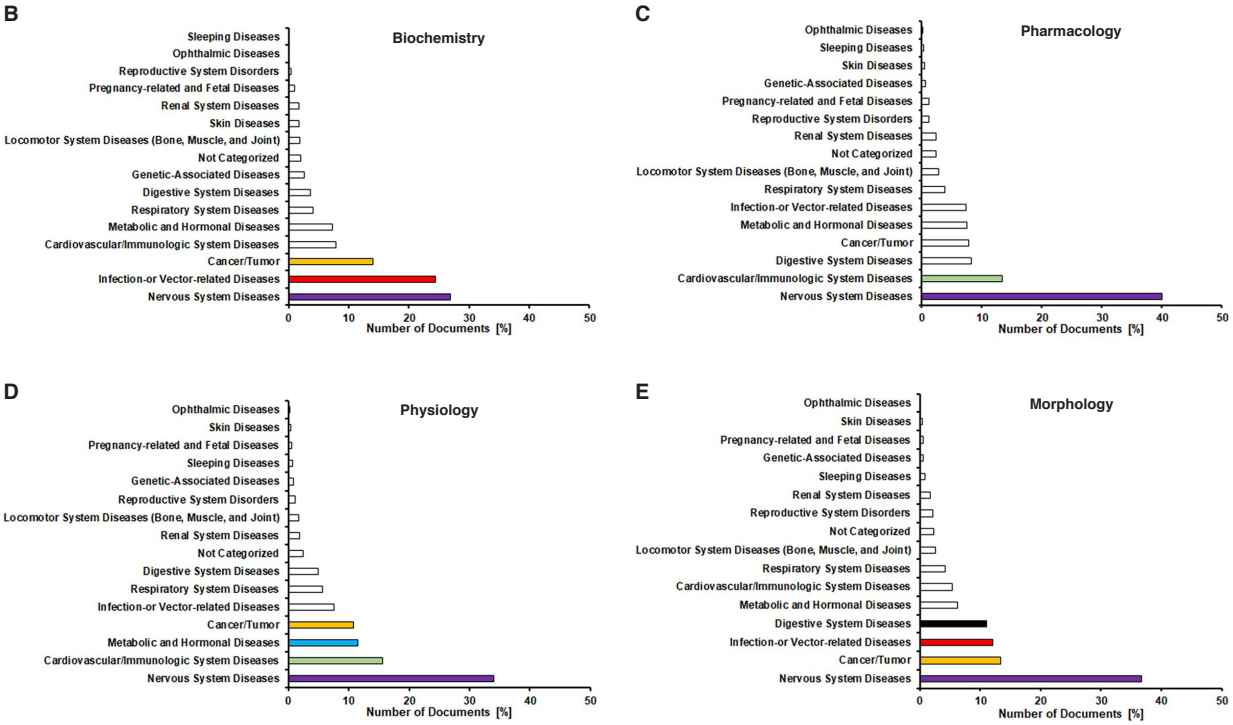


Caption: Figure 4 (A) represents 421 documents with diseases in the MeSH terms and has 176 diseases in total; (B) 3,745 documents and 560 diseases; (C) 2,764 documents and 435 diseases; (D) 3,438 documents and 528 diseases; and (E) 849 documents and 272 diseases. The colored categories represent documents with a percentage above 10%.
Source: the authors.

In Biophysics, the categories of most frequently researched diseases were Infection- or Vector-related Diseases (33.5%), Respiratory System Diseases (15.2%), Cancer/Tumor (12.1%), and Nervous System Diseases (11.9%), which collectively amounted to 72.7% of analyzed documents. In the first category (Infection- or Vector-related Diseases), Chagas Disease stands out with 29 documents. This disease has a high incidence in Brazil with more than one million people infected by the *Trypanosoma cruzi*, a chronic problem for the public health system in the country and the fourth leading cause of death by infectious-parasitic diseases. Other frequent infectious diseases on the sub-area of Biophysics were: Sepsis (11), Leishmaniasis (13), and HIV Infection (10). Regarding the Respiratory System Diseases, the most relevant issue among Biophysics' production was Asthma (10 documents), which affects about 6.4 millions of Brazilians over the age of 18 and 300 million worldwide.[54] Acute Lung Injury (8) and Pneumonia (8), which have high prevalence and are among the five causes of death in Brazil,[55] appear sequentially. The categories of Cancer/Tumor and Nervous System Diseases have an expressive frequency of documents, however, there was no concentration of scientific production, since the distribution of research is in several neoplasms and diseases of the Nervous System.

In Biochemistry, categories with a higher number of documents were Nervous System Diseases (26.9%), Infection- or Vector-related Diseases (24.4%), and Cancer/Tumor (14.0%), totalizing 65.4% of the scientific production. The 1st category mainly concentrates on psychiatric disorders such as Depression (110 documents), Bipolar Disorders (69), and Memory Disorders (66). Global estimates indicated that about 4.4% of population worldwide

live with Depression and 5.8% of Brazilians were affected by this disease. Indeed, Brazil is considered the Latin American country with the highest incidence of Depression, in addition to having the highest prevalence of Anxiety around world (9.3%).[56] Growing interest in the study of the brain may explain the emphasis by Biochemistry's researchers on studying Nervous System Diseases. An emphasis is also observed in Pharmacology, Physiology, and Morphology. Among infectious diseases, Biochemistry has concentrated its scientific production on Chagas Diseases (117), Leishmaniasis Visceral (100), and Dengue (57). Leishmaniasis Visceral is also a major public health problem in Brazil as it is increasing in the country, and untreated cases may lead to a 90% chance of lethality. The first Dengue epidemic occurred in Brazil in the 1980s, but the high incidence of cases in recent years has triggered a growing concern to the country's public health system. In addition, Dengue was considered an epidemy after reintroducing serotypes in 2010 and 2013, and its vector introduced the new arboviruses Chikungunya e Zika in 2015 and 2016.[57] Studies on Cancer were also frequent in the sub-area Biochemistry, especially on General Neoplasms (65), Breast Neoplasms (50), Squamous Cell Carcinoma (32), Lung Neoplasms (21), and Glioblastoma (21). Breast Cancer is a relevant public health problem and the leading cause of cancer death worldwide,[58] with a high incidence in Brazil, especially in the south and southeast regions.[57]

In Pharmacology, the most frequent categories were Nervous System Diseases (40.0%) and Cardiovascular/Immunologic System Diseases (13.4%), which totalized 53.4% of scientific production. In Nervous System Diseases, the most frequent studies were on Hyperalgesia (107 documents), Anxiety (114), and Pain (83), followed by Bipolar Disorders (65), Depression (Depressive Disorder) (89), and Diseases of Memory (54). Altogether, researchers focused on mainly studying two groups of diseases: those that involved pain and psychiatric disorders. While the first group indicates a concern on developing drugs and pharmacological treatment for pain, the second focuses on researching mental disorders. Anxiety, for example, affects 9.3% of Brazilians, and this index put Brazil in the top of the world rank of incidence for this disease.[56] Other focus areas are Cardiovascular/Immunologic System Diseases (13.4%), which mainly included Hypertension (131), Cardiovascular Diseases (25), and Myocardial Infarction (18). These diseases also have an elevated frequency in the scientific production of Physiology, thus indicating a certain intersection between these two sub-areas. Regarding Hypertension, it is estimated that more than 600 million people are affected by this disease worldwide.[59] In Brazil, Hypertension was prevalent in more than 20% of the population in 2013. This disease is a public health concern for its socioeconomic impact to health systems and for being an important risk factor for Cardiovascular and Cerebrovascular diseases, among others.[60]

In Physiology, the most frequent categories were Nervous System Diseases (34.1%), Cardiovascular/Immunologic System Diseases (15.6%), Metabolic and Hormonal Diseases (11.6%), and Cancer/Tumor (10.8%), which totalized 72.0% of scientific production. The most studied Nervous System Diseases were Anxiety (127 documents), Depression (134), Pain (83), and Hyperalgesia (72), and this result was similar to that found for the Pharmacology sub-area. The Cardiovascular/Immunologic System Diseases category reveals a traditional research focus in Physiology. Among documents, the most frequent research themes were Hypertension (145), Hypoxia (53), Cardiovascular Diseases (46), Heart Failure (36), and Myocardial Infarctions (32). All these themes are correlated to cardiovascular diseases which are among the main causes of death in Brazil and worldwide.[57,58] Hypertension is also associated with diseases of the second category, Metabolic and Hormonal Diseases, in which studies on Obesity (122), Metabolic Syndrome (34), and Diabetes (63 documents which includes all types of Diabetes and Diabetes *Mellitus* Type 1 and 2) were the most frequent. Obesity has a high prevalence worldwide and in Brazil, with increasing prevalence in the last years.[55] In the 4th category, of Cancer/Tumor, the most frequent

themes were Neoplasms (43), Stomach Neoplasms/ Stomach cancer (35), Breast Neoplasms/Breast cancer (24), and Adenocarcinoma (17).

In Morphology, the most frequent categories of Diseases were Nervous System Diseases (36.7%), Cancer/Tumor (13.3%), Infection-or Vector-related Diseases (12.0%), and Digestive System Diseases (11.1%), representing 73.1% of scientific production. Regarding Nervous System Diseases, most documents were on Obsessive-Compulsive Disorder (34), followed by Alzheimer Disease (31), Depression (36), and Anxiety (20). Alzheimer's Disease and other dementia disorders are among the top 10 causes of death worldwide, with increasing death rates in Brazil.[55] Regarding Depression and Anxiety, the sub-area Morphology follows a research tendency similar to Biochemistry, Pharmacology, and Physiology sub-areas. The same tendency was found in diseases that were categorized as Cancer/Tumor, which have the following frequencies: Glioblastoma (14), Brain Neoplasms (11), Neoplasms (9), and Prostatic Neoplasms (7). In the category Infection-or Vector-related Diseases, the frequency of disease was: Sepsis (12), Chagas Disease (8), Leishmaniasis (13), and Zika Virus Infection (8). Hospitalization by Sepsis in Intensive Therapy Units presented a substantial increase in Brazil from 2010 to 2016 (19.4% to 25.2%, respectively). Although the mortality index related to Sepsis has decreased in some Brazilian hospitals, there is a need to direct more public health policy efforts in the country towards management improvements in all hospitals.[61] Regarding Zika Virus Infection, the Zika-ZIKV outbreak was identified in 2015 in the northeast of Brazil, an area where Dengue infection was high. Posteriorly, ZIKV was related to cases of microencephaly,[53] forcing the Health Surveillance Secretariat of the Brazilian Ministry of Health to declare a state of health emergency in Brazil supported by the WHO. Since then, there was an intense mobilization of researchers from Brazil and other countries to understand the ZIKV epidemic and its effects.[62] In Digestive System Diseases, Diarrhea (12), Mucositis (10) and Dental Caries (9) were most frequent. According to health data, Diarrhea, for example, is one of the main factors that lead to the death of children of the age of 1 (one) in Brazil.[57]

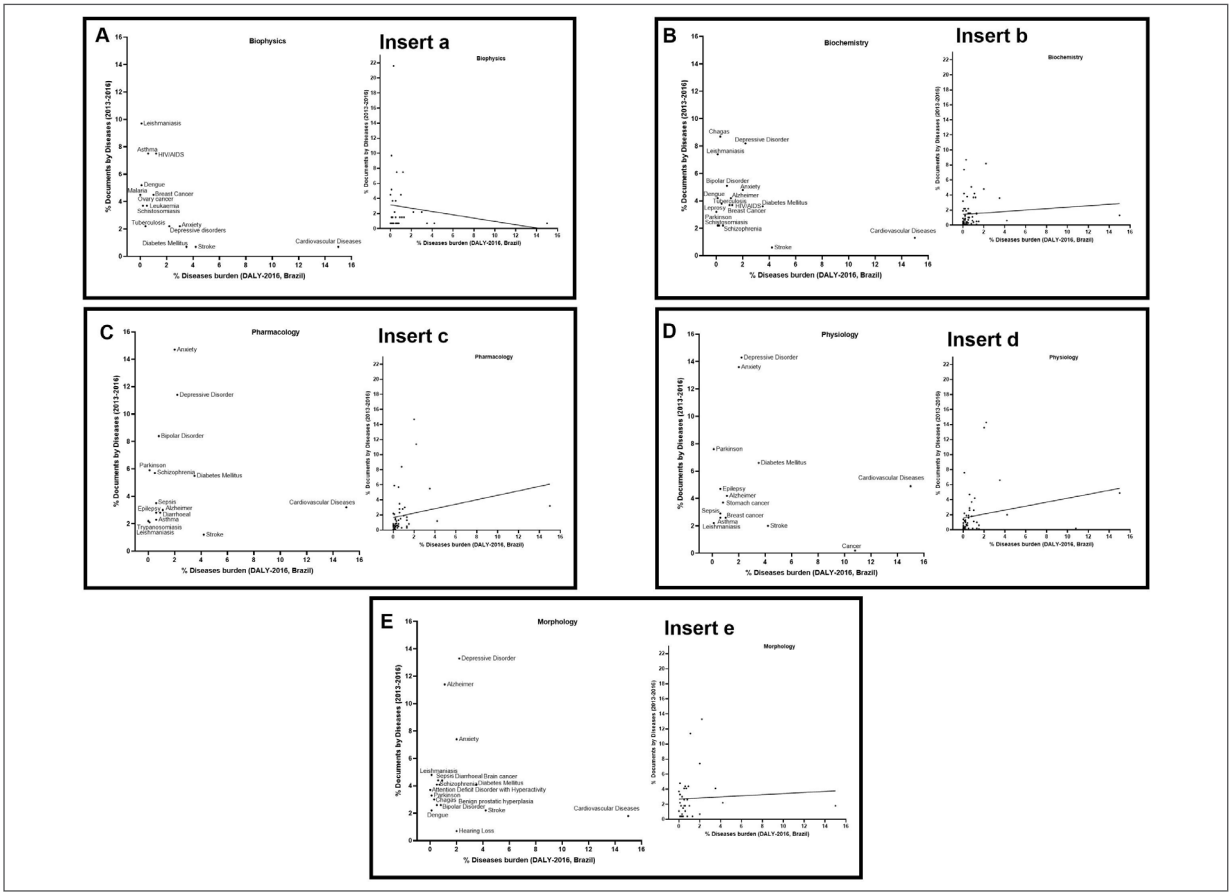
In addition, to understand the specific contribution of each sub-area to the Brazilian public health, we compared the percentage of documents by disease to the burden of disease in DALY 2016, Brazil[37] (Figure 5). The analysis contemplates 30.8% (3,462) of the analyzed documents, given that not all the diseases searched by the respective sub-areas have estimates of burden of disease of the WHO, for example, ZIKV or Microcephaly.

In Biophysics (Figure 5A, insert a), there is negative (not significant) correlation (r = -0.05646, P=0.751) between the percentage of documents and the burden of disease. There are diseases with a high percentage of documents, like Leishmaniasis (9.7%), Asthma (7.5%), HIV/AIDS (7.5) and Dengue (5.2%), while their burden of disease in DALY is inferior to 1.2% (Figure 5A). Another highlight is that Cardiovascular Diseases have a high DALY estimate, but are rarely studied in this sub-area, with only 0.7% of documents compared to 15.0% of burden of disease. Some diseases have similar percentage of documents compared to burden of disease in DALY, for example: Anxiety (3.0% of documents and 2.0% of burden of disease) and Depressive disorders (2.2%; 2.2%).

In Biochemistry, Chagas Disease (8.7%), Depressive disorders (8.2%), and Leishmaniasis (7.4%) are studied more often compared to the estimates DALY/WHO, with burden of disease inferior to 2.2% (Figure 5B). In Cardiovascular Diseases, Biochemistry has search standard similar to Biophysics and has low percentage of documents (1.3%) compared to the burden of disease. Despite that, Biochemistry had a positive and significant correlation (r= 0.4049, P=0.000) among the analyzed variables (documents and burden of disease) – Figure 5B, insert b. Therefore, the research efforts of this sub-area are closer to the Brazilian public health needs. For example, there is a close percentage of documents and burden of disease in Diabetes *Mellitus* (3.6% of documents; 3.5% burden of disease).

Pharmacology follows a standard similar to Biochemistry, with a positive and significant correlation (r= 0.4935, P=0.000) between documents and burden of disease (Figure 5C, insert c). As seen in Figure 5C, the searched diseases have a similar percentage of documents compared to the burden of disease in DALY, for example: Diarrhea Diseases (2.8% documents; 0.9% burden of disease), Epilepsy (2.8%; 0.6%), and Asthma (2.3%; 0.6%). However, the research efforts for Anxiety (14.7%), Depressive Disorder (11.4%), Bipolar Disorder (8.4%), Parkinson Disease (5.9%), Schizophrenia (5.7%), and Diabetes *Mellitus* (5.5%) are superior to the burden of disease estimated by the WHO, which have estimates inferior to 3.5%. Although Pharmacology has 3.2% of documents about Cardiovascular Diseases, which is higher in comparison to Biophysics (0.7%) and Biochemistry (1.3%), it still falls short of attending the health demands, given that the burden of disease is high for the country.

Figure 5 - Percentage of burden of disease in Disability-Adjusted Life Years (DALYs) in Brazil (2016) *vs*. percentage of documents for disease (2013-2016), partial values (A-E). Inserts (a-e), with statistical tests, total values.



Caption: for the graphic representation, (Figure 5A-E) were considered just the diseases that had over 2.0% of documents and also 2.0% of burden of disease in DALY (2016) to help the visualization. For the same purpose, it was removed the Chagas Disease with 21.6% documents (outlier) in Biophysics. Figure 5 (A) represents 110 documents with burden of disease and has 16 diseases in total; Figure 5 (B), 932 documents and 17 diseases; Figure 5 (C), 580 documents and 15 diseases; Figure 5 (D), 675 documents and 14 diseases; and Figure 5 (E) 226 documents and 19 diseases. For the inserts (Figure 5, inserts a-e), with the statistical tests, all values were maintained: Figure 5 (insert a) represents 134 documents with burden of disease and has 34 diseases in total; Figure 5 (insert b) 1,343 documents and 66 diseases; Figure 5 (insert c), 778 documents and 52 diseases; Figure 5 (insert d), 936 documents and 54 diseases; and Figure 5 (insert e), 271 documents and 36 diseases.
Source: the authors.

The sub-area of Physiology showed the highest percentage of documents relating to Cardiovascular Diseases (4.9%) – Figure 5D. It was also identified that from the diseases studied, those closer to the percentage of burden of disease of the WHO are: Breast Cancer (2.6% documents; 1.0% of burden of disease estimated by WHO) and Asthma (2.6%; 0.6%). Analyzing the percentage of documents and burden of disease, we also identified a positive and significant correlation (r= 0.3895, P=0.003) – Figure 5D, insert d. Depressive Disorder (14.3%), Anxiety (13.6%), and Parkinson Disease (7.6%) have high percentage of documents, while burden of disease is inferior to 2.0%. Cancer has one of the highest burden of disease (10.8%) and it has only 0.2% of documents, and is thus rarely studied by the sub-area.

Morphology (Figure 5E) follows a standard similar to Biophysics (Figure 5A). Some diseases have a percentage of documents similar to burden of disease in DALY, for example: Diabetes *Mellitus* (4.1% documents; 3.5% burden of disease) and Hearing Loss (0.7%; 2.0%), with a positive correlation, although this was not significant (r=0.2414, P=0.156) – Figure 5E, insert e. Alzheimer Disease (11.4%), Depressive Disorder (13.3%), and Anxiety (7.4%) had the highest percentage of documents, while the burden of disease estimated by the WHO was inferior to 2.2%. Cardiovascular Diseases are also rarely studied by the sub-area, because they were in only 1.8% of documents.

The analysis shows the contributions of the scientific production of each sub-area compared to the burden of disease in DALY, while the distribution by categories reveals the most frequently researched diseases. Together, the results point to the different emphasis of research of the BS2 in Brazil and different research efforts to meet public health needs. It matters to consider that each sub-area has its own characteristics and research scope, related to its study objects. In this way, the results should be considered in terms of the particularities of each sub-area, including for the purpose of evaluation of the postgraduate programs in Brazil.

Conclusions and perspectives

The scientific production of BPPs belonging to the BS2 field was found to be distributed mainly in the Southeastern and Southern regions of Brazil. Deepening these analyses by using indicators beyond those used by the CAPES Evaluation System, we conclude that the differences observed in scientific communication (Results systematized in Table 2) and in researched diseases among Biophysics, Biochemistry, Pharmacology, Physiology, and Morphology were predominant or more evident than similarities, *i.e.*, all five sub-areas presented specificities.

Regarding the researched diseases in Biochemistry, Pharmacology, and Physiology, the correlations between the percentage of documents and burden of disease estimated by WHO were positive and significant. Therefore, the research efforts of these sub-areas are contributing for meeting the needs of Brazilian public health. In Biophysics and Morphology, this correlation was not significant, although there are diseases with similar percentages of documents and burden of disease. It must be noted that certain diseases are poorly studied in the different sub-areas, which may be associated to the characteristics and research approaches of each discipline.

The results presented here confirm our hypothesis that current indicators applied by CAPES are insufficient for showing the existing differences among all sub-areas. Thus, the BS2 field Evaluation System may be compromised/distorted since these indicators do not consider/recognize the sub-areas specificities. Considering that the CAPES evaluation is based on the performance comparison among the postgraduate programs,[13] there is a need to consider the specificities of the five sub-areas in the evaluation process performed by CAPES.

Table 2 - Similarities and differences in the scientific communication patterns of the Brazilian postgraduate programs - Biological Sciences II (BS2) field.

Similarities and differences in the scientific communication patterns of the Brazilian Postgraduate Programs - Biological Sciences II (BS2) field					
Indicators	**Biophysics**	**Biochemistry**	**Pharmacology**	**Physiology**	**Morphology**
Number of Postgraduate Programs	3	19	16	29	6
Number of Postgraduate Programs (evaluation grade 6 and 7-Quadrienal 2017 by CAPES)	1	10	4	4	1
Number of Postgraduate Programs with the largest number of documents (Rank First to Fifth)	1	4	0	0	0
Number of documents	874	6,609	3,687	5,614	1,169
% of documents with *Qualis* rank A1 (IF ≥ 4.60)	15.9	12.8	10.3	10.8	12.3
Number of researchers/professor	161	902	373	786	173
Number of documents by researchers/professor	5.4	7.3	9.9	7.1	6.8
Impact Factor (JCR) Median	3.1	3.0	2.7	2.7	2.7
Impact Factor (JCR) Mean	3.6	3.3	3.0	3.0	3.1
Impact Factor (JCR) Std. Deviation	3.6	2.7	2.0	2.1	3.1
Co-authorship index	7.2	6.9	7.3	6.6	7.5
Rate of collaboration	90.3	88.6	90.4	88.2	94.2
Mean of citations	15.3	12.8	11.6	11.2	13.7
% of documents without international collaboration	62.9	70.6	75.2	71.6	65.4
% of documents with international collaboration	37.1	29.4	24.8	28.4	34.6
Mean of citations (Documents without international collaboration)	11.7	10.9	10.4	9.8	12.4
Mean of citations (Documents with international collaboration)	21.5	17.2	15.5	14.8	16.3

Source: the authors.

The results of this study can also serve as support for improving the CAPES Evaluation System and encouraging postgraduate programs in their respective sub-areas to conduct institutional evaluations that complement those made by CAPES. Such assessments tend to favor a global improvement of postgraduate programs performance, allowing a better adaptation of Science public policies. The trend of international collaboration producing documents with the greatest impact can encourage internationalization policies and collaboration agreements with other countries. Studies on researched diseases and their relationships with the burden of disease of the local population can provide support to public policy that assists in strategies and policies for intervention, prevention, control and eradication of diseases in Brazil.

As a perspective to expand this study, we intend to assess the same parameters investigated in this study, specifically comparing postgraduate programs evaluated as 3-5 (the lowest evaluation) and programs evaluated as 6-7 (the highest evaluation) in the BS2 field. This comparison would be important since programs classified with higher grades receive higher financial support. Another additional possibility is to expand the study of the most frequently researched diseases and the relationship between the number of publications and the burden of diseases in DALY for different fields in Brazil, including Biological Sciences and Health Sciences, to understand more broadly how research efforts expressed in scientific production contribute to meet the Brazilian public health needs.

Considering the informational limitations in the scientific production of the BS2 field, officially available on Plataforma Sucupira, the following improvements are suggested to this tool: i) including the IF in the document data. This information can make the CAPES Evaluation System more transparent and offer a wider perspective on performance and the applied evaluation parameters; ii) including the DOI. For Sucupira, this would be an important step forward in facilitating new studies based on data reported to CAPES by postgraduate programs. This would make it possible to collect data from documents more easily from international databases such as WoS and PubMed. These changes can also be made through improvements to the data exchange between Brazil's national academic official *curriculum vitae* (Currículo Lattes - CL) and Plataforma Sucupira. Efforts must come

also from CAPES interaction with another public Brazilian institution, the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) – the scientific and technological development national council – to improve the data collection process for BPPs for the purpose of evaluation.

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