RDBCI | Revista Digital de Biblioteconomia e Ciência da Informação
Digital Journal of Library and Information Science

ISSN 1678-765X doi 10.20396/rdbci.v19i00.8662072/2592

ARTICLE

Brazilian scientific productivity in the stem cell area (2001-2019)

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ABSTRACT

Introduction/Objective: Quantitative-descriptive study, whose aim was to obtain a scientific production overview in Brazilian stem cells area, in the period from 2001 to 2019, through bibliometrics indicators of scientific production. Methodology: It has considered original and indexed articles on the Web of Science, including at least one Brazilian author. Results: The results showed an increase, much like the world scenario, in the number of articles (4.675) and authors (25.050), with a tendency for multiple authorship (99.25%). Five periodicals are highlighted by the number of articles published: Plos One (128), Scientific Reports (65), Stem Cell Research & Therapy (55), Brazilian Journal of Medical and Biological Research (54) and Biology of Blood and Marrow Transplantation (49). Conclusion:The research was concentrated in the hematology area until 2005 and, from 2006 on, cell biology started to occupy the centrality of studies and research both nationally and worldwide.

KEYWORDS

Scientific production. Indicators. Bibliometrics.

Produtividade científica brasileira na área de células-tronco (2001-2019)

RESUMO

Introdução/Objetivo: Estudo de natureza quantitativa-descritiva, que teve como objetivo básico obter uma visão da produtividade científica brasileira na área de células-tronco, no período de 2001 a 2019, por meio dos indicadores bibliométricos de produção científica. Metodologia: Considerou-se como unidade de análise os artigos originais e indexados na Web of Science, contemplando pelo menos um autor com afiliação brasileira. Resultados: Os resultados evidenciam um crescimento, que acompanha o cenário mundial, do número de artigos (4.675) e autores (25.050), com tendência pela autoria múltipla (99,25%). Cinco periódicos se destacam, pelo número de artigos publicados: o Plos One (128), Scientific Reports (65), Stem Cell Research & Therapy (55), Brazilian Journal of Medical and Biological Research (54) e Biology of Blood and Marrow Transplantation (49). Conclusão: As pesquisas foram concentradas em hematologia até 2005 e, partir de 2006, a biologia celular passou a ocupar a centralidade dos estudos e pesquisas, tanto nacionalmente como mundialmente.

PALAVRAS-CHAVE

Produtividade científica. Indicadores. Bibliometria.

JITA: BB. Bibliometrics methods

1 INTRODUCTION

In this article, we analyze the production from Brazilian scientific research in the area of stem cells, covering 15 years, that is, from 2001 to 2019. For the purposes of this study, we consider the field comprising all studies with, and in, stem cells, without clipping through one type or another of studies or stem cells.

The monitoring and analysis of scientific production allows us to identify stages of development and, in this context, the bibliometric indicators on the theme collaborate by identifying relevant points in the dynamics of the area. For this study, stem cells were selected, due to their multidisciplinary characteristic (SEGURA et al. 2007), involving various aspects of biological, social, ethical, religious nature, for example. Pereira (2008, p. 9) points out that "[...] stem cells are presented as a source of applications in various fields in which studies and research, both basic and/or applied, are being developed". These results, when disseminated, arouse the interest of the scientific community - as well as the population in general - for the positive prognosis for the application of stem cells in the treatment of certain human diseases, opening up possibilities for new studies and research.

The interest in the study area, stem cells, is due to the broad development of research and clinical studies, around the world and in Brazil, and the possibilities of using these cells not only in medical specialties - with hematology, ophthalmology , cardiology, for example - more also in dentistry and in applications with biomaterials in regenerative medicine and tissue engineering, as well as among others (RODRIGUES et al. 2018; SOARES et al., 2007; REHEN, PAULSEN, 2007).

The objective of this study was to obtain an overview of the Brazilian scientific productivity in the area of stem cells, in the period from 2001 to 2019, through the bibliometric indicators of scientific production. The original and indexed articles on the Web of Science (WoS) were used as the unit of analysis, with at least one author with Brazilian affiliation. This period was subdivided into four five-year subperiods each (2001-2005, 2006-2010, 2011-2015 and 2016-2019) except for the last four-year period (2016-2019), since this subdivision made it possible analyze the growth trend and other aspects peculiar to scientific production. Specific objectives were outlined: (a) to survey the size and growth of production; (b) raise the authors' productivity; (c) identify the core journals; and (d) identify the main areas of research.

This article presents five sections, in addition to the introduction, and a brief review of the literature with an emphasis on bibliometric indicators of production. Then, the quantitative methodological procedures are described, based on Bibliometrics and the survey of production indicators. In the next section, the analysis and discussion of the data are presented in three subsections and, next, the conclusion and the list of references, listing the items cited that supported the theoretical and empirical part of this study.

2 SCIENTIFIC PRODUCTION AND BIBLIOMETRIC INDICATORS

Brazilian scientific production has an intimate connection with higher education and mainly with postgraduate studies, especially stricto sensu (master's and doctorate), "[...] which have the important task of preparing professionals who should work in different sectors of society and who will be able to contribute, based on the training received, to the country's modernization process." (HILU, GISI, 2011, p. 5670). These courses, for the most part, are located at public universities. According to Hilu and Gisi (2011), these institutions hold "[...] 82% of the offer of master's courses and 90% of doctoral courses [...]", data proven by Cirani,

Campanario e Silva, who developed a study analyzing stricto sensu graduate studies in Brazil, from 1998 to 2011. The results show an increase in the number of courses, which jumped from 2,417 in 1999 to 4,660 in 2011. With the increase in the number of courses in post-graduation in Brazil, there was, therefore, the growth of doctors and masters. Marques (2019, p. 39) points out that "The number of qualified doctors has grown from 4,900 in 1999 to almost 22,900 in 2018, an increase of 370%; the number of masters increased at the same rate, from 15 thousand to 51 thousand per year".

Almeida and Guimarães (2013, p. 290) point out that "[...] Brazil is part of a small group of countries (South Korea, China, Iran, Turkey, Taiwan, Singapore, Portugal, Hong Kong, Spain, Mexico and Greece) that achieved high growth rates (eight times or more) in scientific production in the last 30 years; that is, at least four times the world average in the period. ". It is also noteworthy that the growth in the number of publications is due to the global scientific system, given that it is increasingly interconnected (Wong, 2019, p. 361)

The growth in the number of postgraduate programs as well as the increase in the number of researchers, collaborate in the strengthening of Brazilian science, thus having a linear relationship between the number of doctors and the number of publications (ALMEIRA, GUIMARÃES, 2013), they add. Cirani, Campanario e Silva (2015, p 174) that "[...] the more postgraduate courses, provided they are implemented with quality, the greater the knowledge production".

Examining scientific production, one of the products of research - whether it be from an author, research group, area of knowledge, university or a country, for example - allows to compose a picture of scientific, technological and innovation development. Bibliometric, production, impact and relationship indicators make it possible to examine research trends, as well as map and understand areas that are emerging, the so-called emerging ones, in addition to those consolidated. Such scientific reality allows to establish prognoses for the decision making by university managers or research promotion agencies, since these indicators provide a set of relevant data.

Bibliometric indicators are classified as: (a) production - frequency of an item, which may be an author, publication, institution, for example; (b) impact - has the unit of measurement as citation and (c) relationship - frequency of co-occurrence of co-authorship, citations, which may be author, periodical and reference (MALTRÁS BARBA, 2003; SPINAK, 1996), which they reflect scientific activity and can be applied in different scenarios - that is, at the micro, meso or macro level within a previously defined timeframe -, and also of a one-dimensional, two-dimensional or multidimensional nature.

A unidade fundamento para o levantamento de indicadores bibliométricos é a contagem que resulta num valor absoluto, ou seja, um valor bruto, a qual pode ocorrer na publicação em si ou nas citações, e essa última constitui em elemento básico para os indicadores de impacto e de relação.

One of the first studies, pointed out in the literature (MALTRÁS BARBA, 2003; SPINAK, 1996) to use the counting of publications, was carried out by Cole y Eales, in 1917, who analyzed the anatomy publications published in the period from 1543 to 1860. Then, another study, dated 1923 and authored by Hulme, made an analysis of the history of science, and in 1927, Gross y Gross carried out a new modality of study, starting to count the references in articles in the field of chemistry, indexed in The Journal of the American Chemistry Society.

The studies by Cole y Eales, Hulme and Gross y Gross used the simplest indicator, that is, the productivity indicator, which has the procedure of, for example, counting a publication from which other indicators are derived, involving basic math and/or statistics calculations, such as growth rate, proportion, doubling time, average production, growth equations (linear, exponential, etc.), productivity indexes, collaboration index, among others. Maltrás Barba

(2003, p. 127) observes that these indicators are an "approximate estimate" of scientific production.

It is worth mentioning that some of these indicators are available in a multidisciplinary database, such as the Web of Science, Scopus and SciELO, which are one of the main sources of data for the survey of bibliometric indicators. However, these bases do not cover all scientific production, since not all publications are indexed in them, as each one has its indexation policy (PACKER, 2014).

It is worth mentioning that based on this count - either by publishers or authors -, Bradford and Lotka proposed their laws, which form the set of laws of Bibliometrics, although we have others, which do not cover the scope of this article. Thus, in 1927, Alfred J. Lotka published his study related to the counting of authors - today known as Lotka's Law or Inverse Square Law (MACHADO JUNIOR et al, 2016; URBIZAGASTEGUI, 2008) -, concluding that a "[. ..] a limited number of researchers produces a lot in a given area of knowledge, while a large volume of researchers produces little. " (MACHADO JUNIOR et al, 2016, p. 113). In 1934, Samuel Clement Bradfrod proposed the dispersion law that foresees a number of journals distributed in three zones, the first, which would be the nucleus, contains the most relevant titles and the other titles that are distant from the nucleus, respectively located in second and third zones, are dispersed around the main subject to which the law is being applied (MACHADO JUNIOR et al, 2016; VANTI, 2002, p. 153; BRADFORD, 1931).

This entire scope makes up the discipline Bibliometrics in its descriptive context; however, bibliometric studies can still be of an evaluative nature, which studies the impact of published works and relational studies that are oriented towards identifying cognitive aspects, based on relationship indicators (THELWALL, 2008).

3 METHOD

Research of a longitudinal character and of a quantitative nature, as to the objective, it is of a descriptive nature, based on the bibliometric technique and the survey of production indicators.

For the analysis of national scientific production, the period 2001-2019 was divided into four subperiods, three of which are five years old, and one of four years old: the first subperiod covered the years 2001 to 2005, the second from 2006 to 2010, the third from 2011 to 2015 and the fourth from 2016 to 2019. This division criterion allowed a better visualization of the dynamics of the area.

The unit of analysis was the original article, since this type of publication is considered as the main vehicle for registration, having rapid dissemination which allows access and use of information contributing to the generation of new knowledge.

The procedures were carried out in two stages, the first of which consisted of a survey of data in the main collection of the Web of Science/WoS (Clarivate Analytics), which took place on April 13-19, 2016 and updated on April 20 2020, with the search protocol - topic: stem cell. First, data related to world production were collected, covering the period from 2001 to 2019, and then for Brazil, specifically for each subperiod. These records were stored in .txt files and, subsequently, analyzes of exploratory, inferential and bibliometric data were performed, with the help of Microsoft Excel and Jamovi (version 1.2). The level of significance adopted was equal to 5%, for the statistical tests performed (FÁVERO; BELFIORE, 2017).

The 2nd stage consisted of analyzes of world and national production, and, when possible, comparisons were established; then, a descriptive bibliometric analysis was carried

out in order to survey the indicators of Brazilian production, by authorship, periodicals and research area.

Bradford's Law - which establishes "the nucleus and areas of dispersion on a given subject in the same set of journals" (VANTI, 2002, p. 153) - was applied, aiming to survey the main journals in which Brazilian researchers publish their articles. These journals are in the first Bradford area, constituting the core of the collection (BRADFORD, 1961).

Regarding the classification of research categories, the Journal Citation Reports (JCR) was adopted, available on the Capes Journals Portal, which classifies journals in one or more research areas. Thus, for each analyzed subperiod, a ranking by research areas was made.

4 RESULTS AND DISCUSSION

In this session, data are presented and discussed in three subsections. In the first - that is, 4.1 - data on the absolute production of articles published in Brazil and in the world will be presented; in section 4.2, the focus is on the authors; then, in section 4.3, the journals are analyzed identifying the core collection in which the researchers published the results of their studies and research; and in the last section, 4.4, the areas of knowledge of Brazilian scientific production are listed based on the classification adopted by the JCR.

4.1 Scientific Production in Articles Published in Brazil and in the World

In the period from 2001 to 2019, 6,522 publications were retrieved, with 4,676 (71.70%) original articles and 1,846 (26.30%) from other publications, such as abstract, communications at scientific events, reviews, book chapter, editorial. It was concluded that articles are the predominant type of publication by Brazilian researchers, for recording and disseminating information related to scientific production in the area of stem cells.

Table 1 shows the distribution of scientific production data in the stem cell area, in absolute terms, measured in original articles published worldwide and in Brazil. As specified in the methodological procedures, the period from 2001 to 2019 was subdivided into four subperiods - that is, the 1st subperiod comprised the years 2001 to 2005, the 2nd from 2006 to 2010, the 3rd covered the years from 2011 to 2015 and the 4th 2016-2019. In Table 1, in addition to the total production in the subperiods, there is, in the last column, the Brazilian contribution in world scale.

Table 1. Worldwide and Brazilian production of articles in the field of stem cells (2001-2019)

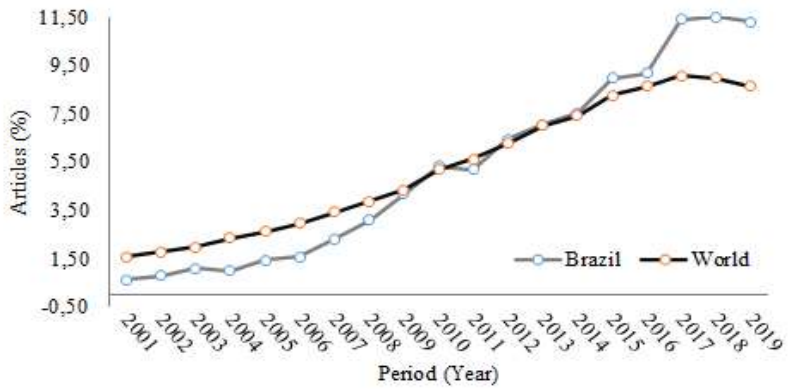
Subperiod	World	Brazil	World contribution from Brazil
2001-2005	28134	234	0,83
2006-2010	54018	770	1,43
2011-2015	94267	1643	1,74
2016-2019	96265	2028	2,11
Total	272684	4675	1,71

Source: WoS and research data.

Table 1 shows the growth in the number of articles in both scenarios. In Brazil, this growth, from 234 to 2028 articles, is due to several factors that may have contributed to the advancement of research in the area of stem cells. For Zorzanelli et al. (2017, p. 132), "[...] the revocation of the Unconstitutionality Action in relation to the Biosafety Law and the creation of the Cell Therapy Centers and the National Cell Therapy Network" would have driven this increase in the number of articles, given that such implemented actions would have generated new dynamics in every research area that had stem cells as its object of study. Acero and Antunes (2011) also highlight other points such as: (a) the research groups that in 2008 reached 2,843, according to data from the CNPQ research group directory, and (b) expansion of the number of researchers involved in the theme. For these authors, "The number of researchers working in these areas was estimated at 1,703, the vast majority of whom had a doctorate level (85.49% of them in PCT and 90.58% in CT)." (ACERO; ANTUNES; 2011, p. 107). PCT would be the acronym in Brazilian Portuguese for 'stem cell research' and CT refers to 'cell therapy'.

The comparison of the number of articles in global and Brazilian terms can be best seen in Graph 1, it is possible to observe the percentage growth in the number of articles starting from the second subperiod, when it exceeds 100 items, precisely in 2007, and the Brazil's global contribution exceeds 1.00%. We can infer that, both globally and in Brazil, there was an accumulated growth of an exponential nature, in which the worldwide doubling of the number of articles grew at intervals of 3,4 years, with a growth rate of 22.68% ($r^2 = 0, 94$); while the Brazilian was estimated at 29.49%, with a doubling time equal to 2.7 years ($r^2 = 0.95$).

Graph 1 – Worldwide and Brazilian growth in the number of articles in the area of stem cells (2001-2019)



Source: WoS.

Brazil, in the analyzed period (2001-2019), occupied the 17th position, at the same time that the contribution of the United States (35.69%) was much higher than the other countries; that is, it occupied the 1st position, followed by China (17.66%). In this global context, Brazil's position with regard to the countries that make up the BRICS is noteworthy, occupying the 3rd position, and the 1st position among the countries of Latin America.

4.2 Authorship Analysis

For the period from 2001 to 2019, the authorship indicator, which shows the number of authors involved in scientific production, accounted for 28,050 distinct authors, who were stratified according to the type of authorship described, by subperiod. Table 2 shows that the number of articles signed by a single author increased during the sub-periods, but on a smaller scale when compared to articles written by more than one author, which for the period 2001-2019 was estimated at 99.25%. Such data contributes to the literature with regard to scientific collaboration and the advantages of collaborative work in advancing scientific activity (GRÁCIO, 2018; KATZ, MARTIN, 1997). As for this growth, Sidone, Haddad and Mena-Chalco (2003, p. 3) observe that "The main characteristic of modern science is the increase in the collaborative profile in all its areas, since about 70% of the articles currently produced in the world are associated with authors from different institutions and, among these, about 44% come from collaborative efforts between researchers from different countries and 56% from collaborations between researchers in the national territory".

In Table 2, we present the comparison of the typology of authorship and destination authors in the four subperiods (2001-2005, 2006-2010, 2011-2015 and 2016-2019) and in the period (2001-2019). The distribution of the authors is characterized by the multiple author, who for this study was measured by articles signed by two or more authors, data estimated by the collaboration index (Subramanyam Index), given that values close to 1 means high collaboration (SUBRAMANYAM , 1982) and for the four subperiods the values were greater than 0.90. There was, therefore, a trend in the number of co-authors in the analyzed subperiods, while the single authorship did not exceed 0.09% for the period (2001-2019). Another data analyzed was the number of authors per article that exceeded the home of the 20 authors, arriving in the 3rd and 4th subperiods to transpose more than 100 authors (Table 2).

The average and interquartile range (Table 2) were also measured in order to examine the number of co-authorships/articles in the analyzed subperiods, so for the first subperiod 15.38% of the articles are of triple authorship, in the second 12.60% of articles were estimated to be signed by five authors, in the third, there are two types of typology, a five-fold (10.21%) and another eight-fold (10.21%) and in the fourth subperiod there was a trend in the typology of articles signed by seven authors (12.48%).

Table 2 – Typology of authorship of Brazilian scientific production in the area of stem cells (2001-2019)

Authorship	Subperiod				2001-2019
	2001-2005	2006-2010	2011-2015	2016-2019	
Unique	3	7	11	14	35
Douple	42	86	104	88	320
Triple	108	162	273	246	789

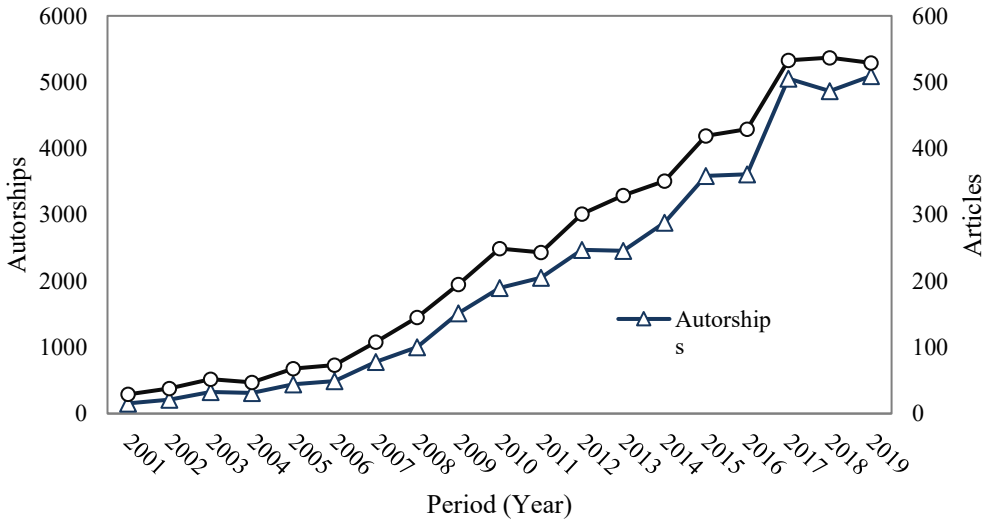
Quadruple	140	332	576	524	1572
≥5	1.145	5.093	12.479	17.747	36.464
Authorships	1.438	5.680	13.443	18.619	39.180
Authors	1.142	4.171	9.375	13.362	28.050
Minimum	1	1	1	1	1
Maximum	28	72	195	236	236
Avarage	5(3-7)	7(5-9)	7(5-9)	8(6-10)	7(5-10)
Collaborationi index	0,99	0,99	0,99	0,99	0,99

Source: research data.

From the data in table 2, we can see that the dynamics in the analyzed subperiods were differentiated, especially with regard to the number of articles, type of authorship and authors. In order to verify if there were differences in the distribution of authorship between the subperiods, and after checking the normality of the data using the Kolmogorov – Smirnov test (FÁVERO; BELFIORE, 2017), the Kruskal-Wallis test (FÁVERO; BELFIORE, 2017) that detected a statistically significant difference (p-value<0.05), between the averages of authorship, in the four analyzed subperiods.

The stem cell area has a multidisciplinary essence (ZHAO; STROTMANN, 2011) and brings together researchers from different areas of scientific knowledge, leading to the development of collaborative research, which results in works with multiple authors. It is also worth mentioning that scientific collaboration is a characteristic of modern science, as signaled by Sidone, Haddad and Mena-Chalco (2003). Another data to be scored is that the research is international and can also be considered multicentric (FOMENTO, 2010; MONTEIRO et al., 2004), perhaps it can explain the high number of authors in the articles, in addition to their interdisciplinarity, although other variables may be examined which goes beyond the purpose of this study.

Graph 2 - Temporal evolution of authorship and production articles Brazilian scientific research in the area of stem cells (2001-2019)



Source: research data.

By analyzing Graph 2, we can see that there was an exponential growth both for authorship ($r^2 = 0.96$) and for articles ($r^2 = 0.96$), implying that the expressive increase in the number of articles is correlated to the number of authors. In order to verify the relationship between the number of authors and the number of published articles, the simple linear regression test was performed (FÁVERO; BELFIORE, 2017), with the variables authorship (independent) and articles (dependent), performed for each subperiod. The result shows, for the four subperiods, that more than 90.00% of the variations in the number of articles are explained by the variations in the number of authors.

When testing the regression model, the result by the F statistical test, it was found that the level of significance was less than 0.05, emphasizing the significance of the linear regression model. Thus, in the analyzed subperiods, the number of authors had a significant influence on the number of articles.

When the authors were analyzed, in order to account for the number of articles per author, a total of 28,050 distinct authors were found, who published 4,675 articles, and were classified into four extracts (PALACIOS-MARQUÉS et al., 2019; URBIZAGASTEGUI, 2008). According to the total number of articles published by authors, in the respective subperiods, the great authors were those who published 10 or more articles, moderated between 5 and 9, aspiring between 3 and 4 and passers-by with 2 or 1 articles.

In Table 3, we can see the distribution of authors by strata in the four subperiods, with growth in the category of great authors going from 1, in the first subperiod, to 51 authors in the 4th subperiod. It is worth mentioning that these authors were responsible for the publication of 10 (≥10) or more articles. As for passers-by authors, these in greater proportion (> 90%), we can infer that the production is linked to an academic rite, relating these authors to graduate students, for example - whose articles must be the result of an academic activity -, or authors who contributed to the development of research being the same from another area, given the high degree of collaboration in the area of stem cells, having a strong interdisciplinary characteristic.

Table 3. Stratification of authors of Brazilian scientific production in the area of stem cells (2001-2019)

Extract	1.º subperiod (2001-2005)		2.º subperiod (2006-2010)		3.º subperiod (2011-2015)		4.º subperiod (2016-2019)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Big	1	0,09	16	0,38	45	0,36	51	0,38
Moderate	9	0,79	71	1,70	208	2,21	260	1,95
Aspiring	50	4,38	200	4,80	534	6,32	713	5,34
Passers-by	1.082	94,75	3.884	93,12	8.588	91,11	12.338	92,34
Total	1.142	100,00	4.171	100,00	9.375	100,00	13.362	100,00

Source: research data.

For the period (2001-2019), the validity of the 20-80 distribution, of the Pareto type, was verified, noting that the rule does not apply to Brazilian scientific production in the area of stem cells, since 21.29% of the authors published 44.04 % of articles while 78.71% published only a single article.

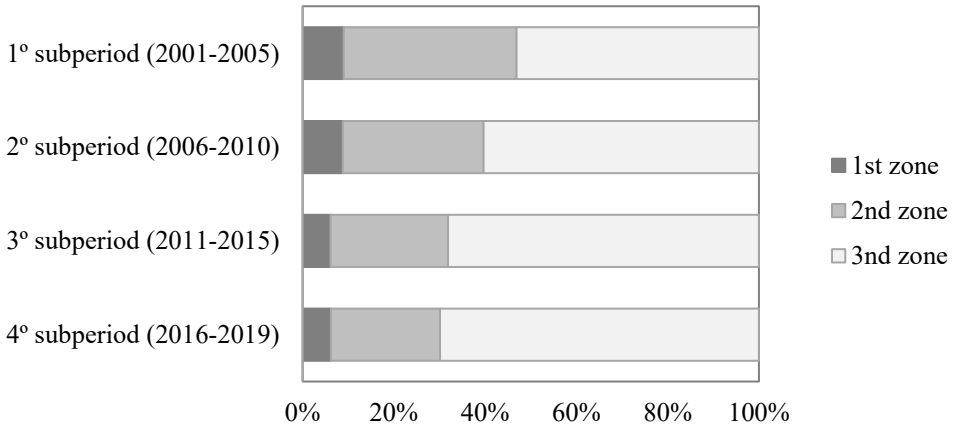
4.3 Core of Periodicals

In order to identify the nucleus of journals - thus meeting the specific objective - the Bradford Law (BRADFORD, 1961), known as the Law of Dispersion, was applied, aiming to

identify the main journals that concentrated a high frequency of articles published by Brazilian researchers. Bradford proposed to group the journals according to their productivity in zones, with the 1st zone containing the most relevant journals - meaning, those that published Brazilian articles most frequently -, which constitutes the core of the studied collection and, therefore, the most prolific journals. The 2nd zone can be called intermediate, and in the 3rd zone, we find dispersion, that is, a variety of journals with few articles published on the subject studied. Machado Junior et al. (2016, p. 114) observes that "Journals with greater publication of articles on a given subject tend to establish a nucleus supposedly of superior quality and greater relevance in this area of knowledge."

Graph 3 highlights the results of applying the Bradford Law, and it is possible to observe differences in the proportion of titles between the size of the zones in each subperiod. An analysis for the 1st zone accounts for 145 titles for the 1st subperiod, of which 13 (8.97%) occupied the nucleus; for the 2nd, the nucleus comprised 37 (8.79%) titles out of a total of 421, in the 3rd subperiod 45 (6.12%) out of a total of 735 titles were added, and in the 4th, 857 titles were found, 53 (6.18%) occupied the nucleus. In the 1st zone (nucleus), a small fraction of the titles that published a large number of articles were concentrated in relation to the other journals in the other zones.

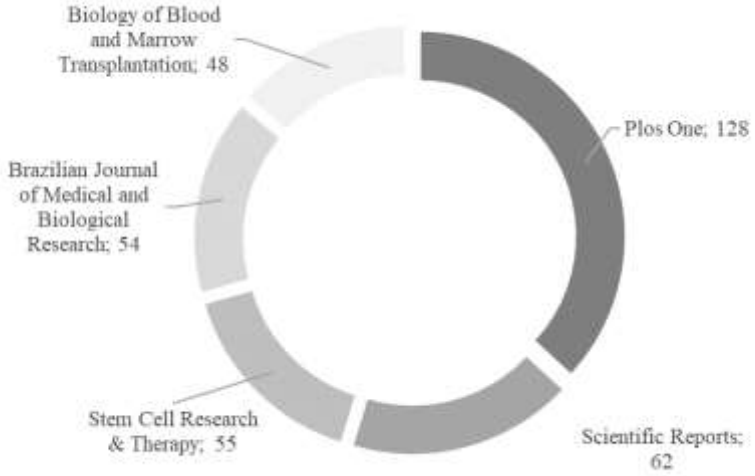
Graph 3 . Distribution by Bradford's Law of Brazilian scientific production journals in the area of stem cells (2001-2019)



Source: research data.

The titles in the 1st zone were grouped for the four subperiods, comprising the core of the collection (core collections) which totaled 90 titles, 20 (22.22%) of which were national, which published 368 articles, with a range from 4 to 54 articles by title, while there was an expressive concentration of production in foreign titles totaling 70 (77.78%), which together add up to 1,182 articles, occurring from 3 to 128 articles/journals. Graph 4 shows the top five titles in number of articles.

Graph 4. Core of the collection of scientific production journals in the area of stem cells (2001-2019)



Source: research data.

For the period (2001-2019), 1,425 titles - 68 national and 1,357 foreign - were recorded - five of which stand out for the volume of published articles (Graph 4), Plos One (128), Scientific Reports (65), Stem Cell Research & Therapy (55), Brazilian Journal of Medical and Biological Research (54) - national - and Biology of Blood and Marrow Transplantation (49).

There is a dynamic in the subperiods in the formation of the core of the collection, predominant foreign titles, mainly in the 3rd and 4th subperiods, another point observed were the national titles, published in the English language, such as Brazilian Journal of Medical and Biological Research and Brazilian Journal of Animal Science. This is a tendency of Brazilian journals - that is, to publish their articles in the English language -, a fact that has been growing in recent years, given the internationalization of Brazilian science. Such publications give greater visibility to the national scientific production, indexed in databases, as it allows a larger audience in the number of readers than published in Portuguese, whose focus is more restricted (SOUZA, 2017).

In a study carried out by Mueller (2005), when examining science publications in scientific areas and the preferred channels, the author observed that foreign journals were the vehicle most used by researchers in Exact, Biological and Health Sciences. This data is close to the results of the core of the analyzed collection, since more than 50.00% of the articles in the 1st zone were published in foreign journals.

4.4 Knowledge area

The areas of knowledge were analyzed according to the classification adopted by the Journal Citation Reports (JCR), for the titles of journals in "research area", with a specific journal being able to be listed among one or more areas. In Chart 1, we have the first five research areas that represent research fields in the Brazilian stem cell area, for the studied subperiods.

Chart 1. Research area of Brazilian scientific production in the area of stem cells (2001-2019)

Research area	Article	Research area	Article
1.º subperiod (2001-2005)		**2.º subperiod (2006-2010)**	
Hematology	40	Cell biology	100
Medicine and Experimental Research	27	Hematology	87
Oncology	26	Medicine and Experimental Research	83
Neuroscience and Neurology	25	Neuroscience and Neurology	69
Immunology	24	Transplants	60
3.º subperiod (2011-2015)	Article	**4.º subperiod (2016-2019)**	Article
Cell biology	277	Cell biology	350
Medicine and Experimental Research	161	Science and Technology - Other Topics	165
Hematology	134	Biochemistry and Molecular Biology	157
Biochemistry and Molecular Biology	123	Medicine and Experimental Research	155
Science and Technology - Other Topics	120	Materials science	135

Source: WoS.

During the subperiods, these areas assumed dynamics that changed the scenario under study, moving from the clinical focus to the development of studies in the field of cell biology. Thus, "hematology", as the center of studies in the 1st subperiod, moved to 2nd and 3rd positions in the 2nd and 3rd subperiods, respectively, as for the 4th subperiod occupies the 10th position. It is worth mentioning that "hematology" was one of the first fields of application of the stem cell in bone marrow transplants, which date back to 1950 (PEREIRA, 2008).

There was an increase in the research area "cell biology" from the 2nd subperiod (2006-2010), placing it at the apex, that is, moving from the 7th position, in the 1st subperiod, to the 1st in following sub-periods. When analyzing the intellectual structure of the Brazilian stem cell area - that is, the knowledge base, the researchers Machado, Vargas-Quesada and Leta (2016) developed a study, focusing on the analysis of periodic quotations, covering the period of 2001 to 2010, whose results signaled cell biology with a hot field of research and study.

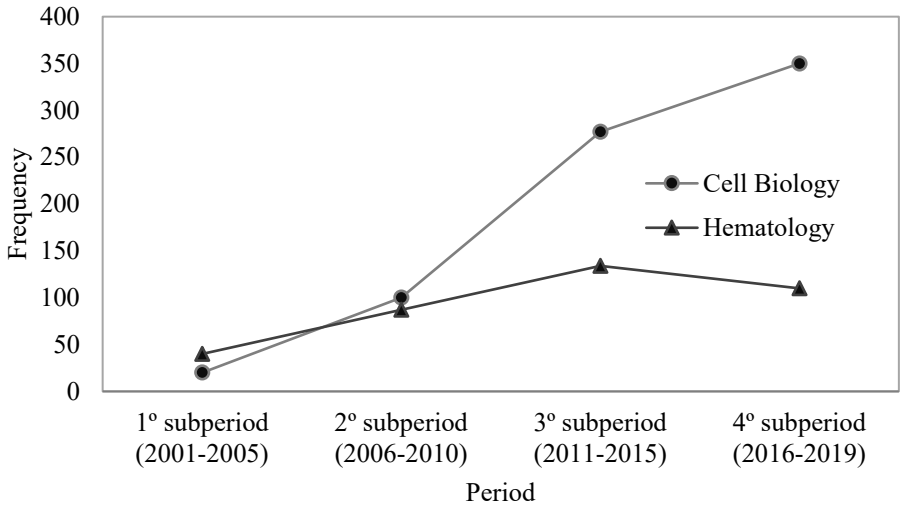
In another study, Li et al. (2009) researched, over a period of 16 years (1991 to 2006), the global scientific production with stem cells, and observed the diversity of research topics pointing, as one of their results, the scope of research in "hematology" , "Oncology" and "cell biology". They also stressed that "cell biology" will play a major role, especially from 2006 onwards. Looking at the data in Graph 5, we can then see this fact in Brazilian scientific production.

We can verify, then, the asymmetry of the research categories in the four subperiods examined, with the categories described above being very distant from the others and giving the center of convergence of the themes presented in Brazilian scientific production.

Based on the study by Li et al. (2009) that places "cell biology" as a growing research field in the stem cell area was plotted, in Graph 5, in order to verify the temporal evolution for the "cell biology" and "hematology" research categories. It is noticed, therefore, that there was growth of both until the 3rd subperiod, however "hematology" declines in the 4th subperiod while "cell biology" continues to rise, with its variability estimated at 80.64% while for "hematology" the variation is around 49.90%. This data collaborates with the results of the aforementioned study, "cell biology" emerging as an area of hot research in the area of Brazilian

stem cells.

Graph 5. Evolution of the hematology and cell biology research areas in Brazilian scientific production in the area of stem cells (2001-2019)

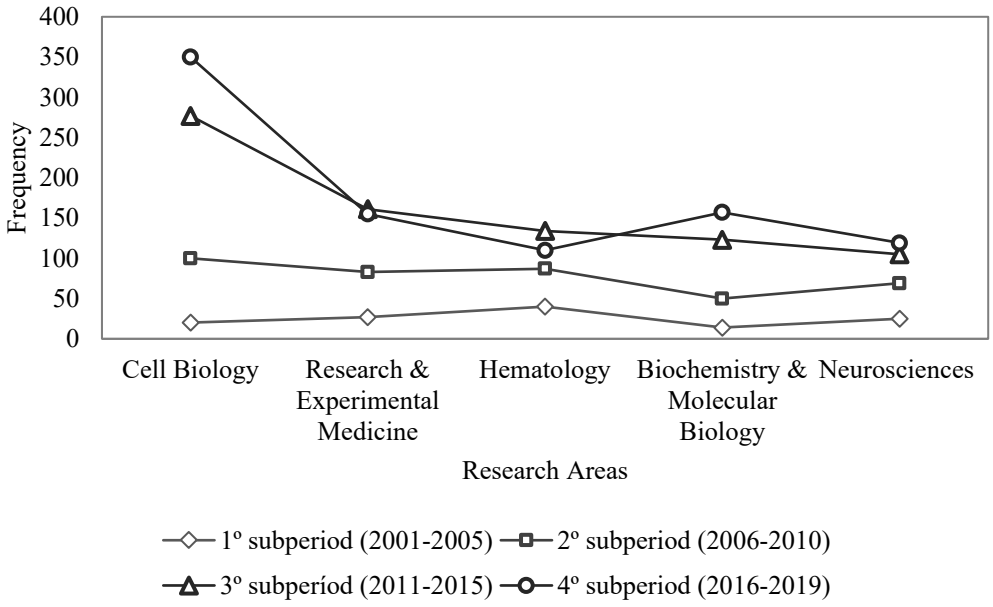


Source: WoS.

The growing understanding of the biological mechanisms, both of the internal and external structure of cells, increasingly leads scientists to develop new studies in order to better understand stem cells that, by themselves, can multiply and transform into specialized cells, such as neurons and cardiac muscles, for example (PEREIRA, 2008). In addition, it can also be induced in laboratories, constituting an important part for human and veterinary regenerative medicine (MACHADO et al., 2018).

After analyzing the research categories in the subperiods, the ranking for the period from 2001 to 2019 was elaborated, bringing together the data of the four subperiods (Graph 6). The ranking was established for each research category and listed the top five for Brazilian scientific production, namely: “cell biology”, “medicine and experimental research”, “hematology”, “biochemistry and molecular biology” and “neurosciences”, those presented in Graph 6 in which the growth trend of each of them can be seen in the respective analyzed subperiods.

Graph 6. Evolution of research areas of Brazilian scientific production in the area of stem cells (2001-2019)



Source: WoS.

In the study cited by Li et al. (2009), the research areas were accounted for in 167, the most common ones, from 1991 to 2006: "hematology", "oncology" and "cell biology", also accompanied by "immunology", "molecular biochemistry and biology" and "transplants". These authors also observe that "hematology" did not have the highest growth rates, and also warns of the growth of "cell biology", especially since 2006, a result that we can observe for the world and for Brazil.

In this study, which covered 19 years (2001-2019), 144 research areas were surveyed, distributed in 1,425 journals specialized in themes related to stem cells, or specialties for specific purposes.

5 FINAL CONSIDERATION

The data obtained regarding the number of articles published by Brazilian researchers in the field of stem cells and indexed in WoS, with at least one author of Brazilian affiliation, highlights the frank expansion of Brazilian scientific production in the area of stem cells, in the period of 2001 to 2019. There was, therefore, an increase in the number of articles (4,675) and authors (25,050), especially from 2006, highlighting the advancement of research in Brazil, as well as the expansion of the contribution of Brazilian research, which increased from 0.83% (2001-2005) to 2.11% (2016-2019) on the world stage.

It was found that of the total of 1,425 journal titles, 95.23% of which are foreign and 4.77% national, showing the participation of Brazilian researchers in the international context of stem cell research. The core of the collection, in the period studied (2001-2019), was made up of 90 titles, which accounts for 6.31% of the total titles, with five concentrating the largest number of articles, Plos One (128), Scientific Reports (65), Stem Cell Research & Therapy (55), Brazilian Journal of Medical and Biological Research (54) and Biology of Blood and Marrow Transplantation (49).

The main areas of research point to "cell biology" as an area of high centrality, occupying the 1st position in the hot ranking of research in the area of stem cells. This result highlights the variability of themes in an area of a multidisciplinary nature such as studies in the area of stem cells, punctuating a consolidated structure of research themes, such as cell biology and hematology, for example.

The bibliometric indicators of production were relevant to the development of this study, allowing a compression of the object studied, the same can be said about the methodological design used and the selection of the analyzed variables.

The scenario presented is stimulating, for the stem cell area, at a time when investments in science and technology in Brazil require more attention in order to maintain the continuity of Brazilian research as well as the maintenance and training of new scientists.

When analyzing the data, other questions were raised, for future studies, such as the impact of Brazilian production in the area of stem cells, in the national and global scenario, and the distribution of the nationality of authorship in articles published in foreign and Brazilian journals.

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ACKNOWLEDGMENTS: Not applicable.
FUNDING: This study was partly financed by Edital PROPCI/PROPG – UFBA 004/2016 – Programa de Apoio a Jovens Professores Doutores – PROPESQ.
CONFLICTS OF INTEREST: Not applicable.
ETHICAL APPROVAL: Not applicable.
AVAILABILITY OF DATA ANDE MATERIAL: Not applicable
AUTHORS' CONTRIBUTIONS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft: Machado, R. N.; Writing – review & editing: Machado, R.N.

REFERENCES

ACERO, Liliana; ANTUNES, Diogo. Conquistas e desafios das pesquisas com Células-Tronco no Brasil. **Desenvolvimento em Debate**, v. 2, n. 1, p. 97-119, 2011. Available on: https://revistas.ufrj.br/index.php/dd/article/view/31926. Access at: 18 Mar. 2020.

ALMEIDA, Elenara Chaves Edler de; GUIMARÃES, Jorge Almeida. Brazil's growing production of scientific article how are we doing with review articles and other qualitative indicators? **Scientometrics**, v. 97. p. 287–315, 2013.

BRADFORD, S. C. **Documentação**. Rio de Janeiro: Fundo de Cultura, 1961.

CIRANI, Claudia Brito Silva; CAMPANARIO, Milton de Abreu; SILVA, Heloisa Helena Marques da. Evolução do ensino da pós-graduação senso estrito no Brasil: análise exploratória e proposições para pesquisa. **Avaliação**, Campinas; Sorocaba, SP, v. 20, n. 1, p. 163-187, mar. 2015.

FÁVERO, Luiz Paulo Lope.; BELFIORE, Patrícia Prado. **Manual de análise de dados**: estatística e modelagem multivariada com Excel®, SPSS® e Stata®. Rio de Janeiro: Elsevier,

2017.

FOMENTO às pesquisas em terapia celular e células-tronco no Brasil. **Revista de Saúde Pública**, São Paulo, v. 44, n. 4, p. 763-764, 2010. Available on: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-89102010000400022&lng=en&nrm=iso Access at: 30 Apr. 2020.

GRÁCIO, Maria Cláudia Cabrini. Colaboração científica: indicadores relacionais de coautoria. **Brazilian Journal of Information Studies**: Research Trends, Marília, SP, v. 12, n. 2, p. 24-32. 2018.

HILU, Luciane; GISI, Maria Lourdes. Produção científica no Brasil: um comparativo entre as universidades públicas e privadas. *In*: CONGRESSO NACIONAL DE EDUCAÇÃO, 10; SEMINÁRIO INTERNACIONAL DE REPRESENTAÇÕES SOCIAIS SUBJETIVIDADE E EDUCAÇÃO, 1, Paraná, 2011. p. 5664-5672. Available on: https://educere.bruc.com.br/arquivo/pdf2011/5221_3061.pdf. Access at: 31 Jul. 2019.

KATZ, J. Sylvan; MARTIN, Ben R. What is research collaboration? **Research Policy**, 26, p. 1-18, 1997.

LI, Ling-Li *et al*. Global stem cell research trend: Bibliometric analysis as a tool for mapping of trends from 1991 to 2006. **Scientometrics**, v. 80, n. 1, p 39–58, 2009.

MACHADO JUNIOR, Celso; SOUZA, Maria Tereza Saraiva de; PARISOTTO, Iara Regina dos Santos; PALMISAN, Angelo. As leis da bibliometria em diferentes bases de dados científicos. **Revista de Ciências da Administração**, Florianópolis, v. 18, n. 44, p. 111-123, 2016. Available on: https://periodicos.ufsc.br/index.php/adm/article/view/2175-8077.2016v18n44p111. Access at: 31 Jul. 2019.

MACHADO, Lucas Simões *et al*. Células-tronco pluripotentes induzidas (células iPS) em animais domésticos e a possibilidade de geração in vitro de gametas. *In*: CONGRESSO NORTE E NORDESTE DE REPRODUÇÃO ANIMAL (CONERA 2018), 9.: 2018: Belém, PA, 10 a 12 de setembro de 2018. **Anais do**... Available on: http://www.cbra.org.br/portal/downloads/publicacoes/rbra/v42/n3-4/p114-119%20(RB746).pdf. Access at: 12 Aug. 2019.

MACHADO, Raymundo N.; VARGAS-QUESADA, Benjamin; LETA, Jacqueline. Intellectual structure in stem cell research: exploring Brazilian scientific articles from 2001 to 2010. **Scientometrics,** v. 106, p. 525-537, 2016.

MALTRÁS BARBA, B. **Los indicadores bibliométricos**: fundamentos y aplicación al análisis de la ciencia. Gijón: TREA, 2003.

MONTEIRO, Rosangela *et al*. Critérios de autoria em trabalhos científicos: um assunto polêmico e delicado. **Revista Brasileira de Cirurgia Cardiovascular,** São José do Rio Preto, v. 19, n. 4, p. III-VIII, dez. 2004. Available on: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-76382004000400002&lng=en&nrm=iso. Access at: 30 Apr. 2020.

MUELLER, Suzana Pinheiro Machado. A publicação da ciência: áreas científicas e seus canais preferenciais. **DataGramaZero**: Revista de Ciência da Informação, v. 6 n. 1 fe.2005. Available on: http://repositorio.unb.br/bitstream/10482/980/2/ARTIGOPublicacaoCiencia.pdf . Access at: 5 Jul. 2019.

PACKER, Abel Laerte. A eclosão dos periódicos do Brasil e cenários para o seu porvir. **Educação e Pesquisa**, São Paulo, v. 40, n. 2, p. 301-323, jun. 2014. Available on: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1517-97022014000200002&lng=pt&nrm=iso. Access at: 06 Agu. 2019.

PALACIOS-MARQUÉS, Ana M. *et al*. Worldwide scientific production in obstetrics: a bibliometric analysis. **Irish Journal of Medical Science**, n. 188, p. 913–919, 2019.

PEREIRA, Lygia da Veiga. A importância do uso das células-tronco para a saúde pública. **Ciência e Saúde Coletiva**, v. 13, n. 1, p.7-14. 2008.

REHEN, Stevens; PAULSEN, Bruna. **Células-tronco**: o que são? para que servem. Rio de janeiro: Vieira & Lent, 2007.

RODRIGUES, Isabella Caroline Pereira *et al*. Engenharia de tecidos cardíacos: atual estado da arte a respeito de materiais, células e formação tecidual. **Einstein** (São Paulo), São Paulo, v. 16, n. 3, p. 1-9, 2018. Available on: https://www.scielo.br/pdf/eins/v16n3/pt_2317-6385-eins-16-03-eRB4538.pdf. Access at: 15 Jan. 2021.

SPINAK, E. Diccionario Enciclopédico de Bibliometría, Cienciometría e Informetría. Caracas: UNESCO, 1996.

SIDONE, Otávio J. G.; HADDAD, Eduardo A.; MENA-CHALCO, Jesus. Padrões de colaboração científica no brasil: o espaço importa? São Paulo, **TD Nereus**, 2013. Available on: http://www.usp.br/nereus/wp-content/uploads/TD_Nereus_09_2013_v2.pdf. Access at: 21 Jun. 2019.

SOARES, Ana Prates *et al*. Células-tronco em Odontologia. **Revista Dental Press de Ortodontia e Ortopedia Facial,** Maringá, v. 12, n. 1, p. 33-40, jan./fev. 2007. Available on: https://www.scielo.br/pdf/dpress/v12n1/a06v12n1. Access at: 5 Jul. 2019**.**

SOUZA, Andréa Cerqueira. Periódicos científicos do Brasil e o dilema: publicar ou não em inglês? **SciELO em Perspectiva**: Humanas, 2017. Available on: https://humanas.blog.scielo.org/blog/2017/09/01/periodicos-cientificos-brasileiros-e-o-dilema-publicar-ou-nao-em-ingles. Access at: 5 Jul. 2019.

SUBRAMANYAM, K. Bibliometric studies of research collaboration: a review. **Journal of Information Science**, n. 6, p. 33-38, 1982.

URBIZAGASTEGUI, Ruben. A produtividade dos autores sobre a Lei de Lotka. **Ciência Informação**, Brasília, v. 37, n. 2, p. 87-102, maio/ago. 2008.

SEGURA, Dora de Castro Agulhon *et al*. Células-tronco: as células capazes de gerar outros tipos de células. **Arquivos de Ciências da Saúde da Unipar**, v. 11, n. 2, p. 115-152,

maio/ago. 2007. Available on: https://revistas.unipar.br/index.php/saude/article/view/1522. Access at: 21 Jun. 2020

THELWALL, Mike. Bibliometrics to webometrics. **Journal of Information Science**, v. 34, n. 4, p. 605–621, 2008.

VANTI, Nadia Aurora Peres. Da bibliometria à webometria: uma exploração conceitual dos mecanismos utilizados para medir o registro da informação e a difusão do conhecimento. **Ciência da Informação,** Brasília, v. 31, n. 2, p.152-162. 2002.

WONG, Chan-Yuan. A century of scientific publication: towards a theorization of growthbehavior and research-orientation. **Scientometrics**, v. 119, p. 357–377, 2019.

ZHAO, Dangzhi; STROTMANN, Andreas. Intellectual structure of stem cell research: a comprehensive author co-citation analysis of a highly collaborative and multidisciplinary field. **Scientometrics**, v. 87, p. 115–131, 2011.

ZORZANELLI, Rafaela Teixeira *et al*. Pesquisa com células-tronco no Brasil: a produção de um novo campo científico. **História, Ciências, Saúde – Manguinhos**, Rio de Janeiro, v.24, n.1, p.129-144, jan.-mar. 2017.

Article submitted to the similarity system

Submited: 13/11/2020 – Accepted: 11/01/2021 – Published: 05/02/2020