Article published online: 2023-07-04

https://doi.org/10.1590/0004-282X-ANP-2020-0480

ARTICLE

Brazilian research on noninvasive brain stimulation applied to health conditions

Pesquisa brasileira em neuromodulação não invasiva aplicada às condições de saúde

Katia Nunes SÁ[1], Gabriel VENAS[2], Mayara Pinheiro de SOUZA[3], Daniel Ciampi de ANDRADE[4], Abrahão Fontes BAPTISTA[5]

ABSTRACT

Background: Brazil has a top position regarding scientific production on noninvasive neuromodulation worldwide. Knowledge of scientometric phenomena involving Brazilian researchers who produce science on this theme may aid confidence in Brazilian clinical and research professionals. **Objective:** To investigate the scenario of research on the theme of noninvasive neuromodulation in Brazil. **Methods:** This was a scientometric study for mapping scientific production on this subject involving network phenomena, the professions of researchers, institutional affiliation, main research unit, total number of scientific articles on noninvasive neuromodulation published in journals, research sub-area and year of obtaining the PhD title. Public data from Lattes Platform curricula vitae and from VOSViewer© were used. **Results:** A total of 54 Brazilian researchers were identified, of whom 16 are research productivity fellows. Most of them are linked to institutions in southeastern Brazil, involving the professions of biology, biochemistry, physical education, physiotherapy, speech therapy, gerontology, medicine and psychology, with 1175 articles published in journals. These studies involve experimental animal and human models to account for mechanisms, observational studies, case reports, randomized clinical trials, systematic reviews, meta-analyses, product and process development, computer modeling and guidelines. **Conclusions:** Brazil occupies a prominent place in the world scenario of research on noninvasive neuromodulation, which is used by different professions for treatment of brain dysfunctions, with a trend towards expansion to other fields.

Keywords: Bibliometrics; Transcutaneous Electric Nerve Stimulation; Magnetic Field Therapy.

RESUMO

Antecedentes: O Brasil ocupa posição de destaque na produção científica de neuromodulação não invasiva no mundo. O conhecimento dos fenômenos cientométricos envolvendo pesquisadores brasileiros que produzem ciência neste tema pode auxiliar na confiança dos profissionais clínicos e pesquisadores brasileiros. **Objetivo:** Investigar o cenário das pesquisas sobre a temática da neuromodulação não invasiva no Brasil. **Métodos:** Estudo cienciométrico para mapeamento da produção científica sobre o tema envolvendo fenômenos de rede, profissão dos pesquisadores, afiliação à instituição, unidade principal de pesquisa, número total de artigos científicos publicados em periódicos sobre neuromodulação não invasiva, subárea de pesquisa e ano de obtenção do título de doutor. Utilizou-se dados públicos dos currículos da Plataforma Lattes e do sistema VOSViewer©. **Resultados:** Foram identificados 54 pesquisadores brasileiros, dos quais 16 são bolsistas de produtividade em pesquisa, a maioria deles vinculados a instituições do Sudeste do Brasil, envolvendo as profissões de Biologia, Bioquímica, Educação Física, Fisioterapia, Fonoaudiologia, Gerontologia, Medicina e Psicologia, com 1175 artigos publicados em periódicos. As pesquisas envolvem modelos experimentais animais e humanos para estudar dos mecanismos, estudos observacionais, relatos de casos, ensaios clínicos randomizados, revisões sistemáticas, meta-análises, desenvolvimento de produtos e processos, modelagem computacional e diretrizes. **Conclusões:** O Brasil ocupa lugar de destaque no cenário mundial das pesquisas em neuromodulação não invasiva, sendo utilizado por diferentes profissões para o tratamento de disfunções cerebrais, que tendem a se expandir para outros campos.

Palavras-chave: Bibliometria; Estimulação Elétrica Nervosa Transcutânea; Terapia de Campo Magnético.

[1]Escola Bahiana de Medicina e Saúde Pública, Programa de Pós Graduação, Salvador BA, Brazil.

[2]Universidade de São Paulo, Ciências da Reabilitação, São Paulo SP, Brazil.

[3]Escola Bahiana de Medicina e Saúde Pública, Fonoaudiologia, Salvador BA, Brazil.

[4]Universidade de São Paulo, Departamento de Neurologia, São Paulo SP, Brazil.

[5]Universidade Federal do ABC, Santo André SP, Brazil.

KNS https://orcid.org/0000-0002-0255-4379; GV https://orcid.org/0000-0002-5277-5225; MPS https://orcid.org/0000-0002-2708-2750; DCA https://orcid.org/0000-0003-3411-632X; AFB https://orcid.org/0000-0001-7870-3820

Correspondence: Katia Nunes Sá; Email: katia.sa@gmail.com.

Conflict of interest: There is no conflict of interest to declare.

Authors' contributions: KNS: created the idea, developed the project, structured the method, collected data, analyzed data, wrote the article and approved the final version; GV: developed the project, analyzed data, wrote the article and approved the final version; MPS, DCA: wrote the article and approved the final version; AFP: collected data, analyzed data, wrote the article and approved the final version.

Received on October 09; Received in its final form on December 29, 2020; Accepted on January 23, 2021.

CC BY

INTRODUCTION

Use of noninvasive brain stimulation (NIBS) has grown exponentially over recent decades due to the potential positive effects that it has had within different sub-areas of healthcare, including psychiatry, neurology and rehabilitation[1-3]. Efficacy has been shown mainly for two methods: repetitive transcranial magnetic stimulation (rTMS), and transcranial direct current electrical stimulation (tDCS), for treating depression[4-6], chronic pain[7,8] and some neurological disorders such as stroke[9,10] and palsy[11].

Brazil is the third highest country in terms of the number of publications of clinical trials, behind only Germany and the United States[3]. Brazilian researchers have also conducted a large number of systematic reviews, with or without meta-analysis[4], and guidelines[7]. However, several aspects of this scientific productivity remain uncharted, such as the profile of scientific contributions of Brazilian research to NIBS, including which subthemes are mostly covered, an outline of the profile of these researchers, their institutional affiliations, existence of collaboration between international research groups, co-authorship and number of citations. This gap may be filled by special methods that have been developed to systematically extract, assess and present data (data science) and the characteristics of published information (scientometry).

Scientometry is a type of scientific research in which the aim is to analyze phenomena that permeate research and influence the efforts of researchers[12]. Conflicts of interest, indicators adopted by regulatory, financing and ranking agencies and discrete biases are inherent to the scientific process. Empirical scientometry analyzes the metadata of researchers' studies and curricula to ensure that science continues to serve society, and not simply to advance the individual interests of researchers, industries, educational institutions, care assistance and governments. The organization of this knowledge can be useful for guiding future research, increasing the robustness of clinical data and also revealing neglected but relevant areas of research.

Scientometry has proven helpful in the development of certain fields[13]. Research conducted in the Latin America and Caribbean region in the field of Zika virus, for example, was highlighted through use of this methodology[14]. The Leiden manifest reinforced this view, by suggesting that this type of study is fundamental for many reasons, including variations according to field of publication, and the need for constant updating of indicators[15].

In the field of NIBS, there are few scientometric data. A recent paper showed that neurostimulation therapies increased patients' interest in controlling depression, but was not specifically focused on NIBS[16]. The top 10 studies in this field have also been highlighted recently, while only showing publication trends over recent years[3]. This gap has also limited the safety of NIBS prescription, since scientometric data also support evidence-based clinical practice. For this reason, the aim of the present study was to delineate the scenario of research on the theme of NIBS, with special attention to the Brazilian scenario.

METHODS

This scientometric study was divided into two steps. In the first stage, mapping of the scientific production on the theme of NIBS was performed using the SCOPUS and Web of Science (WoS) databases. In the second stage, the curricula of the leading Brazilian researchers involved in NIBS research were analyzed.

The SCOPUS and WoS databases were searched with the aid of the VOSViewer© software, version 1.6.13, using the descriptors "*Transcranial Magnetic Stimulation* OR *rTMS* AND *Transcranial Direct Current Electrical Stimulation* OR *tDCS* AND *Noninvasive Neuromodulation*". In the first stage, mapping of the number of citations of the top 10 authors in the SCOPUS database was carried out. The data obtained through the search were issued in "cvs" documents for specific reading through bibliometric software.

The software was used to construct a color diagram of the quotes of the authors, i.e., authors whose works are typically referenced together in articles on NIBS, thereby denoting proximity between the topics covered. The structure of the network revealed relationships around the world, since the main information was collected in a database of abstracts and citations from the literature on peer review. For this study, we only considered co-author networks according to the numbers of citations extracted from the SCOPUS and WoS databases and citations according to countries, in order to analyze the relationship of Brazilian researchers with the worldwide scenario.

The intensity of relationships between researchers and the clusters according to citations were represented by circles of different sizes. The colors were determined by the density of the items at that point and co-authorship was displayed with a force knot based on the citations of the articles.

To delineate the profile of Brazilian researchers, we only included healthcare professionals with a PhD degree who are recognized by the Brazilian Ministry of Education, with or without acting in master's and/or doctoral programs; who are affiliated to some educational and/or research institution; and whose curriculum vitae on the Lattes Platform of the Brazilian Ministry of Science, Technology, Innovations and Communications, via CNPq (available at: http://lattes.cnpq.br), had been updated within the last six months. Those who had only one publication on NIBS in a scientific journal and those who only had publications relating to laboratory animal models were excluded. These criteria were used to help in identifying the most consistent centers of research on NIBS in Brazil.

The scientific production on NIBS among Brazilian researchers was extracted from their curricula vitae and was quantitatively analyzed. The variables analyzed comprised the researchers' professions, institution of affiliation, federal state in which their main activity was conducted, total number of scientific articles published in peer-reviewed journals (in general and in

the subarea of NIBS), research subarea and the year of obtaining a doctoral degree or equivalent.

RESULTS

Regarding the number of peer-reviewed articles, and considering the WoS, the United States, Germany, England and Italy were the most productive, and Brazil was among the 20 most productive countries (Figure 1A). In highlighting the Brazilian position, there were evident relationships of citations with 17 countries, among which Italy, Finland and Australia showed the strongest observed co-citation (Figure 1B).

Secondly, we ascertained who the most cited researchers were (top 10) in the field of NIBS worldwide, according to the SCOPUS database. Felipe Fregni (FF, a Brazilian researcher who works in Harvard University, USA) appeared in first position, with 3,349 citations, followed by Álvaro Pascual-Leone (Harvard University, USA) with 2,514 citations and André Brunoni (AB; University of São Paulo, Brazil) with 1,887 citations. In seventh position there was another Brazilian researcher, Paulo Boggio (PB; Mackenzie University, Brazil) with 1232 citations (Table 1). Although FF is a Brazilian researcher, and is the most cited researcher in the field of NIBS in the world, we did not proceed with analysis on his data because his institutional affiliation is not with a Brazilian entity, and his Lattes CV was out of date by more than twelve months at the time when this search was conducted.

Hence, two Brazilian researchers (AB and PB) were in a key position in this field, as shown by their central position and yellow color on the scale of the network diagram in Figure 2A. Two other Brazilian researchers, with lesser numbers of publications, also appeared in a central position: Joaquim Brasil-Neto (JBN; University of Brasília) and Wolnei Caumo (WC, Federal University of Rio Grande do Sul) (Figure 2A). Through selecting AB and PB by highlighting their names, a large number of co-citations with several eminent scientists in the world can be seen (Figure 2B and 2C).

The WoS database top 10 citation ranking did not show any Brazilian researcher. However, four Brazilian researchers with high number of citations appeared in this database: PB (3690), JBN (1834), AB (1457) and Marco Marcolin (MM, University of São Paulo) (990).

Focusing on Brazil, up to October 22, 2019, 81 researchers in the field of NIBS were identified. Out of these, 14 were excluded because they did not have a PhD degree, 10 because they only had one publication on the subject, one because of only working with invasive neuromodulation, one because of only working with animal models, one because the principal affiliation was not a Brazilian institution and the CV was out of date and one because this person was undergoing postdoctoral training in Finland. Thus, from this initial survey, 54 researchers who met the eligibility criteria remained. Among these, 16 (30.18%) were researchers funded by national productivity fellowships and one was a postdoctoral fellow (Table 2).

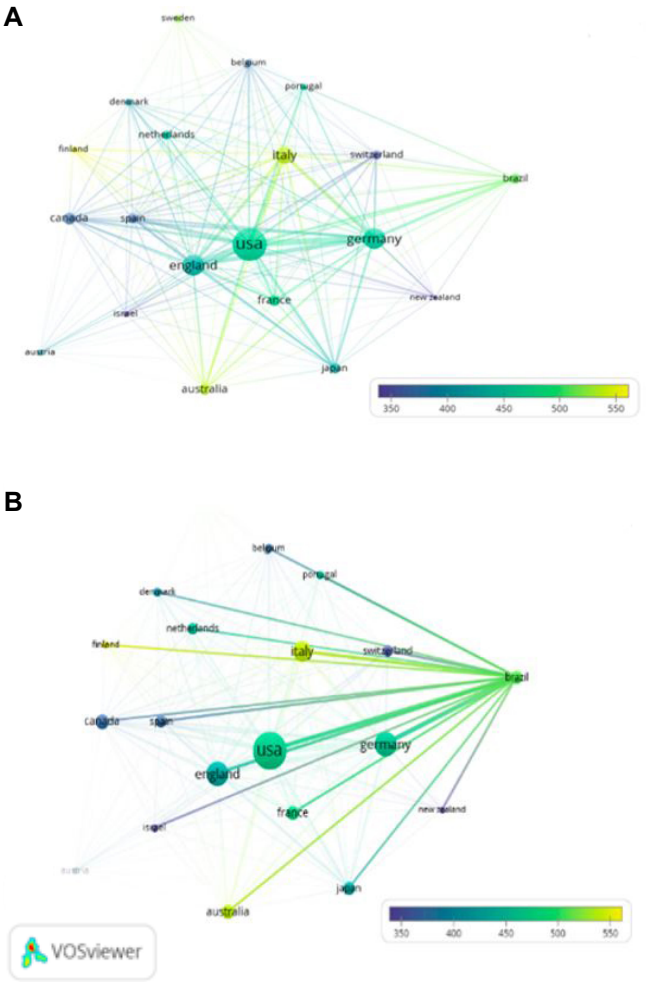

Figure 1. Relationships of the top 20 countries within scientific production relating to noninvasive neuromodulation: A) general data; B) highlighting Brazil. Data from VOSViewer© software, version 1.6.13, with Web of Science database on February 4, 2020.

Table 1. Numbers of citations of the top ten authors within the topic of noninvasive neuromodulation, in the SCOPUS database on February 4, 2020.

Authors	Number of citations (SCOPUS)
1. Fregni, F	3449
2. Pascual-Leone, A	2514
3. Brunoni, A.R.*	1887
4. Nitsche, M.A.	1620
5. Bikson, M.	1571
6. Priori, A.	1510
7. Boggio, P.S.*	1232
8. Ferrucci, R.	1170
9. Wagner, T.	1115
10. Valero-Cabre, A.	1115

Absolute numerical data obtained through the VOSViewer© software; *Brazilian researchers.

Most of the researchers were affiliated with institutions in southeastern Brazil: 21 (39.6%) in São Paulo, seven (13.2%) in

Table 2. Data on Brazilian researchers extracted from the Lattes Platform on October 22, 2019.

		n	%
Research support fellows		16	29.62
Professional category	Physiotherapist	27	50.00
	Physician	19	35.18
	Psychologist	3	5.55
	Biochemist	1	1.85
	Biologist	1	1.85
	Gerontologist/Dentist	1	1.85
	Physical educator	1	1.85
	Speaker therapist	1	1.85
Subarea	Neurofunctional physiotherapy	12	22.22
	Psychiatry	6	11.11
	Motor control	4	7.40
	Pain	4	7.40
	General neuromodulation	3	5.55
	Neurology	3	5.55
	Neuropsychology	3	5.55
	Experimental research	2	3.70
	General physiotherapy	2	3.70
	Neuropediatric physiotherapy	2	3.70
	Acupuncture	1	1.85
	Aphasia	1	1.85
	Aging	1	1.85
	Epilepsy	1	1.85
	Neurophysiology	1	1.85
	Neuroscience	1	1.85
	Parkinson disease	1	1.85
	Rehabilitation	1	1.85
	Respiratory physiotherapy	1	1.85
	Sports performance	1	1.85
Type of institution	Public federal-level	28	51.85
	Private	15	27.77
	Public state-level	11	20.37
Brazil region	Southeast	31	57.40
	Northeast	15	27.77
	South	5	9.26
	Central	3	5.55
	North	0	0.00
Proportion of the number of publications on noninvasive neuromodulation in relation to the total number of publications		1175/4129	28.45

Rio de Janeiro, two (3.8%) in Minas Gerais and one (1.9%) in Espírito Santo. There were also five (9.4%) in Rio Grande do Sul, in southern Brazil, and 15 in the northeastern region, of whom five (9.4%) were in Bahia, four (7.5%) in Pernambuco, three (5.7%) in Piauí, two (3.8%) in Paraíba and one (1.9%) in Rio Grande do Norte. Lastly, there were three researchers in the central-western region: two (3.8%) in the Federal District and one (1.9%) in Goiás. No researcher publishing on this topic was noted in the north of the country (Table 2).

Among the researchers involved with NIBS, considering the number of professionals per category, those who seem most interested in the topic were physiotherapists (27) and physicians (19). Researchers with an academic background in psychology (3), physical education (1), gerontology/dentistry

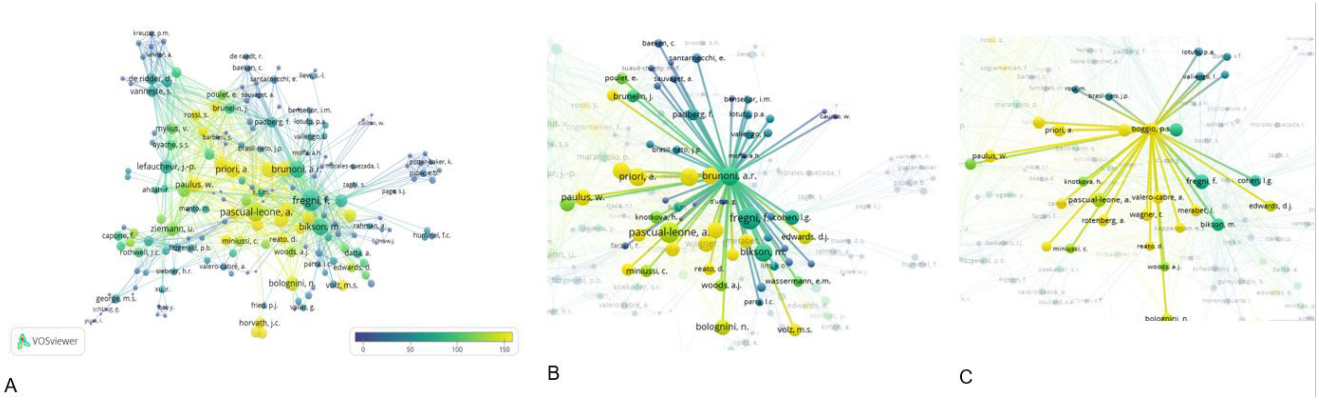

Figure 2. A) Coauthor citation relationship diagram; B) highlighting the Brazilian researcher André Brunoni; and C) highlighting the Brazilian researcher Paulo Boggio. All information was extracted using the VOSViewer© software, version 1.6.13, with the SCOPUS database, on February 4, 2020.

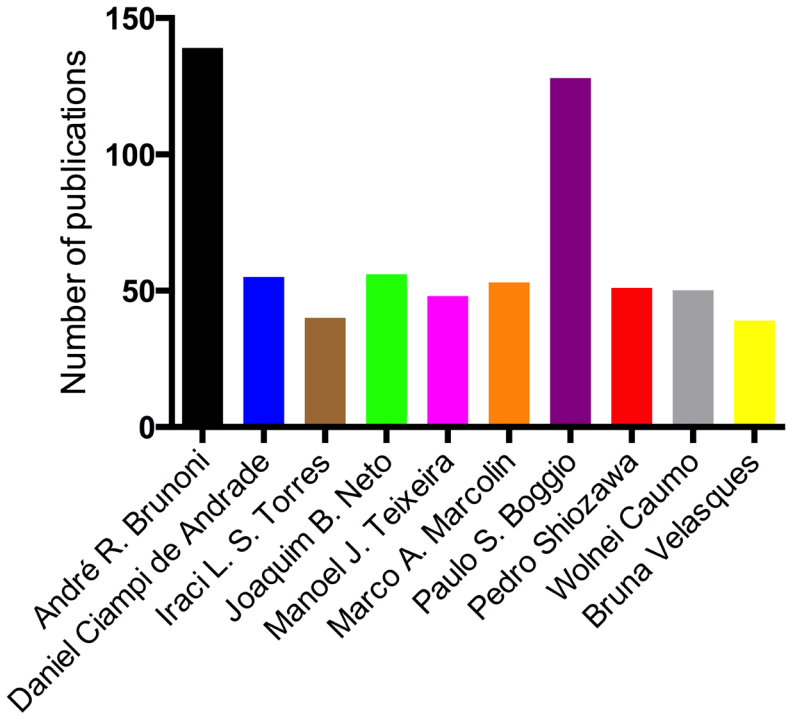

Figure 3. The top ten researchers in terms of the numbers of articles published on noninvasive neuromodulation. Data from the Lattes Platform (Brazilian national official database), on October 22, 2019.

(1), biology (1), speech therapy (1) and biochemistry (1) were also observed in this sample. Although excluded due to eligibility criteria, we also identified a registered dietitian who has also produced research on obesity, and a biomedical scientist who has produced studies on clinical NIBS. The PhD degrees of the researchers who were included in the final analysis were obtained between 1990 and 2019.

A total of 1,175 articles published specifically on the topic of NIBS were extracted from the curricula vitae of the selected Brazilian researchers. The number of peer-reviewed published articles varied among the researchers, and the topic of NIBS was not the main topic of research for many of them. The top 10 most productive Brazilian researchers published a total of 681 peer-reviewed articles on this topic (Figure 3). The median number of articles per researcher was 12 (Q25 = 6.00; Q75 = 27.50). It was observed that physicians, physiotherapists and psychologists were more prolific in relation to the topic of NIBS, but the non-normal distribution of these data showed that there was heterogeneity in the physician and psychologist categories (Figure 4).

With read to the time that had elapsed since obtaining the postgraduate degree, physicians had had the longest experience in research, with the year of completion of their PhD ranging from 1990 to 2016, followed by psychologists ranging from 2007 to 2013 and physiotherapists, who obtained their degrees most recently, from 2007 to 2019.

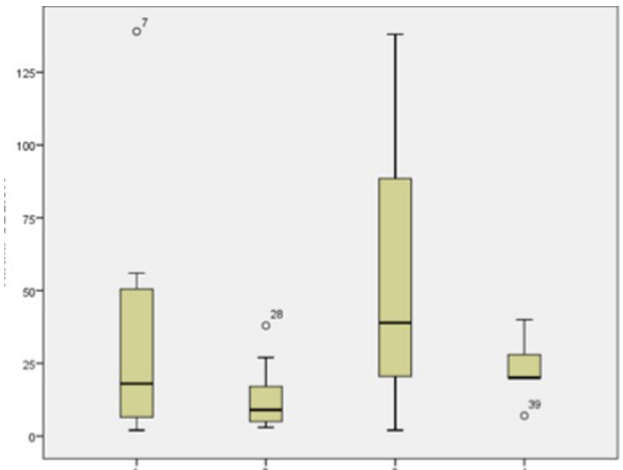

Figure 4. Numbers of publications on noninvasive neuromodulation per researcher according to research categories.

Among the methodologies adopted in the research, it was observed that Brazilian NIBS researchers were associated with peer-reviewed articles of all scientific types. These studies included experimental animal and human models for explaining mechanisms, observational studies, case series, randomized controlled trials, systematic reviews with or without meta-analyses, product and process development, computer modeling and guidelines.

DISCUSSION

This scientometric study delineated the scientific production relating to NIBS within the Brazilian scenario, and its degree of internationalization. It was possible to confirm that Brazil has a high position in this field of research. Two Brazilian researchers are among the top 10 scientists for citations worldwide, in the SCOPUS database, and five are listed in the top researcher ranking of the WoS database. The position of these authors at the center of the network diagram also denotes that there is a strong relationship in the worldwide scenario of co-authorship and citations.

From reading the curricula vitae of these five researchers, the pioneering spirit of the Brazilian researcher JBN, who defended his PhD on NIBS in 1996, needs to be recognized. Also worthy of note is FF, who supervised AB's PhD project in 2009 and occupies the top position for citations in SCOPUS, and who has collaborated with most Brazilian researchers and especially with the five ranked by SCOPUS and WoS. The presence of a Brazilian researcher at Harvard probably opens up possibilities for participation of Brazilian science within the worldwide scenario.

On the other hand, it has been demonstrated that Brazil has low capacity for talent retention, given that it was ranked 80th out of 132 nations evaluated through the 2020 Global Talent Competitiveness Index, conducted by Adecco, Insead and Google[17]. This position is antagonistic in relation to the third position in scientific production in the field of NIBS in the world. It shows that investment in this field would probably help this country to become a model in the world for NIBS research and also for its clinical use. In fact, the Brazilian experience in the clinical use of NIBS was highlighted in a 2013 publication, in which the authors cite the resolution of the Federal Council for Physical and Occupational Therapy, in which clinical use of NIBS was pioneered through giving it open-label approval for use of tDCS for treating certain clinical conditions[18].

It could be seen that Brazil has strong co-author relationships with countries such as Italy, Finland, Australia, United States, Germany and England. This illustrates the relationships between the 20 countries in which articles on NIBS have been most published. International collaboration is fundamental for contemporary science, especially in developing countries[19], and this has helped Brazil to build up its science in this field. These collaborations were probably funded mainly by national agencies, which invested in international training, visiting researchers, equipment and laboratories. Although evaluation of specific data from those funding sources was not the object of our research, future investigations in this area may help to clarify which national policies are helping to boost Brazilian research on NIBS.

From the curricula vitae of the 54 researchers who we identified, we noted that most of them are linked to institutions in the southeastern region of Brazil, followed by institutions in the northeast, central-west and south, while no researcher was found in the northern region of the country. This provides backing for the Brazilian federal government's efforts to prioritize support for research projects and *stricto sensu* postgraduate programs, with the aim of correcting regional research asymmetries[20,21]. Even so, the primacy of research centers in the southeastern region of Brazil has been maintained. This is the richest region of the country, with the largest number of universities and researchers, and the largest fundraising capacity for research.

We were surprised by the heterogeneous distribution of the number of publications on the subject of NIBS among different professionals. However, the interquartile range was very high, especially in relation to psychologists. This phenomenon can be explained by the variability in the time of obtaining the doctoral degree, the specific dedication to the topic of NIBS and the strength of international collaboration. Therefore, research productivity according to professional category should be carefully analyzed in future studies.

One of the criteria adopted for indication of NIBS relates to the professional category[22]. If NIBS is used for treating disease, physicians are the professionals who are qualified for its application. However, physiotherapists can use it for treating movement dysfunctions relating to kinetic-functional diagnoses, speech therapists for rehabilitation of speech and hearing problems, psychologists for cognitive and emotional

dysfunctions, physical educators for improving sport performance, registered dietitians for treating eating problems, and so on. NIBS is a resource for treating nervous system dysfunctions that are a subject of study in various professions. Each profession has its specific competence and field of action that is governed by its own professional council, and the guidelines of each council need to be followed. Thus, use of NIBS is very specific for each profession, but with an obvious intersection between professions, which makes it a multiprofessional field integrated by neuroscience[23].

NIBS is promising in Brazil and has given rise to a substantial number of publications in international journals regarding treatment of brain and peripheral nervous system disorders. It has been shown to be a useful resource in improving motor control and cognitive functions in children and adults with cerebral palsy, stroke, multiple sclerosis, aphasia, balance disorders, chronic pain, attention disorders, dementia, neuropathic conditions, depression, chemical dependence and epilepsy. These topics are in accordance with the recommendations of the US Academy of Sciences[24], and with Brazilian[7], and Europe guidelines[8]. The diverse profile of Brazilian researchers has been making it possible to fill different gaps regarding the use of NIBS.

Focus, dedication to this topic and international collaboration with the most productive countries have been shown to be a way to put Brazil at the top of the international rankings for NIBS science and research. It can be recommended that emerging researchers should concentrate their efforts on addressing questions within the field that are now surfacing, and not to disperse their resources in many different areas. This was one of the characteristics seen in highly productive NIBS Brazilian researchers. It also seems to be important to be connected to experienced research groups in different parts of the world, and to keep up to date on paths towards ensuring quality and scientific rigor in NIBS research[25].

Brazilians of all professional categories demonstrated good quality, transparency, integrity and diversity of scientific methods for studying NIBS, and were able to publish in internationally indexed journals despite the crisis that affects research funding. Research projects ranging from basic to applied science, use of appropriate methodology and consistent international collaboration allowed Brazilian researchers to collaborate with world-renowned researchers on NIBS studies.

Use of specific software for bibliometric analysis can be an important tool for responding to the worldwide and national panorama in several areas. In this study, we used a free Java-based program that is used primarily to analyze and view bibliometric networks. This can create maps of publications, authors or journals based on a co-citation network, or it can create keyword maps based on a co-occurrence network. However, its use gave rise to some limitations: for example, the names of less-cited researchers could not appear in the circle, to represent nodes in the network[26]. Another limitation was our use of Lattes curricula vitae for data collection, since these may be outdated, thus underestimating the results. In addition, article databases may have left out relevant publications present in other databases.

It can be concluded that NIBS is an expanding science in Brazil that already has a high level of both quantitative and qualitative production, and has high international collaboration with recognized capacity to develop research on this theme. The most productive professionals were working in the fields of medicine, psychology, physiotherapy, gerontology, speech therapy, biology and biochemistry, and there was a trend towards expansion of NIBS research to other fields.

REFERENCES

1. Zhao H, Qiao L, Fan D, Zhang S, Turel O, Li Y, et al. Modulation of brain activity with noninvasive transcranial Direct Current Stimulation (tDCS): clinical applications and safety concerns. Front Psychol. 2017 May 10;8:685. https://doi.org/10.3389/fpsyg.2017.00685
2. To WT, Ridder DD, Hart Jr J, Vanneste S. Changing Brain networks through non-invasive neuromodulation. Front Hum Neurosci. 2018 Apr 13;12:128. https://doi.org/10.3389/fnhum.2018.00128
3. Lucena MFG, Teixeira PEP, Pinto CB, Fregni F. Top 100 cited noninvasive neuromodulation clinical trials. Expert Rev Med Devices. 2019 Jun;16(6):451-66. https://doi.org/10.1080/17434440.2019.1615440
4. Brunoni AR, Vanderhasselt MA. Working memory improvement with non-invasive brain stimulation of the dorsolateral prefrontal cortex: a systematic review and meta-analysis. Brain Cogn. 2014 Apr;86:1-9. https://doi.org/10.1016/j.bandc.2014.01.008
5. He H, Lu J, Yang L, Zheng J, Gao F, Zhai Y, et al. Repetitive transcranial magnetic stimulation for treating the symptoms of schizophrenia: a PRISMA compliant meta-analysis. Clin Neurophysiol. 2017 May;128(5):716–24. https://doi.org/10.1016/j.clinph.2017.02.007
6. Mutz J, Edgcumbe DR, Brunoni AR, Fu CHY. Efficacy and acceptability of non-invasive brain stimulation for the treatment of adult unipolar and bipolar depression: a systematic review and meta-analysis of randomised sham-controlled trials. Neurosci Biobehav Rev. 2018 Sep;92:291-303. https://doi.org/10.1016/j.neubiorev.2018.05.015
7. Baptista AF, Fernandes AMBL, Sá KN, Okano AH, Brunoni AR, Lara-Solares A, et al. Latin American and Caribean consensus on non-invasive central nervous system neuromodulation for chronic pain management (LAC2-NIBS-CP). Pain Rep. 2019 Jan 9;4(1):e692. https://doi.org/10.1097/PR9.0000000000000692
8. Lefaucher J-P, Aleman A, Baeken C, Benninger DH, Brunelin J, Di Lazzaro V, et al. Evidence-based guidelines on the therapeutic use of repetitive transcranial magnetic stimulation (rTMS): an update (2014–2018). Clin Neurophysiol. 2020 Feb;131(2):474-528. https://doi.org/10.1016/j.clinph.2019.11.002
9. O'Brien AT, Bertolucci F, Torrealba-Acosta G, Huerta R, Thibaut A. Non-invasive brain stimulation for fine motor improvement after stroke: a meta-analysis. Eur J Neurol. 2018 Aug;25(8):1017–26. https://doi.org/10.1111/ene.13643
10. Ferreira IS, Costa BT, Ramos CL, Lucena P, Thibaut A, Fregni F. Searching for optimal tDCS target for motor rehabilitation. J Neuroeng Rehabil. 2019 Jul 17;16(1):90. https://doi.org/10.1186/s12984-019-0561-5
11. Gillick BT, Gordon AM, Feyma T, Krach LE, Carmel J, Rich TL, et al. Non-invasive brain stimulation in children with Unilateral Cerebral

Palsy: a protocol and risk mitgation guide. Front Pedriatr. 2018 Mar 16;6:56. https://doi.org/10.3389/fped.2018.00056

12. Waltman L, Hook D, Adie E. Reproducibility or producibility? Metrics and their masters. 23rd International Conference on Science and Technology Indicators; 2018 Sep 11; Leiden, The Netherlands: Centre for Science and Technology Studies; 2018. p. 685-7. Available from: https://openaccess.leidenuniv.nl/bitstream/handle/1887/65257/STI2018_paper_120.pdf?sequence=1
13. Moghimi M, Fathi M, Marashi A, Kamani F, Habibi G, Hirbod-Mobarakeh A, et al. A scientometric analysis of 20 years of research on breast reconstruction surgery: a guide for research design and journal selection. Arch Plast Surg. 2013 Mar 11;40(2):109-15. https://doi.org/10.5999/aps.2013.40.2.109
14. Machado-Silva A, Guindalini C, Fonseca FL, Pereira-Silva MV, Fonseca BP. Scientific and technological contributions of Latin America and Caribbean countries to the Zika virus outbreak. BMC Public Health. 2019 May 9;19(1):530. https://doi.org/10.1186/s12889-019-6842-x
15. Kanchan T, Krishan K. The leiden manifesto and research assessment. Sci Eng Ethics. 2019 Apr 15;25(2):643–44. https://doi.org/10.1007/s11948-017-0012-2
16. Tran BX, Ha GH, Vu GT, Nguyen LH, Latkin CA, Nathan K, et al. Indices of change, expectations, and popularity of biological treatments for Major Depressive Disorder between 1988 and 2017: a scientometric analysis. Int J Environ Res Public Health. 2019 Jun 26;16(13):2255. https://doi.org/10.3390/ijerph16132255
17. Bigarelli B. Brasil piora em capacidade de atrair e reter talentos [Internet]. Econômico Valor. Published 2020 Jan 23. [modified 2020 Jan 23, cited 2020 Feb 19]. Available from: https://valor.globo.com/carreira/noticia/2020/01/23/brasil-piora-em-capacidade-de-atrair-e-reter-talentos.ghtml
18. Fregni F, Nitsche MA, Loo CK, Brunoni AR, Marangolo P, Leite J, et al. Regulatory considerations for the clinical and research use of transcranial Direct Current Stimulation (tDCS): review and recommendations from an expert panel. Clin Res Regul Aff. 2015 Mar 1;32(1):22-35. https://doi.org/10.3109/10601333.2015.980944
19. Adams J. The fourth age of research. Nature. 2013 May 30;497:557-60. https://doi.org/10.1038/497557a
20. Nez ED, Franco MEDP. Geopolítica do conhecimento da pós-graduação brasileira. In: Gianezini K, Lauxen SL, Volpato G, Franco MEDP organizers. Educação superior: políticas públicas e instituições em perspectiva. Florianópolis: Dois por Quatro; 2018. p. 33-48.
21. Mazzetti AC. Internacionalização dos programas de pós-graduação com foco em desenvolvimento regional: intenções, contradições e assimetrias [Dissertação de Mestrado]. [Pato Branco (PR)]: Universidade Tecnológica Federal do Paraná; 2018. 167p.
22. Christen M, Müller S. Editorial: the clinical and ethical practice of neuromodulation – deep brain stimulation and beyond. Front Integr Neurosci. 2017 Nov 9;11:32. https://doi.org/10.3389/fnint.2017.00032
23. Kreitmair KV. Dimensions of ethical direct-to-consumer neurotechnologies. AJOB Neuroscience. 2019 Oct-Dec;10(4):152-66. https://doi.org/10.1080/21507740.2019.1665120
24. Forum on Neuroscience and Nervous System Disorders; Board on Health Sciences Policy; Institute of Medicine; The National Academies of Sciences, Engineering, and Medicine. Non-Invasive Neuromodulation of the Central Nervous System: Opportunities and Challenges: Workshop Summary. Washington (DC): National Academies Press (US); 2015. 120 p.
25. Findler F, Schönherr N, Lozano R, Reider D, Martinuzzi A. The impacts of higher education institutions on sustainable development: a review and conceptualization. Int J Sust Higher Ed. 2019;20(1):23-38. https://doi.org/10.1108/IJSHE-07-2017-0114
26. Perianes-Rodriguez A, Waltman L, van Eck NJ. Constructing bibliometric networks: a comparison between full and fractional counting. J Informetr. 2016 Nov;10(4):1178-95. https://doi.org/10.1016/j.joi.2016.10.006