

Bibliometric analysis of Neurosciences research productivity in Saudi Arabia from 2013-2018

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ABSTRACT

الأهداف: تم إجراء هذه الدراسة لمراجعة ديناميكية أبحاث علم الأعصاب في المملكة العربية السعودية من 2013م إلى 2018م.

المنهجية: البحث في قاعدتي سكوبس وسايغال عن دراسات متعلقة بأقسام مختلفة من علم الأعصاب، مقتصرًا على المملكة وقد اجري هذا البحث في جامعة الإمام عبد الرحمن بن فيصل في الدمام في يناير 2019م.

النتائج: احتلت المملكة المرتبة 39 عالمياً في نشر أبحاث علم الأعصاب، وازدادت أعداد المقالات العلمية المنشورة من 123 إلى 332 مقالاً في هذا المجال خلال الفترة من 2013م إلى 2018م. ساهم في هذه الزيادة بشكل رئيسي كلا من جامعتي الملك سعود والملك عبد العزيز. كما أن المنطقة الوسطى والغربية من المملكة (حيث تنتمي الجامعتين) تنتج معظم الأبحاث. وأظهرت الدراسة أن علماء الأعصاب في المملكة يتعاونون مع علماء آخرين من جميع أنحاء العالم. بالإضافة إلى ما سبق، تعد أكثر من 10 مجلات علمية مفضلة من قبل الباحثين لنشر أبحاثهم مجلات عالمية. وأخيراً، تبين أنه من ضمن الفئات الفرعية لعلم الأعصاب فإن علم النمو العصبي يحتاج للمزيد من الاهتمام والدراسة.

الخلاصة: تشهد أبحاث علم الأعصاب ارتفاعاً في المملكة. اتخذت المؤسسات القديمة والراسخة مثل جامعة الملك سعود وجامعة الملك العزيز زمام المبادرة في نشر البحوث العلمية العصبية. وأظهرت الدراسات تعاون دولي جوهري في جميع المجالات الفرعية لعلم الأعصاب. تتطلب المناطق الجنوبية، الشمالية والشرقية بالإضافة لعلم النمو العصبي مزيداً من التركيز والتمويل.

Objectives: To review the dynamics of neuroscience research in the Kingdom of Saudi Arabia (KSA) from 2013-2018.

Methods: Subject category of Neuroscience was selected in the SciVal feature of Scopus database, which includes all relevant categories of the field limiting it to Saudi Arabia.

Results: Saudi Arabia is ranked 39th in publishing neuroscientific research worldwide. The number of

yearly published articles has increased from 123 to 332 during the time period between 2013 and 2018. King Saud University & King Abdul Aziz University & their corresponding regions namely Western and Central regions are the major contributors to publications. Neuroscientists working in Saudi Arabia have collaboration with scientists from all over the world. The top 10 preferred journals are all international. In subcategories of neuroscience, developmental neuroscience seems the one that needs attention.

Conclusion: Neuroscience research is on the rise in KSA. Older and well-established institutions like King Saud University & King Abdul Aziz University have taken lead in publishing neuroscientific research. International collaboration in all subfields of neuroscience is substantial. Eastern Southern and Northern regions and developmental neuroscience require more focus and funding.

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Education and research are the cornerstones that form the basis of sustainable growth in a country. Concepts such as knowledge-based economy and bioeconomy have become popular in the 21st century.¹ University-industry collaborations and protection

of intellectual property rights have given a boost to scientific research and development.² The progress in scientific research requires periodic review. Reviewing existing government policies allows for more flexibility in the adaptation to ever-varying economic and developmental conditions.³ Health and medical research are among the pillars of the scientific advancement of a country, given the challenges of global healthcare. Of all the subfields of medical research, neuroscience research is the most interesting and challenging one.⁴ The term neuroscience encompasses research in the fields of clinical specialties such as neurology, neurosurgery, neuropsychiatry, and psychology as well as non-clinical disciplines such as neurobiology and neurochemistry. It also includes non-medical fields, including biomedical imaging, physics, computer science, and artificial intelligence. Hence, the field of neuroscience is of great significance to the public health as well as a technical advancement perspective.⁵

The Kingdom of Saudi Arabia (KSA) is transitioning to self-sufficiency and knowledge-based economy by 2030. With one of the largest economies of the world, the KSA is giving high priority to the health and education sectors. Saudi universities have already achieved higher international rankings among educational institutions.⁶ Eight Saudi universities have been included in Quacquarelli Symonds' (QS) 2019 world ranking.

Bibliometric assessment is a method used to examine published scientific research contributed by individuals, institutions, and countries.^{7,8} It also examines the collaboration between scientists across borders. Additionally, bibliometric studies take into account the indicators of quantity, as well as quality, of research of a country or field in a given period. Further, this method of assessment can be used to review the results of the implementation of a certain change in policy in a given time frame.⁹ Bibliometric assessment may also be used to extract data regarding a specific subfield or an individual database or journal. These techniques can then be utilized to examine the dynamics of international collaboration, prevailing trends in research, the most productive authors and institutions, journals of preference, and authorship and collaboration patterns. Such studies can be used to direct future guidelines for researchers, academic institutions,

policymakers, and their funding organizations.

An action plan established by the World Health Organization indicated that there is a worldwide increase in neurological and mental disorders, causing a global burden and leading individuals and families into poverty. One of the action plan's objectives is to direct efforts towards strengthening research and healthcare in the fields of neuroscience.¹⁰ Neuroscience research will allow the generation of new knowledge that will enable the prevention of diseases, reduction of the cost of treatment, and finding new therapeutics, thus opening the way for new possibilities in this field. A bibliometric study of neuroscience productivity worldwide has documented a rapid growth of published research during the last 30 years.¹¹ Aware of the importance of neuroscience, researchers from around the world and in the Middle East are conducting bibliometric studies on this topic to provide a solid foundation for policymaking and strategy planning in the society's neuroscientific research.

The KSA is leading the Arab world in many of the parameters of education and healthcare research.¹² Previous bibliometric analyses carried out in a variety of fields have yielded valuable data. For example, one such bibliometric analysis measured computer science research publications carried out between 1978-2012 and found out that King Fahad University of Petroleum and Minerals (KFUPM) and King Saud University (KSU) were the most active institutions contributing 70% of all publications.¹³ Another similar study examined research publications during and after an outbreak of Middle East respiratory syndrome coronavirus (MERS-CoV) in the KSA during 2013-2014.¹⁴ Yet another bibliometric study¹⁵ presented useful findings regarding research collaboration and publication patterns of Egyptian health scientists.

Trends in neuroscience research have been reviewed as a subject of bibliometric analysis in different parts of the world under different keywords, including mental health research, stroke, and epilepsy. Moreover, neuroscience was included in the evaluation studies of biomedical research in the KSA.^{16,17} One such study covering clinical neuroscience ranked the KSA 40th in the world and 4th in the Middle East, highlighting a certain dearth of physician-scientists.¹⁸ Another study focusing on neurology lauded important achievements in published research in this field in Saudi Arabia and also highlighted gaps in the quality of research.¹⁹

Previous studies are restricted in their scope^{20,21} or domain²² and are limited to a city or an institution²³ in addition to the terms of consulted databases. In

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contrast, present study was conducted using the most comprehensive database of global literature, Scopus, including all the basic and clinical aspects of neuroscientific research carried out in the KSA from 2013 to 2018. The main objectives of this study were to examine the publishing trends of Saudi neuroscience researchers, the most productive and frequently cited authors, institutes and journals, and authorship and

collaborative patterns. We also examined subject dispersion under the umbrella term of neuroscience.

Methods. This bibliometric analysis was carried out on the research productivity in the field of Neuroscience conducted by scientists working in or affiliated with institutions in the KSA, including Saudi nationals as well as expatriates. A bibliometric study involves cross

Table 1 - Number of Neuroscience articles produced by Saudi Arabia affiliated researchers compared with top 10 countries in this category during 2013-2018.

Rank	Country	2013	2014	2015	2016	2017	2018	Total
1	United States	23483	25195	25096	25520	26179	27582	153055
2	China	5606	6049	6854	8368	8648	10664	46189
3	United Kingdom	6558	6814	7114	7222	7531	8106	43345
4	Germany	6115	6449	6370	6882	6869	7220	39905
5	Canada	4109	4349	4434	4374	4625	5052	26943
6	Italy	3702	3762	3913	3940	4060	4367	23744
7	Japan	3541	3579	3662	3448	3569	3928	21767
8	Australia	2870	3189	3223	3483	3568	3910	20243
9	France	3107	3114	3271	3225	3557	3578	19852
10	Netherlands	2397	2627	2584	2580	2678	2999	15865
39	Saudi Arabia	123	272	265	262	310	332	1564

Table 2 - Research productivity in neuroscience by institutions in Saudi Arabia during 2013-2018.

Rank	Institutions	Publications (%)	Region	Citations	Authors	Citations Impact
1	King Abdulaziz University	571 (36.43)	Western	8461	347	14.8
2	King Saud University	380 (24.29)	Central	3252	523	8.5
3	King Abdullah University of Science and Technology	101 (6.44)	Western	138	134	13.7
4	Alfaisal University	99 (6.31)	Central	1676	144	16.9
5	Imam Abdulrahman Bin Faisal University	69 (4.40)	Eastern	219	67	3.2
6	King Saud bin Abdulaziz University for Health Sciences	67 (4.27)	Central	301	103	4.5
7	King Khalid University	43 (2.74)	Southern	276	55	6.4
8	Taibah University	29 (1.85)	Western	199	35	6.9
9	Umm Al Qura University	21 (1.34)	Western	93	34	4.4
10	King Faisal University	20 (1.27)	Eastern	144	28	7.2
11	Jazan University	19 (1.21)	Southern	232	35	12.2
12	King Abdulaziz City for Science and Technology	15 (0.95)	Central	71	22	4.7
13	University of Hail	15 (0.95)	Central	69	14	4.6
14	King Fahd University of Petroleum and Minerals	14 (0.89)	Eastern	129	19	9.2
15	Qassim University	13 (0.82)	Central	44	20	3.4
16	Taif University	13 (0.82)	Western	13	22	1
17	Prince Sattam Bin Abdulaziz University	13 (0.82)	Central	21	13	1.6
18	Al-Imam Muhammad Ibn Saud Islamic University	7 (0.44)	Central	21	7	3
19	Princess Nourahbint Abdulrahman University	7 (0.44)	Central	15	7	2.1
20	Najran University	7 (0.44)	Southern	44	11	6.3
21	University of Jeddah	6 (0.38)	Western	17	3	2.8
22	Al Baha University	4 (0.25)	Southern	0	5	0
23	Al Jouf University	2 (0.12)	Northern	3	3	1.5
24	Northern Borders University	1 (0.06)	Northern	10	1	10

sectional research design that focuses on data in a given time period that is harvested on a single point of time. The SciVal feature of the Scopus database was used at Imam Abdulrahman Bin Faisal University (IAU), Dammam Saudi Arabia from January 10, 2019, to May 30, 2019. Scopus is the largest abstract and citation database of peer-reviewed literature. The sample size under study was data generated during a period of 6 years, from January 2013 to December 2018. Targeted data were exported on January 10, 2019; thus, the database was last updated on December 14, 2018. The methodology used for data retrieval from SciVal is as follows. In the main browsing menu of SciVal, we selected the country, i.e. Saudi Arabia. We selected the Subject Area "Neuroscience" which covers its subcategories such as General Neuroscience, Behavioral Neuroscience, Biological Psychiatry, Cellular and Molecular Neuroscience, Cognitive Neuroscience, Developmental Neuroscience, Endocrine, and Autonomic Systems, Neurology, Neuroscience (miscellaneous) and Sensory Systems.

All publication categories, including journal articles, book chapters, books, and conference papers were included in the analysis. Publications performed by at least one author with affiliation to a Saudi Arabian research institution were selected. Neuroscience related publications by Saudi affiliated researchers that were published before January 1, 2013 or after December 31, 2018 were excluded. The results were exported into Microsoft Excel format. The accuracy of the data,

including duplication (3 duplicate records were removed), reliability, and relevance, was ensured by the repetition of the same method by another author using the same parameters. This study did not require ethical approval as the targeted data is publicly accessible in Scopus database and there is no human subject involved.

Results. Saudi Arabian affiliated authors produced 118,663 documents during 2013-2018, with an average of 19,777 documents per year and an average annual growth rate of 6.88%/yr. These documents were divided into 27 broad categories/subjects. The highest numbers of documents were found in the Engineering Sciences (n=24,082; 20.29%) followed by Medicine (n=22,940; 19.33%) and Chemistry (n=18,479; 15.57%). The lowest number of publications (n=664; 0.55%) were on the subject of Veterinary Science. The subject of Neuroscience research is ranked 20th with 1564 (1.32%) publications.

The six-year comparison of neuroscience research productivity of KSA showed a gradual increase. Additionally, the KSA ranked 39th in global neuroscience publications output (Table 1).

The SciVal feature of the Scopus database identified 24 Saudi Arabian institutions that produced neuroscience related research in the specified period (Table 2). King Abdulaziz University (KAU) was the most productive institution, with 571 (36.4%) documents produced by 347 authors. These publications received 8461 citations with an average of 14.8 citations per document. The

Table 3 - Top 15 most productive neuroscience authors affiliated with Kingdom of Saudi Arabia during 2013-2018.

Ranks	Name of Author	Affiliation	Publications	Total Citations	Citation Impact
1.	Kamal, Mohammad Amjad	King Abdulaziz University	78	683	8.8
2.	Alsaadi, Fuad Eid S.	King Abdulaziz University	65	1123	17.3
3.	Al- Ayadhi, LailaYousef	King Saud University Medical College	36	424	11.8
4.	Liu, Yurong	King Abdulaziz University	32	819	25.6
5.	Alsaedi, Ahmed	King Abdulaziz University	31	300	9.7
6.	Ashraf, GhulamMd	King Abdulaziz University	22	156	7.1
7.	Abuzenadah, Adel Mohammed	King Abdulaziz University	19	203	10.7
8.	Attia, Sabry Mohamed	King Saud University College of Pharmacy,	19	133	7
9.	Bakheet, SalehAbdulrahman I.	King Saud University College of Pharmacy,	19	133	7
10.	El-Ansary, Afaf Kamal E.	King Saud University	19	179	9.4
11.	Nadeem, Ahmed	King Saud University College of Pharmacy,	19	133	7
12.	Al-Qahtani, Mohammed Hussain	King Abdulaziz University	17	100	5.9
13.	Bashir, Shahid	King Fahad Specialist Hospital, Dammam,	17	95	5.6
14.	Fayaz Ahmad, Sheikh	King Saud University College of Pharmacy,	17	132	7.8
15.	Bahammam, Ahmed Salem O.	King Saud University Medical College	16	264	16.5

KSU was the next most productive institution with 380 (24.3%) documents contributed by 523 authors. The citation impact of KSU was relatively low (8.5 citations per document). King Abdullah University of Science and Technology was the third most productive institution 101 (6.44%) while Alfaisal University was the 4th most productive institution with 134 authors producing 99 (6.3%) documents that received the highest citations

impact (16.9 citations per document). These are only three institutions that exceeded 100 publications. Three institutions, including Alfaisal University, produced 50 to 100 publications on the subject of neuroscience while eighteen institutions produced less than 50 publications (Table 2).

The region-wise analysis indicated that among the five regions of KSA, researchers affiliated with the

Table 4 - Twenty most frequently collaborative countries with Kingdom of Saudi Arabia in the field of neuroscience during 2013-2018.

Rank	Country	Co-authored publications	Citations	Citations per Publication	Institutions
1	United States	190	1872	9.8	160
2	China	166	3546	21.4	83
3	United Kingdom	88	1623	18.4	64
4	Canada	85	865	10.2	18
5	Egypt	68	467	6.9	25
6	India	58	857	14.7	34
7	Switzerland	49	1056	21.6	10
8	Pakistan	46	561	12.2	13
9	Australia	41	676	16.5	41
10	Germany	41	652	15.9	45
11	Italy	29	369	12.7	33
12	Japan	28	457	16.32	34
13	Sweden	27	432	16	10
14	France	18	415	23.1	41
15	Malaysia	18	111	6.2	13
16	Russian Federation	18	249	13.8	12
17	Spain	18	385	21.4	21
18	Jordan	17	178	10.5	3
19	Netherlands	17	373	21.9	15
20	South Korea	17	204	12	15

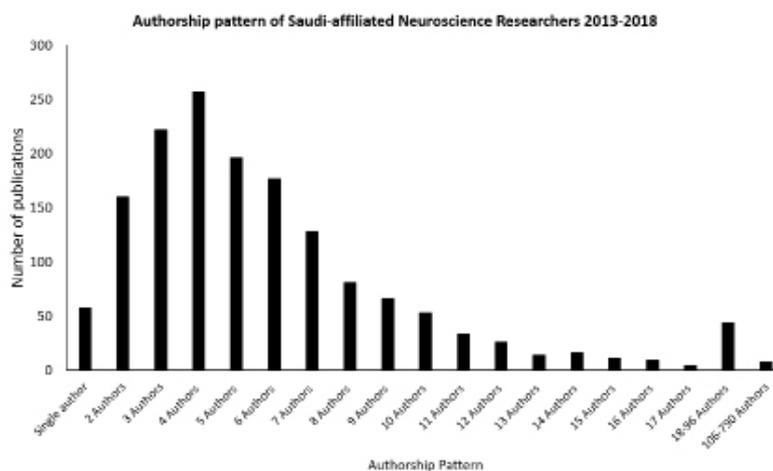


Figure 1 - Authorship patterns of Neuroscience researchers affiliated with Saudi Arabian institutions documented from January 2013 to December 2018. Four-authors pattern was found to be the most frequent one, while 2-10 authors constituted 85% of the publication during this time.

Table 5 -Ten most preferred Journals of Neuroscience researchers affiliated with Saudi Arabia during 2013-2018.

Sr#	Source Title	Publications	Country	Total Citation	Citation Impact	Cite Score	Quartile
1	Neurocomputing	192	Netherlands	3198	16.29	1.07	Q1
2	CNS & Neurological Disorders-Drug Targets	86	Netherlands	711	8.26	0.86	Q3
3	Neural Network	47	United Kingdom	1666	35.44	2.36	Q1
4	PeerJ	35	United Kingdom	58	3.22	1.09	Q2
5	British Journal of Ophthalmology	32	United Kingdom	187	5.84	2.17	Q1
6	Canadian Journal of Neurological Sciences	26	United Kingdom	68	2.61	0.55	Q3
7	Investigative Ophthalmology and Visual Science	25	United States	186	7.44	2.06	Q1
8	Metabolic Brain Disease	22	United States	124	5.63	0.91	Q2
9	Molecular Neurobiology	21	United States	93	4.42	1.61	Q1
10	Neuropsychiatric Disease and Treatment	20	New Zealand	164	8.2	0.91	Q2

institutions located in the Western region produced the majority of the neuroscience research (47.3%) followed by the Central (39.4%) and Eastern regions (6.6%). Seventy-three publications were contributed by the researchers affiliated with the Southern region (4.6%) and only three publications were produced by the researchers of the Northern region (0.2%).

Five hundred and twelve authors contributed 1,564 publications in the targeted period and the most productive authors in the research field of neuroscience in KSA are reported in Table 3. Of the 15 most productive authors, seven authors are affiliated with KAU and another seven to KSU, and one was affiliated with King Fahad Specialist Hospital, Dammam. The author Kamal, Mohammad Amjad of KAU was the most productive, with 78 publications and an 8.8 citation impact, followed by Alsaadi, Fuad Eid S. of KAU with 65 publications, followed by Laila Youseff Al-Ayadhi of KSU with 36 publications. Five authors contributed 19 publications each and 239 others contributed 2 articles each. Ninety-three authors contributed three articles each, and 43 authors contributed four articles each.

The researchers affiliated with the KSA collaborated with scientists from 109 other countries. The majority of publications (12.3%) were co-authored with researchers from institutions in the United States of America, followed by 10.6% publications with authors in China, the United Kingdom (5.61%), and Canada (5.42%). Our analysis indicates that almost one-third of collaborating countries produced more than three-fourths of the total publications, while less than quarter publications produced in collaboration with two-third of all collaborating countries. A large number of publications (78.6%) are noted to be produced in collaboration with 35 countries (32.11%) of the world (with at least 10 publications per country). There were 74

countries (67.9%) with <10 joint publications (Table 4).

Figure 1 displays the authorship pattern of 1,564 publications in neuroscience from 2013-2018. The majority of publications (96%) are the product of collaborative research, whereas only 58 (3.7%) publications were authored by single authors. A four-author pattern was found to be the most frequent co-authorship fashion with 257 (16.4%) publications, followed by three-author pattern accounting for 222 (14.2%) publications and five-author pattern resulting in 196 (12.53%) publications. Authorship patterns from 2 to 10 co-authors produced 1,340 (85.2%) publications, while more than 10 co-authors pattern created 166 (10.61%) publications. There are eight publications with more than 100 co-authors.

The impact of a given publication can also be evaluated by the number of citations it has received. Thirteen publications included in the study received >100 citations. There are 356 (22.7%) publications without any citation, while 175 (11.7%) publications have received only one citation. Majority of publications (n=609; 38.93%) received 2 to 10 citations.

The top 10 sources of publication are all international research journals. A total of 1564 publications on neuroscience were published in 326 source publications/journals. "Neurocomputing" journal of The Netherlands published the highest number of documents (192, 12%) by Saudi Arabian authors, followed by "CNS and Neurological Disorders-Drug Targets" with 86 documents (5.5%) and "Neural Network" with 47 documents (3.1%). There are 133 journals with one publication each and 49 journals with two publications each (Table 5).

All publications of neuroscience were then further divided into ten subcategories determined by Scopus.

The highest number of publications (n=437; 27.88%) deals with the subcategory of General Neuroscience, followed by Neurology (n=368) and Cognitive Neuroscience (n=346). The highest number of citations (n=6303) were given to Cognitive Neuroscience with 18.2 citations per publication. The lowest number of citations (n=190) were received by Neuroscience (miscellaneous).

Discussion. The main objective of this study was to examine the publishing trends of Saudi neuroscience research, including the most productive and highly cited authors, institutes and journals, authorship, and collaboration patterns. We also undertook the subject dispersion under the umbrella term of neuroscience. We focused on the bibliometric analysis of the productivity of neuroscience research in KSA, covering the period from January 2013 to December 2018. For this period of time, the research in the field of neuroscience as a subject category has not been bibliometrically reviewed in KSA previously. Our results have generated significant and new findings regarding the bibliometric dynamics of neuroscience research in the KSA. The results can be used to guide research policy and targets specified in vision 2030.

Our results include a total of 1,564 publications in the neuroscience research during the period under review, with a linear increase in publication output within the KSA over the past 6 years (Table 1). This increase is in line with the overall increase in the visibility and QS ranking of Saudi universities in recent times⁶ as well as in line with the overall increase in published research in the field of neuroscience in Arab world²⁴ and worldwide,²⁵ namely Turkey²⁶ India,²⁷ China,²⁸ Pakistan,²⁹ Africa,³⁰ and Latin America.³¹ The subject of neuroscience ranks 20th when compared to other subject categories in the Saudi context. When compared globally, Saudi Arabia ranks 39th in neuroscience research productivity. This raises alarm as no Saudi author was included in top 10 in the categories of “most productive”, “most cited” or “most cited from Muslim countries” in a bibliometric review of global Muslim Mental health research productivity during 2000-2015.³² One major factor that contributes to the relatively low rank of Saudi Arabia compared to other countries is the modest government expenditure on higher education research when compared to the research expenditure of other first world countries. Saudi Arabia spends only about 0.3% of the gross national product on research.³³ The relatively low productivity may also be attributed to absence of a specialized center of excellence for neuroscience research in the KSA. For comparison,

over 1/3rd of total budget of the University College of London (UCL) is accounted for neuroscience program that considers it a strategic priority.³⁴

A comparison with the Arab world is imperative in order to understand the research progress in KSA. The review by Elie G. Karam²⁴ in 2015 revealed that KSA produced highest number of research publications in the Arab world during 1996-2005 period while it fell to 5th place in the same category during 2006-2015. The analysis also showed that in mental health research articles per year per million population, the leading countries are Kuwait, Bahrain and Lebanon while KSA stood at 10th position. After adjusting this parameter for gross domestic product per capita, Egypt, Jordan and Tunisia are the ones on top while KSA stands at 7th position. Other possible reasons may be a dearth of faculty members, postgraduate research programs, international students, low faculty to student ratio, and poor quality of mentorship. Few specialized labs and funding opportunities are available, which may also be a contributing factor. Although institutional requirements of research and innovation as obligations for job promotion may have increased productivity to some extent, a genuine difference can only be made by a change in policy regarding the prioritization of research areas.¹⁹ Given that research in the field of neuroscience not only improves the quality of life for those with a diagnosis of a neurological disorder but also facilitates progress in many other disciplines, such as engineering and artificial intelligence, it is imperative that this area of research be prioritized.

A comparison with advancements in neuroscience research in Africa also bears significance. In Africa,³⁰ there is a positive correlation between GDP per capita and neuroscience research, while this doesn't apply to KSA. In addition, it is important to mention the Nigerian model. Nigeria, Africa's most populous country, has become a hub of neuroscientific research in the continent, following South Africa and Egypt. Bibliometric studies have cited annual increase in number of publications in Africa in general^{30,35} and in Nigeria in particular.³⁶ The distinguishing features of neuroscientific progress in Nigeria are the involvement of neuroscience research promoters like International Brain Research Organization (IBRO), The World Academy of Sciences, The International Society for Neurochemistry, Teaching and Research in Natural Sciences for Development in Africa and Seeding labs.³⁷ With the establishment of the Neuroscience Society of Nigeria and the introduction of Tertiary Education Trust Fund, the rich medicinal flora of the country seems ready to embrace the world challenges in 21st

century. The impact of these policies remains a highlight of the last 2 decades and presents an inspiration for development of neuroscience as a field of research.

Establishing an organization for Saudi neuroscience research and specialized centers for neuroscience research may provide research grants, hold annual conferences, training programs, and encourage and reward innovation. It would enable the more remote research centers, along with junior researchers, to collaborate with active investigators in the field, to receive technical support, and extend their collaborative network. Furthermore, the unification of resources, coordination initiatives, and facilitation of quality communication among research centers would prove advantageous to all neuroscience researchers. Establishing such a specialized neuroscience research center of excellence, with a dynamic environment, high-quality staff, specialized postgraduate programs, focused efforts, and a vision to develop neuroscience research, would greatly improve the current state of research in this category.

King Abdulaziz University and King Saud University, located in the western and central regions of KSA, respectively, were among the highest producers (Table 2). These universities were established in the year 1967 and 1957, respectively. Older institutions attract international faculty members and students given the well-established research culture and overall reputation. In contrast to Western and Central regions, institutions from the rest of Saudi Arabia, specifically the Eastern, Southern, and Northern regions, were less productive (Table 2). The national policymakers need to give these regions and the institutions therein special attention, incentives, and funding to raise their level of research productivity.

The ease of international communication in the 21st century facilitates collaboration across borders. Estimating the current state of networking and collaboration across disciplines and institutions may be a way of quantifying the research productivity of academia. Another metric that could prove useful in this regard is the number of authors who participate in a given publication. More than 80% of the publications included in this study listed 2-7 authors with faculty members from the USA, China, and the UK as the top contributors to Saudi researchers' collaborative ventures in terms of the number of publications. However, our results indicate that collaborations with France, Spain, and the Netherlands received better citation impact, whereas joint publications with Egypt and Malaysia have generated the lowest citation impact (Table 5). These statistics may help to focus on more productive collaborations in the future.

A given author's choice of target journal varies according to the journal scope, acceptance rate, processing and publication fees, and the impact factor. Observation of the pattern of the type of journals in which the majority of Saudi neuroscience researchers have published can be used to indicate the focus of most of their research. Top journals publishing Saudi neuroscience research include journals such as *Neurocomputing*, *CNS and Neurological Disorder-Drug Target*, and *Neural Network*. This implies that computational neuroscience, as well as patent-oriented research, are priorities. The concept of a university-industry linkage and knowledge-based economy is based on the same idea: that academia should take a practical approach in research. Surprisingly, none of the Saudi journals were among the top 10 sources of publication identified in our study, which highlights the need to improve local journals so that they become more desirable to authors.

As for the subject categorization of subfields of neuroscience, cognitive and general neuroscience remain the most frequently published fields. However, the field of developmental neuroscience remains one with comparatively fewer publications. Genetic and developmental disorders remain a high priority worldwide. For example, autism is listed as the top-cited term worldwide.³⁸ While this area is indeed a priority in KSA,³⁹ developmental neuroscience as a subfield still requires an increase in attention and focus.

Comparing the top institutions of Saudi Arabia to IAU, the current authors' institution, yields encouraging statistics. The IAU contributed 4.4% of the total publications recorded in the reviewed period compared to Alfaisal University, with a contribution of 6.31%, which has an appreciably higher number of faculty members.

Neuroscience in 21st century has emerged as an indicator of scientific growth and social development because of its wide application and potential for future industrial and scientific growth.³⁸ The new initiative and vision launched by the ministry of education in 2017 to motivate institutions to publish high-quality research is an excellent first step in striving to improve the status of biomedical research in KSA.⁴⁰ Supportive leadership with a visionary approach that will encourage quality of research and publication impact in addition to focusing on quantity is highly important.³⁰ Further, institutions should be encouraged to place an emphasis on the publication impact (i.e. quality) rather than merely the quantity of publications.³⁸

Currently, most of the research programs that focus on neuroscience at postgraduate levels are clinically

oriented and tend to focus on clinical training instead of research. Therefore, courses on research methodology should be included within medical and applied medical science curriculum to expose the students to a research environment early in their career. Undergraduate students should be encouraged to participate in research projects and be provided with opportunities to facilitate experience and confidence. To achieve that, emphasizing applied research skills for students enrolled in undergraduate programs, especially the professional ones including Bachelor of Medicine, Dentistry, and Veterinary Sciences should prove beneficial.

Should the implementation of such a program occur, the consideration of factors that can negatively influence research output must be given high priority. Some potentially detrimental factors include lack of funding and support and lack of proper access to the available resources. Moreover, monitoring of other factors that influence the progress of research such as smooth regulations and policies to biological samples ordering, reduction of the time gap for release of funds as well as delivery of scientific equipment, will further enhance research productivity.

The responsibility of young scientists and senior academics is to transfer the acquired knowledge and creative ideas to implement new research mindset, follow research ethics, implement flexible and research-friendly guidelines, provide healthy motivating work environment, increased investment in capacity building and as a result, construct a devoted, valued, passionate workforce.

Our findings can be used to guide a research policy for neuroscience. By highlighting collaboration and publication patterns, identifying regions and sub-categories that need attention and support, we have made it easy for the policymakers to set their priorities right.

Limitations of Study and Future Research Directions. The study is limited to the publications indexed in SciVal feature of Scopus on the subject area of Neuroscience and authors affiliated with KSA published from January 1, 2013 to December 31, 2018. It was beyond the scope of our study to ascertain whether the included research was carried out in KSA or not. Moreover this is purely a quantitative study, and citation analysis and quality of publication of the included research were not analyzed. Saudi researchers working outside KSA but with no current affiliation inside the Kingdom may have been omitted. Other databases like Web of Science, PubMed, and Google Scholar may have some other records which were not included. Future research

with broader criteria of inclusion encompassing wider period of research and including citation analysis of the research can help analyze remaining bibliometric aspects of neuroscientific research in KSA.

Conclusion. This study successfully documents patterns and growth of neuroscience research in the KSA that has not been documented earlier. A steady increase has been observed in the number of publications. Substantial regional and international collaboration is noted. Most productive institutions and authors are based in the central and western regions. We have made concrete suggestions for future policymaking regarding a need to focus on developmental neuroscience. Centers of excellence are needed to boost research in this area. Eastern, Southern, and Northern regions need support in terms of research strategy and uplifting of existing labs. Given the modest growth of research in the field Neuroscience, comparing productivity in the KSA with the global neuroscience community sheds light on the necessity for continued assessment of progress in this area.

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