Expedited Original Article

Biomedical research in the Kingdom of Saudi Arabia (1982-2000)

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ABSTRACT

Objective: Because of the leading position of the Kingdom of Saudi Arabia in biomedical research among the Arab States, we aimed this study at providing a detailed analysis of the development of this domain in the Kingdom.

Methods: More than 1500 queries were mainly directed to the PubMed bibliographic database. Tags, boolean operators, and wild cards were utilized.

Results: Most of the Saudi biomedical citations originated from the capital city of Riyadh (70%), particularly from the King Saud University (29.5%) and King Faisal Specialist Hospital (21.5%). One of every 5 Saudi papers either describes a disease, a blood related analysis, or surgical observations. Only 0.5% of Saudi papers appear in the 200 highest impact-factor journals.

Conclusion: A steady advancement in biomedical research is observed in the Kingdom mainly in years 1987-1996. The absence of uniformity in writing the addresses of authors in published articles from Saudi Arabia results in misleading data about the geographical distribution of biomedical research and sometimes improper rating of the scientific institutions in the Kingdom. The most dynamic biomedical fields in the Kingdom observed in the present analysis are Hematology, Surgery, Cancer, Pharmacology, and Microbiology. The main reasons behind the small number of Saudi papers appearing in high impact-factor journals are the bias and the economics of scientific publishing. We hope that the present study will lay the foundation for more detailed investigations on the directions of biomedical research in the Kingdom and will be of great importance to better found future strategies in this important realm.

Keywords: Biomedical research, scientific publications, bioinformatics, Kingdom of Saudi Arabia.

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In the last few decades, the Kingdom of Saudi Arabia (KSA) has witnessed different developments in the fields of industry, commerce, agriculture, and others. Similarly, advancement in the fields of medicine and public health controls is very well remarked. This may be concluded from the advancing level of health care in the Kingdom, the low value of death rates (6.02 versus 9 deaths/ 1,000 individuals in world populations; July 2000 estimates), the long life expectancy (68 versus 64 years in world populations; July 2000 estimates), and the publication of several Saudi medical-related journals with international representation. The Kingdom Saudi Arabia occupies a leading position in terms of biomedical research among not only the Gulf Corporation Council countries,[1] but also when compared to the other 22 Arab States. For this reason, we aimed at a detailed analysis of the development of this type of research in KSA between the years 1966 and 2000.

Methods. The 2 main scientific bibliographic databases queried in this study were the Science Citation Index (SCI), which is a bibliographic database maintained by the Institute of Scientific Information and is available in hard copy (SCI) or digital formats (expanded-SCI) for subscribed

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institutions (http://www.isinet.com/demos/webofscience/). The 2nd was PubMed which, is a free-of-charge popular internet tool that provides access to bibliographic information, primarily drawn from MEDLINE and PreMEDLINE, as well as publisher-supplied citations. PubMed is the National Library of Medicine's (NLM) premier bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, the health care system, and the preclinical sciences. PubMed contains bibliographic citations and author abstracts from more than 4,000 biomedical journals published in 71 countries. The database contains over 10 million citations starting from 1966 until present. Coverage is worldwide, but most records are from English-language sources or have English abstracts (http://www.ncbi.nlm.nih.gov/entrezquery.fcgi?db=PubMed).

To test the capabilities of both databases, the expanded-SCI database was queried for research articles published by 'Saudi scientists' (within this article this term includes Saudi or foreign scientists recruited in KSA) using the search tool available in its digital form covering the years 1994-2000. However, the flexibility of PubMed as well as the new features added in its latest release allowed us to conduct advanced queries by (1) using tags to search in various fields of the bibliographic record (for example [affiliation], [Journal], and so forth), (2) by using the "*" wildcard, a special character that will match any other(s), including "no character", to broaden a query (for example, pharmac*= pharmacy, pharmacology, and so forth) or (3) by using Boolean operators (namely, AND, OR, NOT) to add more versatility to the query strategy. In order to investigate the different aspects of development of biomedical research in KSA, more than a dozen search strategies were applied and a total of more than 1500 queries were sequentially directed using a devoted high-end computer with an ultra-speed network connection. All searches were completed within a period of 6 hours on 18 June 2001 to guarantee unbiased results because of the daily updating of PubMed. Some examples of search queries sent to PubMed are briefly indicated: Total biomedical articles published in KSA from year 1966 to 2000: Query="Saudi Arabia"[affiliation]; Limit controls=1.1.1966-31.12.2000. Total biomedical articles published solely by hospitals in KSA: Query="Saudi Arabia"[affiliation] AND hospital [affiliation] NOT university[affiliation]. Common keywords in biomedical articles published in KSA using tags, boolean operators and a wildcard operator: Query="Saudi Arabia"[Affiliation] AND pharmac*. Searching for articles published by Saudi authors in a specific journal: Query="Saudi Arabia" [Affiliation] AND "am j hum genet"[TA]. Biomedical research articles published from institutes in the Buraidah region in KSA: Query="Saudi Arabia"[Affiliation] AND (Buraidah OR Buriydah OR Buraydah OR Buryadah).

Results. ***Science Citation Index versus PubMed.*** Identical simple queries were directed to expanded-SCI and PubMed databases to analyze the number of research articles published by Saudi scientists as reported in these indexes. Because of the restricted coverage of the expanded-SCI digital format, the search was only limited to years 1994-2000. PubMed always revealed a smaller number of citations when compared to the expanded-SCI. On average, this was equivalent to 30.6% of citations referred by the SCI system and ranged from 26.7% (1999) to 34.2% (1995). The explanation for this difference can be attributed to 2 main reasons: 1. SCI is not limited to biomedical bibliography since it covers all other aspects of science, such as: Ecology, Physics, Chemistry, Mathematics, Geology, and so forth. 2. When queried regarding research in KSA, PubMed sorts only citations written by first authors whose addresses are located within the Kingdom, whereas expanded-SCI sorts citations irrespective of the position at which Saudi authors' names appear among all contributing authors. Accordingly, PubMed was preferably used as the basis of all subsequent analyses mainly due to the following reasons: 1. The specialization of PubMed in biomedical bibliography. 2. PubMed search may go back to year 1966, an option that is not available in SCI or expanded-SCI. 3. The limitation of the citations revealed by PubMed to articles whose first-author is a Saudi scientist reflects a major contribution of KSA in the study. 4. The added features to the latest release version of PubMed permits remarkable search flexibility, not available in the SCI or expanded-SCI systems.

Kingdom of Saudi Arabia versus other Arab States. We performed comparative analyses to deduce the number of biomedical citations published between the years 1966 and 2000 by authors from 23 Arab States including KSA. Despite the fact that citations from KSA started to appear in the year 1982, data demonstrates that KSA is by far the most productive, and accounts for approximately 28% of the total publications made by all Arab States (**Table 1**). Excluding Egypt, which contributes to 23% of biomedical research in the Arab world, all other Arab countries had much limited contributions of less than 10% each.

Distribution of biomedical research within the Kingdom of Saudi Arabia. Subsequently, we analyzed in detail the addresses of Saudi authors who contributed to the 5962 citations published in years 1982-2000. **Table 2** shows that most of the Saudi citations originated from the capital city of Riyadh (70%). Scientists from Jeddah, Abha, and Dammam contributed, all together, to 17% of research

Table 1 - Total biomedical citations published in 1966-2000 by authors from 23 Arab States including the Kingdom of Saudi Arabia.

Country	Total	(%)
Saudi Arabia	5962	(27.6)
Egypt	5065	(23.4)
Kuwait	1772	(8.2)
Lebanon	1564	(7.2)
Tunisia	1445	(6.7)
Morocco	1405	(6.5)
Jordan	1059	(4.9)
United Arab Emirates	740	(3.4)
Sudan	565	(2.6)
Algeria	391	(1.8)
Oman	383	(1.8)
Iraq	326	(1.5)
Libya	266	(1.2)
Qatar	182	(0.8)
Bahrain	176	(0.8)
Syria	90	(0.4)
Yemen	61	(0.3)
Somalia	46	(0.2)
Mauritania	42	(0.2)
Palestine	37	(0.2)
Djibouti	25	(0.1)
Comoros	15	(0.1)
Eritrea	8	(0.04)

publications. Other cities had, by far, much less contribution (**Table 2**). To explain the differences observed in **Table 2**, we further dissected the results among the main research institutions present in the Kingdom. **Table 3** shows that 51% of biomedical research published from KSA originated from the King Saud University (29.5%) and King Faisal Specialist Hospital (21.5%). The location of both institutes in the capital city of Riyadh or its suburbs, thus, explains the data of **Table 2**. The King Saud University, founded in 1957, was formerly known as the Riyadh University (until 1982). Despite the presence of some of its colleges in Al-Qasim and in Abha, data demonstrates that the main campus at Riyadh is the leading contributor in biomedical research (data not shown). In fact, the first internationally recognized Saudi biomedical research paper cited in PubMed was written by Dr. S. S. Pareek from Riyadh (King Saud) University. The paper reported a case of unusual syphilitic alopecia on the legs of a young Saudi Arabian male.[2]

Objectives of biomedical research in the Kingdom of Saudi Arabia. Biomedical research in KSA is not only restricted to analyses of human subjects. Reports of human subjects' account for only 81.1% of the total papers published until year 2000. Of these papers, 63.1% describe a male and 61.1% a female subject. This is in agreement with the sex ratio in KSA that is approximately 1.24 males/female (July 2000 est.). On the other side, 16.3% of the reports include animal subjects (29.1% females and 49.7% males). The remaining 2.6% of papers do not have a proper index. Reports on human subjects were further investigated to ascertain the age structure of the individuals analyzed. Two main classifications are followed in PubMed: Children (0-18 years) and adult subjects (19+ years). Within these 2 main categories, several sub-categories are included (Newborn: Birth-1st month, Infant: 1-23 months, Preschool child: 2-5 years, Child: 6-12 years, Adolescent: 13-18 years, Adult: 19-44 years, Middle aged: 45-64 years, Aged: 65+ years, etc.). No remarkable differences were observed for data extracted from female or male individuals. The

Table 2 - Geographical distribution of biomedical research in the Kingdom of Saudi Arabia between the years 1982 and 2000.

Year	Riyadh	Jeddah	Abha	Dammam	Dhahran	Khobar	Others	Total
1982	1	0	0	0	0	0	0	1
1983	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0
1985	1	0	0	0	0	0	0	1
1986	8	0	0	0	0	0	0	8
1987	84	8	2	14	3	2	10	123
1988	235	28	17	20	14	9	22	345
1989	212	14	12	24	10	5	23	300
1990	276	26	22	25	5	8	40	402
1991	304	46	22	32	5	11	24	444
1992	294	38	35	28	11	9	48	463
1993	308	36	27	22	8	2	32	435
1994	316	28	26	14	4	8	48	444
1995	362	39	34	12	7	8	54	516
1996	389	37	22	14	12	3	49	526
1997	356	33	29	18	10	8	53	507
1998	378	32	18	13	7	5	46	499
1999	326	31	14	9	6	12	42	440
2000	317	55	26	10	10	15	75	508
Total	**4167**	**451**	**306**	**255**	**112**	**105**	**566**	**5962**
%	**69.9**	**7.6**	**5.1**	**4.3**	**1.9**	**1.8**	**9.4**	

Table 3 - Distribution of biomedical research in the Kingdom of Saudi Arabia according to scientific institutes. Specific addresses of contributing campuses are indicated in parentheses.

Institute	Citations	(%)
King Saud University (Riyadh, Al-Qasim, and Abha)	1760	(29.5)
King Faisal Specialist Hospital (Riyadh)	1283	(21.5)
King Khalid University Hospital (Riyadh)	474	(8.0)
King Faisal University (Al-Khobar, Dammam)	355	(6.0)
King AbdulAziz University (Jeddah)	232	(3.9)
King AbdulAziz University Hospital or King AbdulAziz Hospital (Jeddah)	147	(2.5)
King Khalid University (Abha)	100	(1.7)
Armed Forces Hospital (Riyadh)	39	(0.6)
King Fahd University (Dhahran)	39	(0.6)
King Khalid Hospital (Riyadh, Najran region, Tabuk, Hail)	36	(0.6)
Umm Al-Qura University (Makkah)	17	(0.3)
King Fahad National Guard Hospital (Riyadh)	8	(0.1)
North West Armed Forces Hospital (Tabuk)	8	(0.1)
Dammam Central Hospital (Dammam)	5	(0.1)
Others or Unidentified	1459	(24.5)
Total	**5962**	**(100)**

majority of the reports discuss cases of individuals from the adult category (65.6%), more specifically subjects of 19-44 years of age (58.2%). The number of reports including older patients decreases significantly until it reaches the lowest value of 7.1% (80+ years of age). In the children category, most of the reports discuss subjects of 6-18 years of age (Child: 31.7%, Adolescent: 35.2%). All these values are in accordance with the age structure of the Saudi Arabian population that may be classified in 3 main categories: 0-14 years (43%), 15-64 years (55%), and 65+ years (2%; July 2000 est.).

To better understand the main objectives of biomedical research in KSA, we classified the published reports according to some of the 'subsets' adapted by PubMed. These are: AIDS, Complementary Medicine, Core Clinical Journals, Dental Journals, Nursing Journals and Toxicology. Results show that the most proliferating fields in KSA are toxicology (12.5% of published citations) and core clinical reports (9%). The other subsets are less represented (namely, Dental medicine, 4.1%; complementary medicine, 2.8%; AIDS, 0.8%; nursing, 0.5%). As the above values were not satisfactory and did not reflect the objective of most of the published research papers from KSA, we analyzed the occurrence of the frequently encountered root keywords. An example of a root keyword is the term bacteri*, in which the "*" wild-card sign means any combination of characters. Thus, the root keyword "bacteri*" will include: bacterium, bacteria, bacteriology, etc. In total, 95 root keywords (approximately 400 keywords) were analyzed. The choice of root keywords was based on 2 main strategies: 1. Keywords occurring in the yearly indexes of Saudi medical journals (mainly from the Saudi Medical Journal). 2. Frequent keywords queried in modern medical sciences. This strategy resulted in more useful knowledge regarding biomedical research in KSA. One of every 5 Saudi papers either describes a disease (21%), a blood related analysis (20.9%), or surgical observations (18.8%). One of 8 Saudi papers discusses the issues of cancer (12.7%), drug assays (11.6%), or infection (11.6%). Other interests include: X-ray applications (7.4%), syndromes (7.1%), heart-related observations (6.6%), pregnancy-related issues (6.2%), microbiology (6.2%), liver-related research (5.1%), ultrasound (4.8%), transplantation (4.6%), diabetes (3%), tuberculosis (2.6%), and so forth.

Evaluating biomedical research in the Kingdom of Saudi Arabia. To evaluate the level of biomedical research in KSA, 2 strategies were followed: 1. PubMed's paper classification system. 2. Published Saudi papers in high impact journals. The majority of Saudi papers are published in English (99.9%). Only 7 papers were published in German (5) or French (2). Saudi scientists publish review papers at a rate of 6.4% and clinical trial papers at a rate of 5.1%. Only 2.6% of Saudi papers are classified as randomized controlled trials. To further assess Saudi papers, we analyzed in detail the occurrence of Saudi papers in the 200 highest impact-factor journals (**Table 4**). Only 0.5% of Saudi papers appear in such journals, however, all appear in the first 100 highest impact-factor journals. Of these papers, the first 3 are for scientists from the King Faisal Specialist Hospital and Research Center.[3-5]

Table 4 - Saudi citations that appeared in the highest impact-factor journals between years 1982 and 2000. Journals are listed in the decreasing order of impact factor (1997 SCI classification). Numbers in parantheses indicate the year(s) of publication of the corresponding paper(s).

Journal	Saudi Citations
New England Journal of Medicine (1990)	1
Science (1994)	1
Endocrine Reviews (1994)	1
Pharmacological Reviews (1999)	1
Lancet (1989-2000)	6
Journal of Experimental Medicine (1997)	1
Gastroenterology (1990-1994)	2
American Journal of Human Genetics (2000)	2
Circulation (1991)	1
Annals of Neurology (1988-1996)	6
Journal of Immunology (1998)	1
Oncogene (2000)	1
Journal of the American College of Cardiology (1989-1997)	3
American Journal of Pathology (1991-1997)	2
American Review of Respiratory Disease (1998)	1
Arthritis and Rheumatism (1998)	1

Discussion. Despite the short history of biomedical research in KSA, the present study demonstrates a steady advancement in this field in the Kingdom when compared to other Arab States. For example, although the first PubMed-recognized scientific reports from Lebanon date back to the year 1966, reports published by Saudi authors are 4 times more than those published by Lebanese authors. The major boosts in biomedical research in KSA occurred mainly in years 1987-1988 and 1990-1996. Since year 1996, however, a plateau phase is dominant (**Table 2**). Current estimates, based on a general query to PubMed performed on 28 November 2001, do not show an increase in the rate of papers published by Saudi scientists (498 papers, estimate for 2001). It is possible then to say that the plateau phase will continue through year 2001 despite the recent recognition of the Saudi Medical Journal by the PubMed database.

An important observation that was noted when analyzing the details of the 5,962 Saudi papers published between years 1982 and 2000 is the absence of uniformity in writing the addresses of authors. Divergence occurs mainly at 2 main levels: citing the cities or scientific institutions of KSA. For example, the Buraidah region occurs as: Buraidah, Buriydah, Buraydah, or Buryadah. King Fahd and King AbdulAziz Universities occasionally occur as King Fahad or King Abdul Aziz Universities. In some other cases, the name of the city where the institute is located is completely omitted. Such tendency, if left uncontrolled, may result in misleading data about the geographical distribution of biomedical research in KSA or improper rating of the scientific institutions of the Kingdom. That is why implementing a uniform system is of great importance.

The analyses of the objectives and quality of biomedical research in KSA, show that the most dynamic biomedical fields in KSA are: Hematology, Surgery, Cancer, Pharmacology, and Microbiology. However, the newly born research fields of molecular medicine, modern biology, and genetics only account for 2.2% of the published papers from KSA. Among the 5,962 papers analyzed, a high ratio of review papers was encountered. This may reflect the significant professional standard of authors from KSA since, usually, review articles are invited and mainly reference authors are only considered. However, only a very small portion of the total Saudi papers appear in high impact-factor journals. Although this observation may underestimate, at first sight, the actual quality of Saudi biomedical research, many investigations point out that the main reason behind such values are the biases and economics of scientific publishing. Several barriers retard scientists from developing countries to publish their work in indexed journals. Scientific publishing activities are usually characterized as top-down initiatives in the hands of traditional publishers and major universities. One major obstacle is the comparison of the quality of science reported from developing countries and its significance to industrialized countries. Another major obstacle is the one applied by high impact factor journals where articles submitted by authors from developing countries may be declined because of the author's address.[6] The main example that can better explain this issue is the publication of 6 Saudi papers in the journal Lancet. This relatively higher ratio observed in **Table 4** may be best explained by the new strategy adapted by the Lancet journal in which the address of the author is hidden from the referee to guarantee more objective judgments.[7] Recent surveys, however, indicate that the "publication scenario" will certainly change in the very near future. Pushed by the international need to share scientific data on-line and by the market forces, information is already moving at a quick rate on to the Internet.[8] Scientific networked information today includes not only conventional articles, but also personal communications and live records, promoting collaborative work among scientists around the world.

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