

Bibliometric analyses of biomedical research outputs in Lebanon and the United Arab Emirates (1988-2007)

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ABSTRACT

الأهداف: تقييم الطرق المتبعة لقياس ومقارنة المنتج العلمي الطبي الأحيائي كما ونوعاً في كل من لبنان والإمارات العربية المتحدة.

الطريقة: تم استخلاص حصيلة بحوث الطب الأحيائي في لبنان والإمارات العربية المتحدة للأعوام 1988م و 2007م من قاعدة البيانات (PubMed) وبعدها تم ترتيب البيانات في قاعدة بيانات محلية ومن ثم تمت معايرة البيانات تبعاً لحجم عدد السكان في الدولتين.

النتائج: تشير البيانات إلى نمو نتاج بحوث الطب الأحيائي في لبنان عبر الفترة التي تمت دراستها في هذا البحث، بيد أن نتاج الطب الأحيائي في الإمارات العربية المتحدة علق في مرحلة ثبات بين عام 1998م وعام 2007م. وفي لبنان نجد أن معظم نتاج الطب الأحيائي صادر من مؤسسات في العاصمة بيروت، وبالأخص من الجامعة الأمريكية. وبدراسة معمّقة للتوجه البحثي الطبي الأحيائي في لبنان نرى تركيزاً على أفرع الطب الباطني، التخدير، الجراحة، زراعة الأعضاء، الطب الوراثي، طب الأطفال، طب التوليد، السرطانات، وتخفيف الألم. أما في الإمارات العربية المتحدة، فإن معظم نتاج الطب الأحيائي يصدر من جامعة الإمارات بمدينة العين. وتشير الدراسة المعمّقة لتوجهات البحث الطبي الأحيائي في الإمارات العربية المتحدة إلى تركيز معظم الجهود حول طب الأطفال، طب التوليد، التشنوهات الخلقية، زراعة الأعضاء، طب الأمراض الجلدية، أمراض السكري، وزواج الأقارب.

خاتمة: يوضّح البحث سرعة تعافي النتاج البحثي الطبي الأحيائي في لبنان بعد فترة حروب امتدت بين عامي 1974م و 1992م، وحفز استمرار البحث العلمي في المؤسسات الجامعية الخاصة عملية التعافي مباشرة بعد تلك الفترة. وفي الإمارات العربية المتحدة دخل نتاج البحث الطبي الأحيائي في مرحلة جمادٍ منذ النصف الثاني للقرن الفائت. وقد يكون سبب هذا الجمود تركّز البحث الطبي الأحيائي إجمالاً في مؤسسة علمية واحدة هي جامعة الإمارات، لذلك فإن تطور هذا النتاج لن يتحقق إلا حين تشترك المؤسسات الجامعية الأخرى بعملية البحث الطبي الأحيائي في الدولة.

Objective: We assessed the role of bibliometric methods in representing quantitative and qualitative differences in biomedical research outputs in Lebanon and the United Arab Emirates (UAE).

Methods: Data on biomedical research productivity for years 1988-2007 were obtained from PubMed then imported into a specifically designed local database system and normalized to the population size for each country.

Results: Data reveal a continuous increase in research production in Lebanon, whereas a plateau phase is observed in the UAE between 1998 and 2007. In Lebanon, most of the citations originated from the capital city of Beirut, mainly the American University of Beirut. Detailed analysis of biomedical research objectives in Lebanon indicate a focus on internal medicine, anesthesiology, surgery, transplantation, medical genetics, pediatrics, obstetrics, neoplasms, and pain management. In the UAE, most of the biomedical publications originate from Al-Ain University. Detailed analysis of biomedical research objectives in the UAE indicate developed interest in pediatrics, obstetrics, clinical dysmorphologies, transplantation, dermatology, diabetes, and consanguinity.

Conclusion: Biomedical research outputs quickly recovered in Lebanon following a long war (1974-1992) mainly supported by uninterrupted activities in private higher education institutes. In the UAE, the plateau phase for biomedical research output size could be due to the limitation of most of the research in the country to Al-Ain University. This situation may only improve when other institutes offering biomedical programs engage also in research activities.

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Bibliometric analysis involves the application of mathematics and statistical methods to scientific publications as reflected in bibliographies.¹ These methods are primarily quantitative, but are also used to make pronouncements about qualitative features of the scientific literature.² In the biomedical fields, scientists utilize many high quality citation databases to search for published literature. Of these databases, PubMed, the online version of Medline, is the most significant barrier-free biomedical resource available on the World Wide Web. PubMed provides a strong health discipline indexing coverage, and currently catalogues over 17 million biomedical articles in 5,200 journals in 37 languages.³ The free access of PubMed and its friendly interface lead many scholars to develop search techniques to analyze global trends for biomedical research productivity and to provide objective and useful tools to evaluate the results of scientific activity in different locations worldwide.⁴⁻⁷ In the Arab World, early attempts to study biomedical bibliometrics took place in the Gulf Corporation Council region,⁸⁻¹⁰ including thorough quantitative investigations on medical publications from the United Arab Emirates (UAE),¹¹⁻¹⁵ and Saudi Arabia.¹⁶ More recently, a series of publications embarked on analyzing biomedical research in Tunisia,¹⁷⁻²⁰ Morocco,²¹ Algeria,²² Lebanon,²³ Palestine,²⁴ Egypt,^{25,26} and Libya.²⁷ Most of these investigations included geographical distribution studies and quantitative analysis of medical publications from Arab countries by using either raw data or normalized data according to population size and gross domestic product (GDP) spending. Yet, a small number of these studies presented limited qualitative features and biomedical research directions in Arab countries.^{15,22,23,25,27,28} Since 2001, we initiated a line of research concentrating on the development of bibliometric techniques to study aspects of biomedical research in the Arab World. Initially, we utilized raw data to classify Arab countries according to their crude outputs of biomedical publications using the address of the principal investigator indexed in PubMed.¹⁶ Concurrently, we applied several techniques to examine the detailed anatomy of research in Saudi Arabia and Palestine^{16,24} by analyzing the geographical distribution of proliferate locations in biomedicine in these countries. Additionally, we applied a variety of methods to depict the objectives in biomedical research, and tried to qualitatively evaluate the throughput of

Saudi and Palestinian citations.^{16,24} Since comparison of raw data between different countries implies certain bias, we also carried out a meta-analytical study of biomedical research publication outputs normalized to population sizes.⁶ On the other hand, normalization to annual GDP spending could be misleading in the case of small countries.⁶ Throughout our analyses, we also realized that not all principal investigators from Arab countries publish their international manuscripts in English. An important proportion of papers from the Arab World do also appear in French language, especially in Maghreb countries and Lebanon, due to their recent historical determinants.²⁹ For this reason, we suggested detailed search strategies for investigators to precisely mine information on Arab biomedical publications indexed in PubMed.^{24,29}

In the present study, we aimed at assessing the role of bibliometric methods in depicting quantitative and qualitative differences in biomedical research outputs in Lebanon and the UAE, 2 countries sharing many common characteristics such as demography, education, and healthcare (Table 1).³⁰ The growth of information and communication technologies and the globalization of industry, taking place in the last 2 decades, prompted us to mine bibliometric data for years 1988-2007.

Table 1 - Selected demographic and healthcare indicators for Lebanon and the UAE.³⁰

Indicators	Lebanon	UAE
Area (square kilometers)	10,452 ^g	83,600 ^g
Population size	4,055,000 ^g	4,248,000 ^g
Urban population (% of total)	87.0 ^g	77.0 ^g
Crude birth rate (per 1000 population)	16.9 ^e	15.5 ^c
Crude death rate (per 1000 population)	4.1 ^e	1.6 ^c
Population growth rate (%)	1.1 ^g	3.5 ^g
Fertility rate (total)	2.2 ^g	2.3 ^g
Adult (15+ years) literacy rate, total (%)	88.0 ^a	88.7 ^c
Population median age (years)	27.0 ^g	30.0 ^g
Per capita GNP (US\$)	9,600 ^g	26,810 ^f
Per capita GDP (US\$)	5,949 ^e	38,613 ^g
Expenditure on health as % of GDP (total)	8.7 ^f	2.6 ^f
Ministry of health budget as % of government budget	3.6 ^f	7.7 ^b
Physicians (per 10000 population)	23.6 ^f	16.9 ^c
Dentists (per 10000 population)	8.8 ^e	2.9 ^c
Pharmacists (per 10000 population)	8.1 ^c	4.1 ^c
Hospital beds (per 10000 population)	36.0 ^f	18.0 ^f
Population with access to local health services (%)	98.0 ^a	100 ^c
Antenatal care coverage (%)	76.0 ^c	100 ^d
Births attended by skilled health personnel (%)	98.0 ^c	100 ^f
Life expectancy at birth (total years)	70.0 ^g	78.0 ^g
Infant mortality rate (per 1000 live births)	27.0 ^g	8.0 ^g
Maternal mortality ratio (per 10000 live births)	15.0 ^f	3.7 ^f

UAE - United Arab Emirates, GNP - gross national product, GDP - gross domestic product, ^gyear 2000, ^byear 2001, ^cyear 2002, ^dyear 2003, ^eyear 2004, ^fyear 2005, ^gyear 2006

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Methods. In this study, we utilized an improved search strategy based on our previous proposal²⁹ to obtain precise data on biomedical research productivity in Lebanon and the UAE as of PubMed (<http://www.pubmed.com>) within a single hour (on 5.6.2008). These data include non-English citations and exclude those with false-positive affiliations (namely, “Lebanon Magnetic Imaging, Pennsylvania”, “Bronx-Lebanon Hospital Center, New York”, “Lebanon City, Indiana”, and many others). Furthermore, the address-based search on PubMed automatically excludes letters to the editors and commentary articles; hence, reviews, journal articles, case reports, and similar types of citations are included in the present data. This search also restricts results to papers in which the principal investigators are affiliated to Arab institutions. Although this could be considered as an important limitation to the study, the choice of selecting papers with main authors being from Arab institutions reflects a major involvement in the research reported and can give a fair representation of research directions in biomedical sciences.

Results for years 1988-2007 were collected in “Medline format” text files and imported into a specially designed local FileMaker database system to inspect for the presence of inconsistencies and to conduct various analyses. The number of biomedical articles originating from Lebanon and the UAE over the period 1988-2007 was used as an index of total biomedical research production. To allow for balanced comparison, data were normalized to global research output, represented by the total number of articles indexed in PubMed per year from 1988-2007, and according to the population size of each country. For the later, historical population data were obtained from the United States Census Bureau (<http://www.census.gov/ipc/www/idb/>). Order 2 polynomial trendlines were calculated according to the least squares fit through points by using the following equation: $Y=b+c_1X+c_2X^2$, where b =index (linest ($Y,X^{(1,2)}$),1,3), c_1 =index (linest ($Y,X^{(1,2)}$),1,2), and c_2 =index (linest ($Y,X^{(1,2)}$),1). This choice is guided by the fact that second order polynomials allow the presentation of 10-year window schemes and allow better comparisons for the periods 1988-1997 and 1998-2007. This characteristic is not possibly obtained by using linear polynomial trendlines, whereas higher order polynomials may portray unwanted noise. In order to evaluate the journals that published biomedical articles from Lebanon and the UAE, the 2006 Science Edition of the Journal Citation Reports (JCR), published by Thomson Reuters, was utilized to retrieve journal impact factor data. The JCR Science Edition was accessed as part of the ISI web of Knowledge package at www.isiknowledge.com. Data for the 100 highest impact factor journals were only considered.

Results. By inspecting raw data for biomedical research production in Lebanon (total: 3087; mean: 158 per year) and the UAE (total: 1996; mean: 102 per year), a clear increasing trend is observed in both countries, although the increase is more prominent in Lebanon especially in the last 10 years (Figure 1). Data normalized to global biomedical outputs and country population size reaffirm the progress in biomedical research outputs in Lebanon over the studied period (mean: 0.03% of global biomedical output and 4.4 publications/100,000 population), whereas the trend in the UAE demonstrates a plateau phase in the period between 1998 and 2007 (mean: 0.02% of global

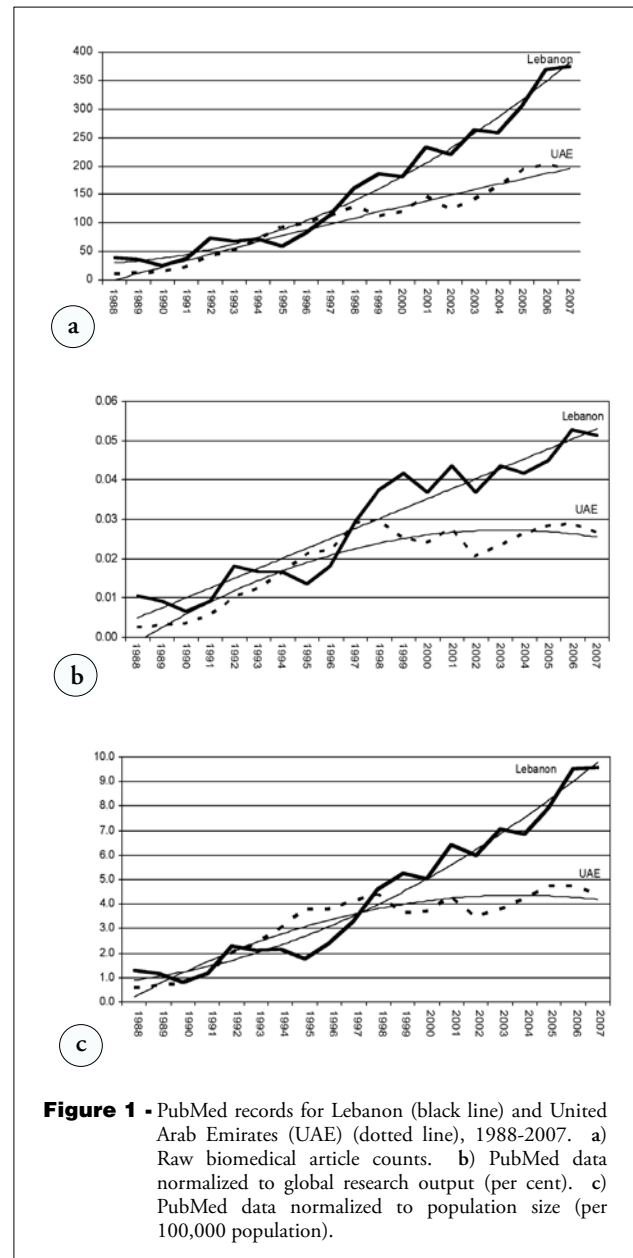


Figure 1 - PubMed records for Lebanon (black line) and United Arab Emirates (UAE) (dotted line), 1988-2007. a) Raw biomedical article counts. b) PubMed data normalized to global research output (per cent). c) PubMed data normalized to population size (per 100,000 population).

biomedical output and 3.4 publications/100,000 population). Detailed address analysis from Lebanon indicate that most of the citations originate from the capital city of Beirut (96.3%), mainly from the American University of Beirut (60.1%) where the College of Medicine leads other faculties in terms of country-wide productivity (47.6%), specifically the departments of internal medicine (10.0%) and anesthesiology (5.9%; Table 2). However, most of the biomedical outputs from the UAE originate from the city of Al-Ain (70.3%), mainly from Al-Ain University (59.9%) where the Faculty of Medical and Health Sciences produces half of the country-wide biomedical output (50.0%), specifically the departments of pediatrics (7.0%) and obstetrics and gynecology (4.6%; Table 2).

Table 2 - Geographical and institutional distribution of biomedical publication outputs for Lebanon and UAE, 1988-2007.

Country	N	(%)
Lebanon	3087	(100)
<i>City</i>		
Beirut	2972	(96.3)
<i>Institution</i>		
American University of Beirut	1854	(60.1)
<i>College/Faculty</i>		
Medicine	1468	(47.6)
<i>Department</i>		
Internal Medicine	310	(10.0)
Anesthesiology	181	(5.9)
Surgery	127	(4.1)
Obstetrics Gynecology	107	(2.5)
Pediatrics	91	(2.9)
Ophthalmology	74	(2.4)
Other department	578	(18.7)
Other institutions	356	(11.5)
Hotel Dieu de France Hospital	492	(15.9)
Saint Joseph University	145	(4.7)
Other institution	481	(15.6)
Other cities	115	(3.7)
United Arab Emirates	1996	(100)
<i>City</i>		
Al-Ain	1398	(70.3)
<i>Institution</i>		
UAE University	1193	(59.9)
<i>College/Faculty</i>		
Medical Health Sciences	995	(50.0)
<i>Department</i>		
Pediatrics	139	(7.0)
Obstetrics Gynecology	91	(4.6)
Physiology	73	(3.7)
Community Medicine	71	(3.6)
Biochemistry	70	(3.5)
Anatomy	68	(3.4)
Other department	483	(24.2)
Science	81	(4.1)
Other Medical Health Sciences	117	(5.9)
Tawam Hospital	149	(7.5)
Other universities	56	(2.8)
Abu Dhabi	244	(12.3)
Mafraq Hospital	84	(4.2)
Other cities	160	(8.0)
Dubai	216	(10.9)
Sharjah	90	(4.5)
Other cities	42	(2.1)

Biomedical research in Lebanon (11%) and the UAE (30%) also include animal-based reports of the total biomedical research outputs. The majority of non-human subjects analyzed in Lebanon include rats and mice, whereas in the UAE animal studies involve rats, mice, and camels. On the other hand, human subjects accounted for 86% of the total biomedical output in Lebanon, whereas this figure decreases to 64% in the UAE. In both countries, more female subjects than male subjects were analyzed. A detailed study of the age structure of the human subjects studied in Lebanon and the UAE, indicate that adults of 19 years and above are the most studied group (Figure 2). This is more prominent in Lebanon where more than half of the biomedical research outputs describe this category (51.9%), especially the group of 19-44 years of age (37.2%). However, in the UAE research is equally distributed on adult subjects (19+ years; 30.2%) as well as young children (0-18 years, 28%; Figure 2).

To understand some aspects of the objectives of biomedical research in Lebanon and the UAE, we classified collected articles according to the subsets adapted by PubMed (AIDS, Bioethics, Cancer, Complementary Medicine, History of Medicine, Space Life Sciences, Systematic Reviews, and Toxicology). Results show that the most proliferating fields in Lebanon and the UAE are: cancer (36.7% and 27.1%, respectively), Toxicology (13.1% and 15.1%, respectively), and Complementary Medicine (9.9% and 14.1%, respectively). However, to explore the full scale objective of most of the published research papers in Lebanon and the UAE, we exhaustively analyzed the frequency of 32500 and 23000 keywords occurring in these articles, respectively. These keywords were further grouped into 2000 root keywords to explore detailed

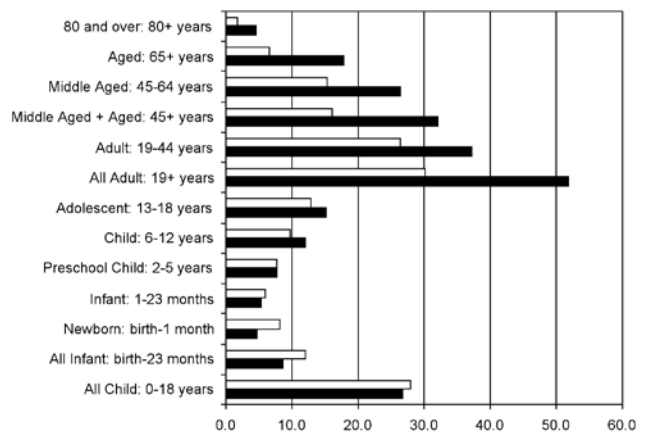


Figure 2 - PubMed records for Lebanon (black bars) and the United Arab Emirates (white bars), 1988-2007, distributed according to age intervals of human subject groups analyzed.

directions of biomedical research in the 2 countries (data not shown). In Lebanon, the top most encountered keywords include: pregnancy (8.7%), tomography (4.7%), neoplasm (4%), anesthesia (4%), pain (3.6%), magnetic resonance (3.4%), skin (3.2%), intestinal absorption (3.1%), hepatitis (2.9%), and wounds (2.7%). In the UAE, the most encountered keywords include: pregnancy (14.9%), diabetes (7.5%), kidney (4.7%), skin (3.8%), consanguinity (3%), liver (3%), bacterial DNA chemistry (2.9%), pancreas (2.8%), tomography (2.8%), and immunohistochemistry (2.8%). Some of the keywords are also indicative for the type of research conducted in Lebanon [treatment outcome studies (5.9%), retrospective studies (5.4%), risk factor analysis (5.3%), differential diagnosis (4.8%), and follow-up studies (4.7%)] and UAE [risk factor analysis (6%), disease prevalence studies (5.1%), time factor analysis (4.7%), prospective studies (4.3%), and questionnaire-based studies (4.2%)]. Furthermore, most utilized reagents in Lebanese studies involve: anti-bacterial agents (2%), anesthetics (2%), adenosine A2A receptor (1.7%), immunosuppressive agents (1.5%), and antibodies (1.4%), while in the UAE most utilized reagents include: blood glucose (3.3%), cholecystokinin B receptor (2.2%), insulin (2.1%), antibodies (2%), and plant extracts (1.8%).

Most of the biomedical articles from Lebanon appear in English (86%) and French (14%) journals, while those from the UAE are almost exclusively written in English (99.7%). Many articles from Lebanon appear as case reports (30.9%) followed by review articles

(16.1%), comparative studies (11.1%), and clinical trials (7.2%). In the UAE, most of the articles appear as case reports (14.9%) and comparative studies (12.9%) followed by review articles (7.1%) and clinical trials (4.8%). A detailed analysis of impact factors for journal destinations for biomedical articles from Lebanon and the UAE reveal that only a minor fraction of papers do appear in the 100 highest impact factor journals listed by the JCR 2006 Science Edition. From Lebanon, only 13 citations (0.4%) have appeared in high impact factor journals including: Lancet, Progress in Neurobiology, Circulation, Blood, and Angewandte Chemie (English Edition). In the UAE, only 5 citations (0.3%) have appeared in high impact factor journals such as: Lancet, Journal of Clinical Oncology, and the American Journal of Human Genetics. The overwhelming majority of biomedical articles from Lebanon and the UAE are usually destined to local, regional, and international journals with low impact factor values (Table 3). However, some differences between Lebanon and the UAE can be clearly observed. A major group of articles from Lebanon appear at the Lebanese Medical Journal (14.1%), the Middle East Journal of Anesthesiology (3.0%), and Transplantation Proceedings (1.6%). Interestingly among one of the most favored destination for biomedical articles from Lebanon is the high impact factor journal "Gut" (0.6%) which is one of the top 200 journals worldwide according to JCR 2006 Science Edition. However, the absence of local UAE Journals indexed at the PubMed database (for example Emirates Medical Journal) leads to the misinterpretation that

Table 3 - Principal journal destinations for biomedical research articles from Lebanon and the UAE, 1988-2007.

Country	Journal	Count (%)	Impact factor*
Lebanon	Le Journal Medical Libanais (The Lebanese Medical Journal)	434 (14.1)	-
	Middle East Journal of Anesthesiology	93 (3.0)	-
	Transplantation Proceedings	48 (1.6)	1.0
	American Journal of Medical Genetics. Part A	35 (1.1)	2.1
	Canadian Journal of Anesthesia (Journal Canadien D'anesthésie)	24 (0.8)	2.0
	International Journal of Gynecology and Obstetrics	19 (0.6)	1.1
	Gut	18 (0.6)	9.0
	Journal of Endodontics	18 (0.6)	3.1
	Anesthesia and Analgesia	17 (0.6)	2.1
	Archives de Pédiatrie (Organe Officiel de la Société Française de Pédiatrie)	16 (0.5)	0.3
UAE	Saudi Medical Journal	39 (2.0)	0.3
	Annals of Saudi Medicine	36 (1.8)	0.4
	Clinical Dysmorphology	32 (1.6)	0.5
	Eastern Mediterranean Health Journal (La Revue de Santé de la Méditerranée)	31 (1.6)	-
	Transplantation Proceedings	29 (1.5)	1.0
	International Journal of Dermatology	23 (1.2)	1.0
	Annals of the New York Academy of Sciences	22 (1.1)	1.9
	International Journal of Gynaecology and Obstetrics	21 (1.1)	1.1
	Molecular and Cellular Biochemistry	20 (1.0)	1.9
	Annals of Tropical Paediatrics	19 (1.0)	0.9

*According to JCR Journal Citation Reports© 2006 Science Edition. UAE - United Arab Emirates

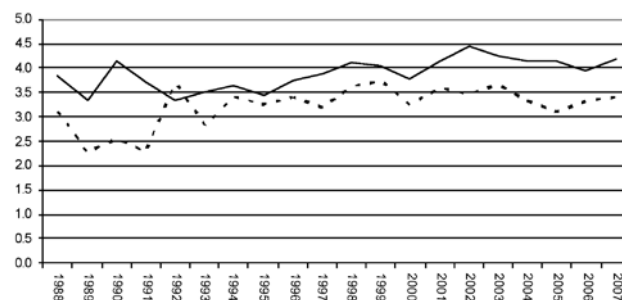
Table 4 - The most proliferate author and first-author names featuring on biomedical articles from Lebanon and the United Arab Emirates (UAE), 1988-2007.

Country	First-Author	Count (%)	Author	Count (%)
Lebanon	Baraka AS	92 (3.0)	Baraka AS	148 (4.8)
	Megarbane A	43 (1.4)	Megarbane A	78 (2.5)
	Abboud B	35 (1.1)	Taher A	69 (2.2)
	Mansour AM	32 (1.0)	Araj GF	61 (2.0)
	Atiyeh BS	31 (1.0)	Saade NE	58 (1.9)
	Nasr E	22 (0.7)	Tamim H	46 (1.5)
	Mikati MA	21 (0.7)	Abboud B	45 (1.5)
	Nasr EM	21 (0.7)	Slaba S	45 (1.5)
	Araj GF	20 (0.6)	Jabbur SJ	44 (1.4)
	Masri MA	19 (0.6)	Khalil A	44 (1.4)
UAE	Adeghate E	50 (2.1)	Bener A	87 (3.7)
	Al-Gazali LI	41 (2.0)	Adeghate E	74 (3.4)
	Bener A	40 (1.9)	Al-Gazali L	67 (2.9)
	Rizk DE	38 (1.4)	Rizk DE	57 (2.3)
	Conlon JM	27 (1.4)	Sztriha L	45 (2.1)
	Lammers WJ	27 (1.3)	Lestringant GG	41 (1.9)
	Sztriha L	25 (1.2)	Frossard PM	38 (1.8)
	Al-Waili NS	23 (1.1)	Ezimokhai M	36 (1.8)
	Ali BH	22 (1.1)	Wasfi IA	36 (1.8)
	Eapen V	21 (1.0)	Wernery U	36 (1.7)

authors in the UAE prefer to publish their results in regional journals such as Saudi Medical Journal (2.0%) and Annals of Saudi Medicine (1.8%). None of the top 10 journal destinations for UAE articles is of high impact factor.

Finally, analysis of authors and rates of co-authorship from Lebanon and the UAE reveals important characteristics. In Lebanon, the 10 most proliferate first-authors are responsible for 10.9% of the total biomedical publication output in the country (Table 4). This figure increases to 20.7% when considering the 10 most proliferate (first and co-) authors from Lebanon. In the UAE, the 10 most proliferate first-authors are responsible for 14.2% of the total biomedical output in the country while this figure increases to 23.2% when considering the 10 most proliferate authors in the country (Table 4). Annual co-authorship data from Lebanon and the UAE reveal a developing trend of having more authors on biomedical articles, although such rate is always higher in Lebanon (range: 3.3-4.4; mean: 4.2) than in the UAE (range: 2.3-3.7; mean: 3.5; Figure 3).

Discussion. Lebanon is a small country located on the eastern coast of the Mediterranean Sea (Table 1). The Lebanese population exhibits an elevated level of urbanism (90% of total population versus 58% in the surrounding region). The capital city of Beirut is the most populated area and also the major source of research output in Lebanon. On the other hand, the UAE consists of 7 Emirates: Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al-Khaimah, and Fujairah. Abu Dhabi, Dubai, and Sharjah comprise

**Figure 3** - Annual rates of co-authorship in biomedical research articles from Lebanon (black line) and the United Arab Emirates (dotted line), 1988-2006.

more than half of the population agglomerates while the other Emirates are relatively small and each consists of one main inhabited town. While Abu Dhabi and Dubai form the political and economic capitals, respectively, the oasis town of Al-Ain could be considered as the biomedical capital of the UAE (Table 2). Populations in Lebanon and the UAE have high rates of adult literacy when compared to the average for populations of the Middle East and North Africa (65.8%). Besides Arabic and English, widely used in the UAE, the majority of Lebanese people can also communicate in French; hence, accounting for the considerable size of articles published in French. Reasons that may contribute to these improved characteristics are the well-established education systems, to which the government and private sectors have major contributions at the primary, secondary, or university levels.

Despite the long devastating war that raged in Lebanon (1975-1992), the educational system did not

suffer major long term damages. Soon after the war ended, the Lebanese government implemented a 3-year plan to make major reforms in the educational system with a budget of approximately 270 million US Dollars. At present, one governmental and 41 private higher education institutions are operating in Lebanon. Yet, private universities, many offering programs of medicine or public health, are key elements in biomedical research productivity. It is because of these institutions that the rate of biomedical research publications soon improved after the end of the war in the 1990s. Indeed, indicators point out that the percentage of young people studying disciplines in the natural sciences is 15.8% (58.9% males versus 41.1% females); this number is on a par with countries such as Australia and Germany.³¹ Most of these students are enrolled in deep-rooted private universities (namely, American University of Beirut, University of Saint-Joseph, Balamand University, and others) besides the major governmental Lebanese University. On the contrary, biomedical research outputs in the UAE seem to enter into a plateau phase similar to observations made in other Gulf States, including Saudi Arabia.⁶ Major explanations to the condition prevailing in the UAE are the recent introduction of biomedical research with the opening in 1989 of the first medical school in Al-Ain University, which is almost the major source of biomedical research outputs in the country (Table 2). Despite the presence of many higher educational institutions in the UAE, only few of these do offer programs of natural sciences, medicine or public health. Many of these universities are degree awarding branches of foreign universities that are sometimes considered by many educators as ephemeral occurrences with marginal efforts in research and development. Most of these institutions give strong priority to teaching rather than research, a policy that is believed to be counterproductive³² and ignores the basic fact that the lack of high-quality research by faculty members limits training opportunities for students.³³ The remedy to this situation will only occur once major private universities (namely, University of Sharjah, the Gulf Medical University in Ajman, and the Ras Al-Khaimah Medical and Health Sciences University) improve their academic research potentials to become incubators of scientific research and generators of knowledge. This situation seems to be helped by the operation of several funding sponsors such as the Sheikh Hamdan Bin Rashid Al-Maktoum Award for Medical Sciences, the Harvard Dubai Foundation for Medical Research, and the Terry Fox Cancer Research Fund that strongly believe that unpublished research has limited value.

Similar to other Arab States, human power seems not to be a limiting factor for research in Lebanon

and the UAE.³⁴ A handful number of scientists in either country produce more than 10% of biomedical publications every year (Table 4). A study conducted in the American University of Beirut, indicates that a significantly higher publication rate is observed among newly recruited faculty members.²³ This observation could be a major source of hope that newly established biomedical colleges in the UAE could soon turn into the productive phase once research and teaching are equally valued and dealt with. The establishment of equal-opportunity collaborations with international groups will further lead to profound change of publication profile in terms of language, journal impact factor, and research interests²² and will result in more original publications than locally performed research.²³

Among the most important fields that were queried in this study are those containing information regarding authors and their addresses indicated in corresponding scientific papers. As expected, the occurrence of errors or inconsistencies in such key fields leads to loss of relevant valuable information. The present data from Lebanon and the UAE exposed us to a wide variety of errors and inconsistencies, including absence of uniformity in reporting addresses at the level of city, institution, faculty, and department names. This is a further extension to similar observations in detailed data extracted from Saudi Arabia, Turkey, Palestine, and the UAE.^{15,16,24,35} Major reasons for these inconsistencies are (1) the transliteration of addresses from native languages into English or French,²⁹ (2) the common use of truncated addresses in which names of departments and/or faculties are spelled without indicating the name of corresponding institutions, thus, rendering the address field uninformative, and (3) the incorrect typing of names or the use of abbreviations to express names of universities or research centers. This situation emphasizes the primary responsibility of authors to grant precision of their affiliation addresses and avoid the continuous accumulation of errors and inconsistencies in bibliographic databases that can have a negative impact on the visibility of their institutions.

On the other hand, author names are not flawless either. In most of the cases, mistakes result from differences in spelling names in the 2 major foreign languages utilized in several Arab countries (namely, English and French). Other sources of errors include the inconsistent use of median names or variations in family names due to change in marital status of the author; thus, resulting in complete substitution of the family name or the use of a compound family name. Similar international concerns emerging from similar erroneous information have been widely reported.³⁶⁻³⁸

Despite the slightly higher median age in the UAE, more biomedical research in Lebanon focuses

on adult human subjects, especially those in the age group of 19-44 years (Figure 2). The major outlines of biomedical research in the country could be easily extracted from various types of data produced in this study. These include: 1) address data reflecting the importance of internal medicine, anesthesiology, and surgery (Table 2); 2) journal data emphasizing the importance of transplantation, medical genetics, and pediatrics (Table 3); 3) keyword data indicating a focus on obstetrics, neoplasms, and pain management. Most of these disciplines are concordant with basic Lebanese community health needs mostly directed towards emergency and war medicine especially in the 1990s. On the other hand, differences in biomedical research interests are reflected in the UAE where a considerable amount of research is directed towards animal sciences with considerable economical values. As far as human health is concerned, the most productive departments are those that deal with maternity and pediatrics (Table 2) while journal destinations indicate high activity in the fields of pediatric clinical dysmorphology, transplantation, and dermatology (Table 3). At a higher resolution, keywords occurring in UAE papers reveal common interest in pregnancy-related aspects, diabetes, and consanguinity. Again, these issues properly represent local health concerns.

In accordance to observations in many Arab countries,^{14,16,20,24} a very minute proportion of biomedical papers from Lebanon and the UAE do appear in high impact factor journals. This could be due to the limitation of scientific research in the region to case reports with minimal evidence-based analysis. Such outputs can only be published in very specialized international journals of relatively low impact factors. On the other hand, regional journals, mostly not indexed in major databases, offer a very safe refuge for a majority of authors who do not want to be restricted with paper size or to be subject to the expensive economies required to publish in many international journals. In Lebanon, preferred destinations include the *Journal Medical Libanais* and the *Middle East Journal of Anesthesiology* and other journals published in Lebanon, the majority of which are indexed in major biomedical bibliographic indices such as PubMed or Index Medicus.³⁹ On the other hand, most of the biomedical papers produced in the UAE are destined to the *Emirates Medical Journal*,^{14,15} a major medical journal in the UAE, but not indexed in PubMed or evaluated by the *Journal Citation Reports*, while others appear in regional journals, mainly the *Saudi Medical Journal* and *Annals of Saudi Medicine* (Table 3).

The present study indicates that co-authorship is an established model in biomedical research publishing in

the UAE and Lebanon; although it is more prominent in the later (Figure 3). This is in line with global data that demonstrate a developing trend in co-authorship patterns in biomedical sciences as well as in mathematics, computer science, chemistry, and physics.⁴⁰ In Lebanon, such a norm is maintained through collaborations made between biomedical research groups in major universities of Beirut as well as from existing opportunities to collaborate with European research groups under the support of Euro-Mediterranean partnerships (for example Euromed, MEDA European fund, and EU-Lebanon Association Agreement). Due to the conditions of such agreements, Lebanese scientists maintain leading positions in such collaborations and appear as first authors in resulting publications. The situation in the UAE is not as proliferate due to the inadequate threshold of scientists performing research in the country, mostly located in the UAE University, as well as the nature of international collaborative research based on individual attempts. The experience of the Centre for Arab Genomic Studies in reviewing more than 60,000 published biomedical articles published by Arab scientists in local, regional, and international journals indicate that most of collaborative activities between UAE and international scientists are mostly restricted to trading information or medical samples for advanced analysis abroad. Accordingly, UAE scientists do not appear as leading authors in corresponding research outcomes and subsequently drop from the sight of PubMed-based geographical search that depends on the addresses of first authors.^{41,42} This observation could further be justified with the results of a recent detailed study on co-authorships and networks of global science in which Arab States revealed tight association with the main core of advanced countries in the 1990s, including the USA (namely, Egypt, UAE, Qatar, Saudi Arabia, Jordan, Bahrain) and France (for example, Algeria, Tunisia, Morocco, and Lebanon). In the year 2000, however, the network of Arab countries in the Eastern Mediterranean and Gulf regions has become more structured, but disconnected from the main grouping of more advanced countries. In contrast, Maghreb countries and Lebanon integrated themselves further close to the core of more advanced countries.⁴³

In conclusion, the present study further demonstrates the robustness of PubMed data to assess the geographical distribution of biomedical research in the region and depict a detailed retrospective view of research directions in the field. Also, bibliometric methods used in the study made it possible to differentiate between the quantitative and qualitative characteristics of biomedical publications produced in Lebanon and the UAE in the last 20 years. The study also emphasizes the role of scientific network buildup in boosting the aforementioned characteristics.

Certainly, basic biomedical sciences, such as molecular biology and genetics, are dramatically stemming to form specialized megasciences that require the formation of highly organized interdisciplinary global networks to meet the required elevated financial demands. Such a situation should be an important stimulus to motivate linkages among Arab and international research groups based on the principles of joint ownership and cooperation. Above all, inter-Arab networks have to be further improved in order for scientists to benefit from local experiences to develop research activities with clear beneficial outcomes, meet endogenous needs, and build self-reliance in science and innovation.

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Corrections, retractions and “Expressions of Concern”

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