Scientometric Analysis of the 2003 Sleep Research Literature in Medicine and Biology

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Abstract
The distribution of journal articles published in 2003 involving sleep research in the fields of medicine and biology from the *ISI* (Institute for Scientific Information) *Current Content* databases was analysed. The following parameters were considered: the number of articles per country, the average journal impact factor of each country, the ISI journal subject category, and the top producing countries' populations and gross domestic products. Among the 2325 articles considered – authored (or co-authored) by researchers from 66 countries – the six most prolific were the USA, Germany, Japan, The United Kingdom, France and Canada; other publishing countries, in decreasing order of productivity, include Italy, Australia, and The Netherlands. Comparisons between the USA and the European Union (EU) countries, and the journal distribution of sleep publications among the subdisciplines of the life sciences and clinical medicine are also presented.

Introduction

Sleep is a key activity of humans and animals that has continuously fascinated researchers. During the second half of the 20th century, great strides have been made on understanding the sleep process: its mechanisms and its interactions with most of the biological processes of humans and animals. The importance of sleep research was recognized and formalized with the emergence of several journals specifically dedicated to the study of the sleep process. The most representative journals are *Sleep* (created in 1978), *The Journal of Sleep Research* (created in 1992), and *Sleep Medicine Reviews* (created in 1997).

Qualitative subject reviews on various aspects of sleep research are regularly presented in the literature; for example, sleep function (Bennington 2000), sleep mechanisms (Siegel 2004), sleep disorder (Richert & Baran 2003), sleep phylogeny (Nicolau et al. 2000), to name but a few. However, a quantitative (or bibliometric) description of the sleep research literature has not been undertaken to date.

The objective of this study is to provide an overview of the sleep literature in medicine and the life sciences. Using some bibliometric indicators, the results are presented and discussed with respect to the economic and population dynamics of representative countries. Our intention is to provide a broad view of the sleep research literature, that, though subjectively selected, demonstrates preliminary publication trends based on productivity of countries through the journals in which they published.

Methods

The raw data obtained for this study were extracted from the *Current Contents/Life Sciences* and *Current Content/Clinical Medicine* databases established by the Institute for Scientific Information (ISI) for the publication year 2003.

The data collection was performed in two successive steps: Step one aimed at extracting publications dealing with sleep or sleep-related phenomena from the biological and clinical database. The keyword used to extract the desired publications was *sleep** where the asterisk was used to retrieve all words beginning with sleep. The fields searched for occurrences of *sleep** were the title, abstract, and the keywords.

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The second step was to refine the selection obtained. The abstracts of each publication were scrutinized and retained only when published in journals and categorized as journal articles; publications were excluded when the relationship between sleep and the work presented was too vague.

For each country, the following measures were computed.

- The average impact factor for each country is based on the 2002 journal impact factor (JIF) for each journal.[1] If there is more than one article in a journal, then the JIF is multiplied by the number of articles in that journal; this is then summed for each journal and divided by the total number of articles produced by each country.[2] The JIF is one measure of journal influence as gauged by the uses made of journals through citations; it is used worldwide by researchers and clinicians.
- The mean of co-authors; for internationally co-authored papers; a full count was credited to each contributing country.
- The median of the cited half life for the sleep research journals.
- The percentage of international collaborations.
- The percentage of intra-national collaborations.
- The ratio of the number of journal articles and the total population of the 15 most productive countries was computed and considered as a measure of diffusion of the sleep research literature within a given country.
- The ratio between the number of journal articles and the Gross Domestic Product (GDP) which provides a simple economic index.

All journals were classified into one of the scientific subdisciplines belonging either (or both) to the field of *Life Sciences* or *Clinical Medicine*. This classification was made through the journal classification established by the ISI.

For the most prolific 25 journals the journal rank within the Life Sciences and Clinical Medicine subdisciplines (JRK) was computed using the following formula:

$$JRK = 1 - (n - 1)/N,$$

where n = descending ranking number within subdiscipline
N = total number of journals in the subdiscipline.

With this formula, JRK = 1 for the first ranked journal and JRK = near 0 for the last ranked journal.[3] Finally, it should be noted that the European Union (EU) is defined as the 25 official Member States as of 05-01-2004, and journal articles originating from England, Scotland, Northern Ireland, and Wales are grouped under the United Kingdom (UK).

Results

During the study period, there were 2325 journal articles on sleep research in the fields of medicine and biology; these articles were authored (or co-authored) from researchers in 66 countries.

Publication Distribution

The distribution of the journal articles on sleep research during the year 2003 is shown in Table 1, ranked by countries in decreasing order of the number of journal articles.[4] As can be seen, the USA is

[1] The 2002 *Journal Citation Reports* (JCR) was the latest available to the researchers at the time of data analyses. Although the articles analyzed for this study were published in 2003, the journal Impact Factors for 2002 are suitable to use since submission of articles would have been made (most likely) sometime in 2002.

[2] In publications where authors come from more than one country, each contributing country gets a 'whole' (rather than a 'fractional') count.

[3] For information on the calculation of the journal rankings (JRK), see http://alpha1.infim.ro/~ltpd/Science_Journal_Ranking_Version_2003.txt (accessed 7 April 2005).

by far the most prolific country (905), followed by Germany (204), and a group of countries (Japan, the UK, France and Canada) with approximately one-sixth of the USA publications. Then, 29 countries are ranked in decreasing number of publications (102 to 7); the remaining countries (31) produced five or fewer journal articles. This highly skewed distribution of journal articles over countries is typical of various informetric laws (Wilson 1999).

With regard to broad geographical distribution, Europe predominates with 10 countries among the top-15 ranked countries producing 85% of the publications; North America has two countries and accounts for nearly 39% of the publications, while the Asia-Pacific area is represented by Japan and Australia for nearly 10%. Most of the EU countries appear in the first half of the ranked countries which account for nearly 98% of the journal articles. The other half of the countries producing just over 2% of the journal articles are primarily in Africa (see Table 1).

The average impact factor ranges from 0.3 to 6.2 with the top-15 countries ranging (more narrowly) from 2.3 to 3.5. Nine countries in ranks 16 to 35 have average IFs of 2.0 or below. It is interesting to note that two countries (Malaysia and Vietnam) with the highest average IF of 6.2 each have one (and the same) co-authored journal article published in the J*ournal of Allergy and Clinical Immunology* with a JIF of 6.2.

Also presented in Table 1 are other indicators such as the cited half life, the mean co-authors, and the percentages of articles with intra-national and international collaboration for each country. Concerning the top-15 most prolific countries, the mean number of co-authors ranged from 4.3 to 6.4 with an average of 5.2 authors, while the median cited half life ranged from 5.8 to 7.0 years; however, standard errors calculated for each country show that no country can be dissociated with these measures. When percentages of international collaboration were considered, most of the top-15 countries ranged from 14% to 31% except for Belgium (52%), The Netherlands (54%) and Switzerland (60%). On the other hand, the intra-national collaborations ranged from 42% (Germany) to 80% (Finland) except for Switzerland (30%), Belgium (36%) and The Netherlands (38%).

The ratio between the number of articles per population, and the ratio between the number of articles and the Gross Domestic Product of the 15 most prolific countries are shown in Table 2. The 15 countries can be divided in two groups: 1st – USA, Japan, Germany, France, United Kingdom, Italy, and Spain with high total population (>40 million), a small number of articles per million inhabitants (ranging from 1.3 for Spain to 3.1 for USA), and a small ratio between the number of articles and the GDP (ranging from 0.04 for Japan to 0.10 for the UK); and 2nd – Canada, Australia, The Netherlands, Belgium, Sweden, Switzerland, Israel and Finland with small populations but with higher values for the number of articles per million inhabitants (from 4.3 for The Netherlands to 8.6 for Switzerland), and for the number of articles per GDP (from 0.15 for Canada to 0.38 for Israel).

Journal Characteristics

This study involves articles published in 663 journals belonging to all subdisciplines of the *Life Sciences* and *Clinical Medicine* disciplines. The distribution of the article among the journals is as follows: the 25-most productive journals (representing 3.7% of the total number of journals) concentrate 31% (729 articles) of the total number of articles published. On the other hand, approximately two third of the journals (65%) have only one or two articles. This highly skewed distribution of articles over journals is typical of Bradford's law of scattering of journal papers on a subject.

[4] Note that the total number of 'unique' journal articles is 2325; however, because of the 'whole' counting method used for allocating publications over countries, there are a total of 2709 'non-unique' publications distributed over the 66 countries.

Table 1. Number of sleep-related journal articles (in decreasing order) and other indicators for 66 countries from the ISI *Current Contents* databases for Life Sciences and Clinical Medicine for 2003.

Country	Number of articles in 2003	Average impact factor (using 2002 JIFs)	Cited half life Median (2002)	Mean co-authors and (standard error)	% of articles with intra-national collaboration	% of articles with international collaboration
USA	905	3.4	6.9	4.6 (2.9)	61	19
Germany	204	2.8	6.0	5.2 (2.9)	42	27
Japan	174	2.5	6.8	6.1 (2.8)	55	17
United Kingdom	163	2.9	6.1	5.1 (4.8)	48	31
France	145	2.3	6.4	5.5 (5.0)	57	28
Canada	144	3.4	6.9	4.4 (2.0)	57	29
Italy	102	2.8	6.1	6.4 (2.8)	49	21
Australia	85	3.0	7.0	4.6 (2.1)	54	31
Netherlands	70	2.8	6.1	5.5 (2.8)	38	54
Switzerland	63	3.5	5.5	5.0 (2.4)	30	60
Sweden	62	2.7	6.9	4.3 (2.1)	48	30
Belgium	57	3.5	5.8	5.6 (3.9)	36	52
Spain	55	2.9	6.6	5.9 (3.1)	60	21
Israel	47	2.7	6.3	4.7 (2.2)	76	25
Finland	41	2.4	6.5	5.1 (2.3)	80	14
Brazil	32	1.8	5.9	4.2 (2.0)	43	9
Austria	28	2.3	5.7	6.0 (3.0)	50	39
China	27	2.2	7.7	4.7 (2.0)	48	33
Mexico	21	1.9	6.8	5.0 (2.7)	57	9
Russia	21	2.7	6.4	4.4 (2.1)	28	28
Taiwan	21	1.5	6.9	4.6 (1.9)	85	19
Denmark	19	2.5	6.9	3.7 (1.9)	42	47
India	19	1.8	6.4	3.6 (1.7)	26	21
Turkey	19	1.2	7.1	4.4 (2.2)	52	75
Norway	18	2.0	6.4	3.8 (2.6)	38	16
New Zealand	17	2.5	7.5	4.6 (2.2)	64	23
Greece	15	2.1	6.2	5.8 (5.3)	40	33
Singapore	11	2.2	7.4	3.9 (2.5)	36	36
Ireland	10	2.9	7.5	5.7 (3.0)	30	40
Poland	10	1.7	6.2	4.9 (2.3)	30	70
South Korea	10	1.4	4.7	5.2 (3.3)	60	10
Hungary	9	4.4	7.0	3.7 (1.6)	33	55
South Africa	9	2.1	8.4	4.5 (2.6)	11	54
Czech Republic	8	2.3	5.5	5.1 (2.1)	50	50
Argentina	7	0.9	5.4	4.7 (2.3)	42	28
Chile	5	2.7	6.8	5.8 (1.7)	20	80
Thailand	5	1.5	7.4	3.0 (4.4)	20	20
Cote d'Ivoire	4	2.4	8.0	7.7 (1.2)	50	75
Kenya	4	4.4	8.4	9.2 (2.5)	0	100
Nigeria	4	0.9	5.5	4.2 (3.2)	50	25
Uruguay	4	2.4	6.9	3.7 (1.5)	0	50
Saudi Arabia	3	0.4	4.2	3.6 (2.0)	50	0
Albania	2	2.2	5.1	3.0 (0.0)	0	100
Bulgaria	2	1.1	6.1	5.5 (4.9)	50	50
Congo	2	1.7	6.5	3.0 (0.0)	0	100
Croatia	2	3.0	7.7	5.5 (3.5)	0	50
Egypt	2	2.8	7.5	7.5 (6.3)	0	100
Jordan	2	1.0	7.0	2.5 (0.7)	50	0
Oman	2	0.5	6.1	3.0 (0.0)	50	0
Portugal	2	2.0	3.3	5.5 (0.7)	50	0
Uganda	2	2.2	6.7	4.5 (2.1)	0	50
Cameroon	1	0.2	10.0	3.0 (0.0)	0	0
Gabon	1	1.0	5.7	4.0 (0.0)	0	100
Gambia	1	1.7	9.3	4.0 (0.0)	0	100
Iran	1	1.2	7.6	3.0 (0.0)	0	0
Lituania	1	0.9	3.7	7.0 (0.0)	0	100
Malaysia	1	6.2	5.4	10.0 (0.0)	100	100
Morrocco	1	0.4	8.8	7.0 (0.0)	0	0
Pakistan	1	1.4	4.7	2.0 (0.0)	100	100
Central African Republic	1	2.7	9.6	8.0 (0.0)	0	100
Senegal	1	1.7	3.8	9.0 (0.0)	0	100
Sudan	1	1.1	6.0	3.0 (0.0)	0	100
Tunisia	1	0.5	6.0	5.0 (0.0)	100	0
United Arab Emirates	1	0.3	4.2	2.0 (0.0)	100	0
Vietnam	1	6.2	5.4	10.0 (0.0)	0	100
Zaire	1	1.7	3.8	6.0 (0.0)	100	100

Table 2. Demographic and economic indicators for the top-15 most productive countries in decreasing order of population in 2003.

Country	2003 Population (in millions of inhabitants)	Ratio: no. of articles/millions of inhabitants	2003 GDP (billions US dollars)	Ratio: no. of articles / GDP
USA	290.3	3.1	10400	0.08
Japan	127.2	1.3	3550	0.04
Germany	82.3	2.4	2184	0.09
France	60.1	2.3	1540	0.09
United Kingdom	60.0	2.7	1520	0.10
Italy	57.9	1.7	1438	0.07
Spain	40.2	1.3	828	0.06
Canada	32.2	4.4	923	0.15
Australia	19.7	4.3	528	0.16
Netherlands	16.1	4.3	434	0.16
Belgium	10.2	5.5	297	0.19
Sweden	8.8	7.0	227	0.27
Switzerland	7.3	8.6	231	0.27
Israel	6.1	7.7	122	0.38
Finland	5.1	8.0	136	0.30

Table 3 shows the 25 top-ranked journals along with the following information: ISI journal subject categories under the broad headings of *Life Sciences* and *Clinical Medicine*, journal impact factors, journal ranks within the journal subject disciplines (JRK), cited half life in years, and number of sleep research articles. Not surprising, the journal, *Sleep* ranks first with 117 articles followed by a distant second, the *Journal of Sleep Research* (49). Most of the journals (84%) appear in disciplines belonging to *Life Sciences*, and only 56% appear in disciplines belonging to *Clinical Medicine*. Their impact factors are distributed in the range 0.7-8.0 with 56% having IFs >3.0; the cited half lifes are distributed in the range of 2.6-10 years. Nearly all the JRK values are high (between 0.58 and 1.00) with the exception of one journal, *Psychiatry and Clinical Neurosciences* (0.21).

Comparison between USA and EU productivity

Of the 2325 'unique' journal articles published in 2003, there were 905 (38.9%) with at least one USA author, while 912 (39.2%) articles had one or more EU author(s).[5] Among these two sets of articles, 89 were written collaboratively between USA and EU authors. This represents nearly 10% of the articles from either the USA or the EU. Additionally, the percentages of publications involving intra–EU collaboration (56%) was similar to those of intra-USA collaboration (61%). This similarity between the USA and EU was also observed for their international collaboration – both were at 19%.

The general distributions of all 2003 articles in sleep research from the ISI *Current Contents* databases for the journal subject categories in the fields of *Life Sciences* and *Clinical Medicine* are presented in Figures 1a and 1b; Figures 1c and 1d show comparable subject distributions for the USA and the EU countries. One can readily see that articles dealing with sleep research are widely distributed in all categories of the *Life Sciences* and *Clinical Medicine* with *Neurosciences & Behavior* and *Neurology* representing the most publications. Concerning the *Life Sciences* subject categories (Figure 1d), there are no differences observed between the EU countries and the USA (χ^2 test, $p = 0.11$). However, for publications in the broad area of *Clinical Medicine* (Figure 1c), the EU countries differ from the USA (χ^2 test, $p = 0.02$); major differences appear in the subject categories *Cardiovascular and Respiratory Systems* (68 for the USA versus 94 for the EU countries), while *Pediatrics* (57 versus 32), and *General & Internal Medicine* (55 versus 34) show greater numbers of publications for the USA. The others categories in which noticeable differences can be observed are *Clinical Psychology & Psychiatry* (53 versus 32) and *Otolaryngology* (37 versus 28).

[5] Note that in Table 1, the total number of articles from 18 contributing EU countries is greater than 912; in fact, it is 1001. The difference is due to the 'whole' allocation of articles to each EU country when there is more than one EU author on an article.

Table 3. Characteristics of the top-25 most used journals in sleep-related research as seen through the ISI *Current Contents* databases for Life Sciences and Clinical Medicine for 2003.

Journals	Life Sciences	Clinical Medicine	JIF	JRK	cited half life (years)	number of articles
Sleep	Neuroscience & Behavior	Neurology	3.7	0.70	7.0	117
Journal of Sleep Research	Neuroscience & Behavior		3.2	0.60	5.1	49
Chest	Cardiosvascular & Hematology Research	Cardiovascular & Respiratory Systems	2.9	0.68	7.3	47
Brain Research	Neuroscience & Behavior		2.4	0.82	9.7	43
Journal of Applied Physiology	Physiology		4.7	0.97	10.0	41
American Journal of respiratory and Critical Care Medicine	Medical Research, Organs & Systems	Cardiovascular & Respiratory Systems	6.5	1.00	4.3	35
Pediatrics	Medical Research, General Topic	Pediatrics	3.4	0.97	7.2	34
Neurology	Neuroscience & Behavior	Neurology	5.3	0.87	6.1	31
Neuroscience Letters	Neuroscience & Behavior		2.1	0.78	6.8	28
Clinical Neurophysiology	Neuroscience & Behavior		2.1	0.66	2.6	26
Journal of Neuroscience	Neuroscience & Behavior		8.0	0.94	5.1	26
Respiratory, Physiology & Neurobiology	Medical Research, Organs & Systems		2.3	0.60	10.0	25
Neuroscience	Neuroscience & Behavior		3.4	0.91	6.8	24
European Respiratory Journal	Medical Research, Organs & Systems	Cardiovascular & Respiratory Systems	2.9	0.71	5.2	23
Journal of Psychosomatic Research		Clinical Psychology and Psychiatry	1.8	0.61	8.5	22
European Journal of Neuroscience	Neuroscience & Behavior		4.1	0.92	4.1	21
Journal of Neurophysiology	Neuroscience & Behavior		3.7	0.89	7.4	17
Otolaryngology, Head and Neck Surgery		Otolaryngology	1.0	0.61	7.4	17
Acta Oto-Laryngologica	Medical Research, Organs & Systems	Otolaryngology	0.7	0.58	10.0	16
Epilepsia	Neuroscience & Behavior	Neurology	3.5	0.75	6.6	16
Movement Disorders	Neuroscience & Behavior	Neurology	2.9	0.73	4.9	16
Laryngoscope		Otolaryngology	1.3	0.70	9.7	15
Journal of Physiology London	Physiology		4.6	0.94	9.5	14
Journal of Clinical and Endocrinal Metabolism	Endocrinology, Nutrition & Metabolism	Endocrinology, Metabolism & Nutrition	5.2	0.91	6.0	13
Psychiatry and Clinical Neurosciences		Clinical Psychology and Psychiatry	0.6	0.21	3.8	13

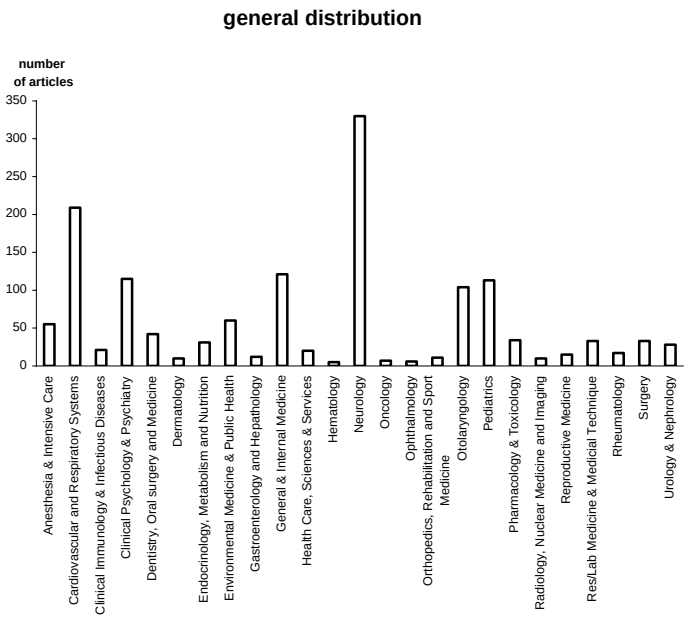

Figure 1a. Global publication profile of the Sleep literature in **Clinical Medicine** as seen through the ISI *Current Contents* databases for 2003.

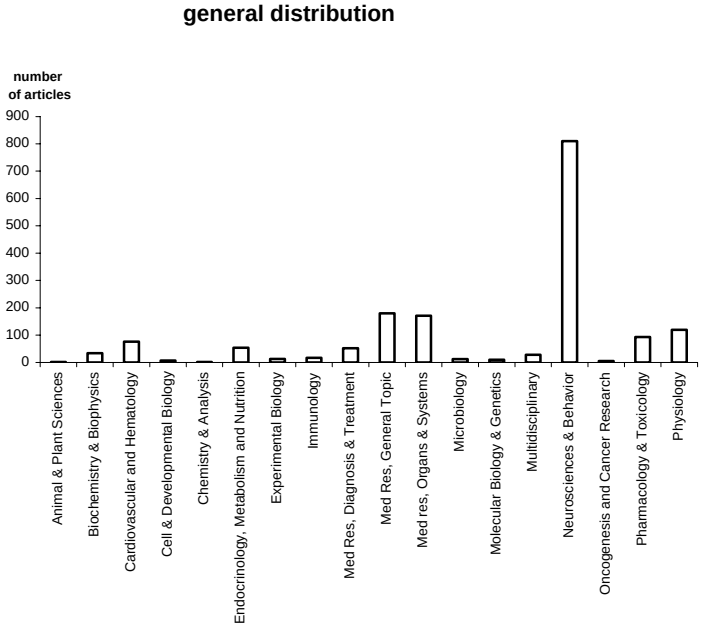

Figure 1b. Global publication profile of the Sleep literature in **Life Science** as seen through the ISI *Current Contents* databases for 2003

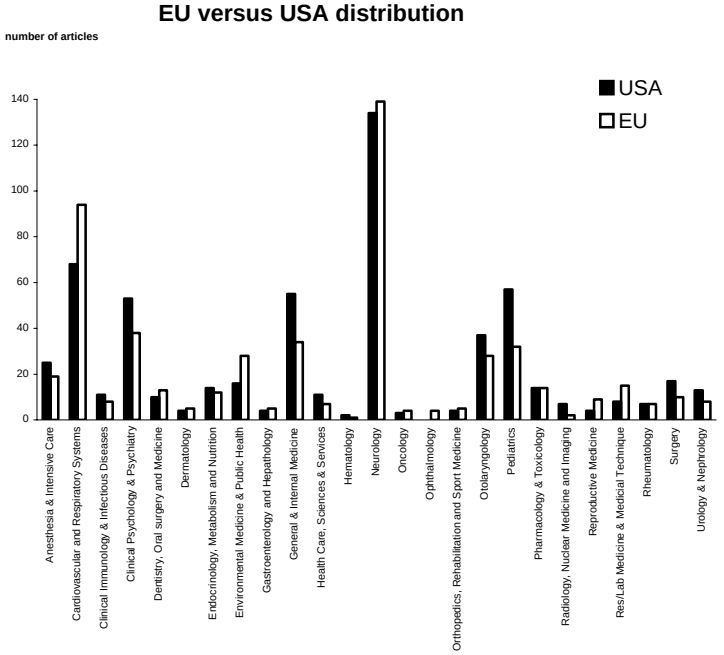

Figure 1c. USA and EU countries publication profiles of the Sleep literature in Clinical Medicine as seen through the ISI *Current Contents* databases for 2003.

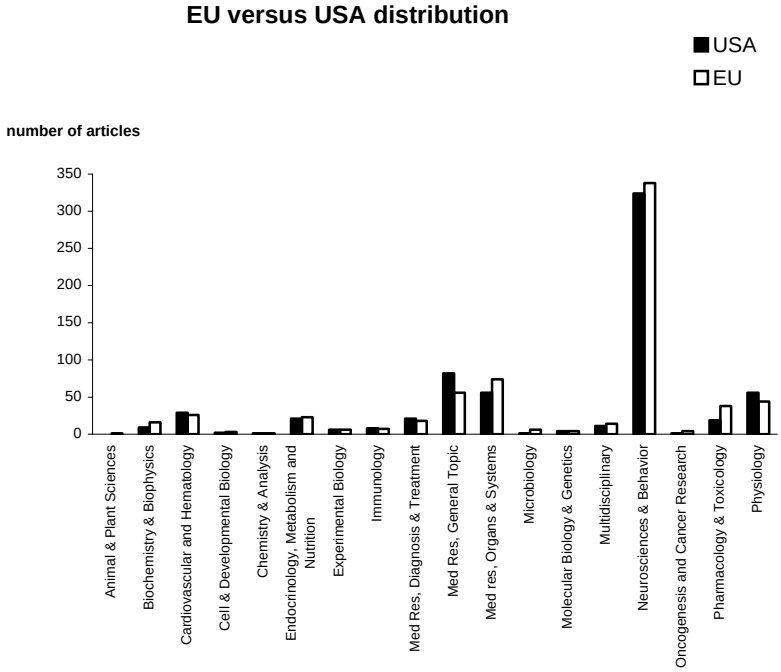

Figure 1d. USA and EU countries publication profiles of the Sleep literature in Life Science as seen through the ISI *Current Contents* databases for 2003

Discussion

The quantitative overview presented in this study is indicative of the high scientific productivity in sleep and sleep-related phenomena from researchers in medicine and biology. Besides the USA at 905 articles, there are five countries producing from about 100 to 200 publications; these are: Germany (204), Japan (174), the United Kingdom (163), France (145), Canada (144) and Italy (102). As expected, 14 of the Top-15 producing countries in this study are also present as leading producers of scientific publications in the field of medicine and biology in an earlier study by Glanzel et al. (2002). The only exception is Finland which is ranked 15th in this study and ranked 16th in the study by

Glanzel et al. (2002). This agreement is not surprising as the field of sleep research and sleep-related phenomena is largely connected with the other fields of research in medicine and biology. Deeper comparison with this last study can not be made as there are important differences between the two studies: the period of investigation, the publication types analyzed, the definition of the scientific fields, the ISI databases searched, etc.

Mainstream scientific output analysis in African countries placed South Africa has the most productive in the 1990s (Narvaez-Berthelemot et al. 2002). This agrees with publications on sleep research; that is, South Africa is the top-ranking African country in our study with nine articles (Table 1). The remaining African countries in Table 1 produced fewer than five articles. This weakness in African (and other developing countries) productivity in sleep research can be overcome by increasing international co-authorship between developing countries and developed countries such as the USA and the EU countries.

When the ranking was considered using other variables such as the number of articles per inhabitants, or number of papers per GDP, small countries in the European geographical area (The Netherlands, Belgium, Sweden, Switzerland and Finland) ranked higher than more populated EU countries (Germany, France, the UK, Italy and Spain). The same observation was also made in other studies related to some specific medical fields such as ophthalmology (Ugolini et al. 2001) and oncology (Mela et al. 1999), to name a few. A higher percentage of the GDP allocated to research or a better utilisation of resources can be advanced as explanations for our results, though other reasons are certainly possible.

No deep analysis can be drawn from the countries at the tail end of Table 1 as the number of articles are too small (<6), suggesting either isolated research and/or researchers or relatively modest investigation involving sleep research. Nevertheless, it is worth noting that some sleep-related research of high quality is performed in small, and developing, countries.

As expected, research on sleep or sleep-related phenomena appears in all disciplines of biology and medicine (see Table 3). The most prolific journals (*Sleep* and *Journal of Sleep Research*) are dedicated to experimental and clinical research on sleep, but their readers may belong to a variety of primary disciplines, including pneumology, neurology, psychiatry, psychology, otolaryngology, and dentistry to name a few. Additionally, while these journals may be of prime interest to sleep researchers worldwide, sleep-related journals may also be important as they can reflect research activities in the subscribing (and therefore readership) countries. The other prolific journals are either specialized journals for which sleep plays an important part (e.g., *Chest, Pediatrics, Otolaryngology, Head and Neck Surgery*), or journals on the general subject of neuroscience (e.g., *Neurology, Neuroscience Letters, Journal of Neuroscience*). The high impact factors of the top-11 journals range between 2.1 to 8.0; this is representative of the overall interest of the scientific community for sleep research. The high (or leading) positions of the journals within their journal subject categories is reflected by the high journal ranking index (JRK), between 0.66 to 1.00 (Table 3). The JRK is a supplementary indicator confirming the 'liveliness' of the Sleep community. Additionally, 45 articles were published in journals with Impact factors >10 (e.g., *New England Journal of Medicine, Nature, Science*).

Also as expected, the worldwide distribution of sleep research publications in the *Life Sciences* and *Clinical Medicine* is characterized by high productivity in the subject disciplines of Neurosciences (*Neurology* for Clinical Medicine and *Neurosciences & Behavior* for the Life Sciences). This leading discipline is followed by disciplines with fewer publications (*Cardiovascular & Respiratory Systems, Pediatrics, Clinical Psychology and Psychiatry*, for Clinical Medicine, and *Medical Research, General Topic*, *Organs and Systems*, and *Physiology* for Life Sciences). The rest of the subject fields produced considerably few publications. An interesting approach would be to correlate the results of this study with a bibliometric study focusing on research in the broad area of Neuroscience to establish the importance (with respect to the number of publications) of sleep research within that of other subject areas of Neuroscience. Unfortunately, to our knowledge, the existing bibliometric studies of the literature of neurosciences are either centered on specific countries (Gomez et al. 1990, Glanzel et al. 2003, Xu 2003, Pareja 2004); focused on a specific sub-discipline of Neuroscience (Schwechheimer & Winterhager 2001); measured citation impact of journals in clinical neurology (Yue & Wilson 2004a); or correlated results of peer assessment of journal quality in clinical neurology

with that of journal citation impact (Yue & Wilson 2004b). One can hope that this gap will be filled in the future.

The results of this study also confirm the leadership of two major geographical areas, the USA and the EU. The profiles of the USA and EU are similar, but a slight difference can be observed in the field of *Clinical Medicine*. The level of collaboration between the EU and USA is negligible (~10% of articles) as contrasted with that of intra-USA (61%) or intra-EU articles.[6] In fact, some factors such as geographical distance or specificity in clinical approaches can explain these apparent practices. Moreover, in order to establish their own communities, these two poles have developed their own Sleep societies and society-sponsored journals: The American Academy of Sleep Medicine and the journal, *Sleep*; and the European Sleep Research Society and the *Journal of Sleep Research*. Additionally, one could say that these comparisons are small-scale snapshots of the EU-USA race for leadership in science and technology as discussed in a previous study by Shelton & Holdridge (2004). Nevertheless, these two major sleep research poles can be viewed as necessary for the harmonious and balanced progress in sleep research, even if there is the absence of a third research front in the Asia-Pacific area.

Another important fact is that the EU, which is increasingly becoming an integrated geographic area, has more in common with the USA in research productivity; however, unlike the homogeneity of the USA, the EU25 is still a group of disparate countries with great diversity in scientific productivity. In fact, this heterogeneity is present in our study; for example, Table 2 indicates that ten EU countries are present among the top-15 most productive countries, while Table 1 shows that a number of EU countries are either producing fewer than 30 publications (e.g., Austria, Denmark, Greece, Poland the Czech Republic) or do not feature at all (e.g., Luxembourg, Estonia, Malta). Several factors, such as population, cultural differences and language biases, could explain these discrepancies (Van Leeuven et al. 2001, Inönü 2003). However, the mandate of EU politics to implement European research areas as central icons, combined with the establishment and development of various sleep organizations such as the *European Sleep Research Society* or the *European Society of Sleep Technologists* will probably homogenize the scientific activities related to sleep research.

Limitations of the Study

One major limitation of this research project – the restriction of the ISI databases to primarily English language journals in the broad area of Neurosciences – meant that only three journals with the word 'sleep' in the title appear: *Sleep, Journal of Sleep Research*, and *Sleep Medicine Reviews*. Other journals concerning sleep research exist but are not included in the ISI databases: for example, *Behavioral Sleep Medicine, Sleep and Biological Rhythms,* to name two. It is worth noting that electronic sleep journals are available (Shipman 2004), most of which are too new to be considered for inclusion in the ISI databases. Furthermore, we considered only document types designated as 'articles' by ISI, while other document types were excluded (e.g., book chapters, abstracts, technical notes). The major advantage of this restrictive approach is that all 'articles' are peer-reviewed ensuring a 'uniform' level of quality. The selection of keywords and the criteria used for inclusion or exclusion of the retrieved articles were based on the judgements of the investigators, and remains open to criticism. It must be noted, as well, that this study was not designed to compare the distribution of sleep research publications through time; rather it was to provide a one-year snapshot of sleep productivity in high-quality, international and referred journals in the ISI databases; a longitudinal study is out of the scope of this study.

Another drawback of this study is the absence of citation analysis at either the journal level or at the article level. As the study is for recent (2003) publications on sleep-related research, citation

[6] Table 1 shows only individual intra-national collaboration for the EU countries; however a composite percentage reveals this to be quite high. Likewise, international collaboration between the USA and the EU countries are not shown in Table 1; though the USA has only 19% of its publications with co-authors outside the USA. The EU countries show percentages of international collaboration only for individual EU countries – this is as high as 54% for The Netherlands (EU15 Member States) and 70% for Poland (EU25 Member States). Reference to the EU25 is made (although the 2003 data reflects the EU15 Member States), since readers in 2005 onwards will reflect on the EU25 rather than the former EU15. We note that the results presented in this study are not greatly changed as only 20 of the 912 articles are from the remaining 10 countries representing the EU25.

analysis was not appropriate to pursue at this time. As mentioned earlier, Yue & Wilson (2004a, 2004b) have looked at journal citation analysis on the broader subject area of clinical neurology, but not specifically on journals or articles which published sleep-related research.

Further analysis of the literature of sleep research could be expanded to include: more years (e.g., a five-year span to include a journal citation or co-citation study); more electronic databases (e.g., *MEDLINE, EMBASE*); more keywords (e.g., insomnia, dreams, somnolence, somnabulism, narcolepsy, wakefulness) to amplify the results of this study. Nevertheless, this research has shown the importance of sleep-related research in both the Life Sciences and Clinical Medicine. Moreover, this work can be considered as complementary to the various qualitative reviews regularly published on the subject of sleep, offering to the reader a better understanding of the research richness in the beginning of the millennium.

Finally, the sleep research literature could be explored in more depth for additional socio-economic issues such as: the percentage distribution in particular countries of the sleep research literature with respect to the total publications in all medical topics; and the interest of specific sleep literature in the various countries – for example, psychological aspects of sleep in developed countries as contrasted with tse tse derived sleep problems in developing countries. In searching widely for literature touching on such issues, we found a bibliometric study of research publications in the journal, *Tropical Medicine and International Health*, listing trypanosomiasis (sleeping sickness) in the top-10 of papers published by disease from 1996 to 2003 (Glover & Bowen 2004).

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