

Cardiovascular Scientific Production in Spain and in the European and Global Context (2003-2007)

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Introduction and objectives. The publication of research articles has increased considerably in recent years in all biomedical fields. The present study examines the position of Spanish quality research in cardiology in the European and world context, and its evolution during the 5-year period 2003-2007.

Methods. Using the Science Citation Index Expanded of Thomson Reuters as data source, we compared Spanish cardiovascular scientific production with that of the rest of countries in the European Union and of the most important countries worldwide, along with relative productivity as per number of inhabitants and Gross Domestic Product, and the number of citations in the journals of the Cardiac & Cardiovascular Systems area of the Journal Citation Reports (CCS-JCR).

Results. Spain ranks sixth in the European Union and ninth worldwide in scientific production (tenth worldwide if only the journals of the first quartile of the CCS-JCR area are considered). As regards the number of citations received, Spain ranks seventh in the European Union and eleventh worldwide. In terms of relative productivity as per number of inhabitants and Gross Domestic Product, the Spanish ranking is less favorable (positions 15 and 18, respectively).

Conclusions. The ranking of Spanish cardiovascular research is similar to that of other biomedical fields, though its position is less favorable in relation to certain demographic and economical indicators. In order to maintain adequate investigational levels, it is necessary for the European governments and scientific societies to regard the promotion of high-quality cardiological research as a priority concern.

Key words: *Scientific production. Cardiology. Spain. Europe. Relative productivity.*

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La producción científica cardiovascular en España y en el contexto europeo y mundial (2003-2007)

Introducción y objetivos. La publicación de artículos de investigación ha aumentado de manera considerable en los últimos años en todas las áreas biomédicas. El objetivo de este trabajo es determinar el lugar que ocupa la investigación cardiológica española de calidad en el contexto europeo y mundial y su evolución durante el quinquenio 2003-2007.

Métodos. Utilizando como fuente de datos la base de datos Science Citation Index Expanded de Thomson Reuters, se comparó la producción científica cardiovascular española con la de los países de la Unión Europea y los más destacados del mundo, así como la productividad relativa respecto al número de habitantes y producto interior bruto y el número de citas recibidas en las revistas del área «Cardiac & Cardiovascular Systems» del Journal Citation Reports (CCS-JCR).

Resultados. España ocupa el sexto puesto en el ranking europeo y el noveno en el mundial de la producción científica, pasando al décimo mundial si se consideran únicamente las revistas del primer cuartil del área CCS-JCR. En número de citas recibidas, España ocupa el séptimo lugar europeo y undécimo mundial. En la productividad relativa respecto al número de habitantes y el producto interior bruto, la posición española es menos favorable, ocupando la decimoquinta y la decimoctava posición, respectivamente.

Conclusiones. En investigación cardiovascular, España ocupa posiciones similares a otras áreas biomédicas, si bien su situación es menos ventajosa respecto a algunos indicadores demográficos y económicos. Para que se mantengan los niveles adecuados de investigación, es necesario que los gobiernos y las sociedades científicas europeas consideren el fomento de la investigación cardiológica de alta calidad como un objetivo primordial.

Palabras clave: *Producción científica. Cardiología. España. Europa. Productividad relativa.*

ABBREVIATIONS

CCS: Cardiac and Cardiovascular Systems
JCR: Journal Citation Reports
GDP: Gross Domestic Product

INTRODUCTION

Cardiovascular disease (CVD) is the primary cause of morbidity and mortality in the European Union (EU), the United States, and other industrialised nations. In the EU it is estimated that 80 million people are at risk of suffering a vascular accident within the next ten years, and that the number of deaths caused by CVD will increase by 60% between 2000 and 2020.¹ Resources aimed at these diseases have been estimated at €169 trillion per year, of which 62% is spent on treatment, prevention, and control.²

Scientific research is considered one of the pillars of economic development and growth in both industrialised and less developed nations.³ In recent years the publication of research articles has increased considerably in all biomedical areas, putting Spain in seventh position in Europe and eleventh worldwide during the period 1994-2002.⁴ Spanish scientific productivity in the cardiovascular field has also increased significantly in recent years. According to the Institute for Scientific Information Science Citation Index database,⁵ during the 1990-1996 period, the total cardiovascular productivity of Spanish authors increased by 83% and remained at 80.9 % between 1994 and 1999.⁶

The amount of economic resources and investments aimed at research is not exactly known, given the diversity of funding sources (regional, national and supranational, both public and private).³ However, the scale is such that it is necessary to utilise measures or indicators which can quantify research results and their impact. Bibliometric indicators, linked with other economic and social indicators, allow for the precise assessment of the developmental state of research and therefore provide a basis for political and scientific decision making.^{4,7}

The position occupied by Spain in Europe and worldwide with regard to cardiology research is not known, nor if this position corresponds to Spain's current status of eighth world economic power in terms of gross domestic product. An understanding of the Spanish position is fundamental in being able to remedy insufficiencies, as well as reaching a level

of critical understanding that would allow for the advancement of knowledge in the field.^{3,8} The aim of this study is to determine the position held by high-quality Spanish cardiology research both in Europe and worldwide, and its progress in recent years.

MATERIAL AND METHOD

Database Selection

The Science Citation Index Expanded (SCI-E) database from Thomson Reuters was used to examine Spanish productivity in the cardiovascular field.⁹ The SCI-E is routinely used in studies analysing scientific activity, since this database encompasses all scientific and technological fields and allows us to examine the repercussions or impact of publications after the publishing date. This study covers the 5-year period 2003-2007. All analysed documents were original articles: revisions, editorials, and letters were not included, neither were abstracts of communications to conferences, bibliographic articles, corrections, reprints, or announcements.

Strategy for Document Recovery and Bibliographic Searches

The downloading of information from the SCI-E was carried out online, using the *Web of Knowledge*¹⁰ platform, version 3.0, in January 2009.

With the aim of collecting all scientific productivity in the field, we selected articles published in all 78 journals included in the *Cardiac & Cardiovascular Systems* (CCS) category under *Journal Citation Reports* (JCR) during 2003-2007. During this period new journals were added to the JCR and some were removed. This fluctuation in the category is as follows: 2003: 70 journals; 2004: 71 journals; 2005: 72 journals; 2006: 74 journals; 2007: 74 journals.

To compare Spanish cardiological productivity with that of other countries, articles from each of the 27 European Union member states, as well as Norway and Switzerland, were searched. The European Union countries are as follows: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom. To assess the position of Spain and other European countries among the rest of the world, articles from the United States, Canada, Mexico, Brazil, Japan, Australia, China, India, New Zealand, and Russia

were also searched. These countries were selected due to being the most productive nations in each continent.

With the aim of garnering cardiovascular research of the highest scientific quality from both Spain and the above-mentioned countries, articles in journals from the first quartile of the CCS-JCR category were identified. The number of journals included in the first quartile did not remain constant during the 5-year period, with 18 in 2003, 2004 and 2005, and 19 in 2006 and 2007. Of the 24 journals identified in the category, only the 13 that were included in the first quartile for all 5 years were selected for analysis in this study.

To identify the quality and repercussions of published articles, the number of citations received by each country and the average number of citations per article were determined. This average was reached by dividing the total citations received by the total number of published articles. The time period for the number of citations was from the date of each article's incorporation into the SCI-E up to the date of the bibliographic search (January 2009).

Finally, in order to determine the productivity of each country, the relationship between the number of articles and either the population or gross domestic product (GDP) was determined.

RESULTS

Scientific Contribution to All Journals in the CCS-JCR Category

The total number of original articles published worldwide in journals within the CCS category during the 5-year period 2003-2007 was 54 968. Of this number, 22 389 (39%) were published by the 27 EU nations, 20 625 (35%) by the United States, and 15 346 (26%) by countries in the rest of the world. Those European countries which published the most articles were Germany (n=5445; 9.92%), United Kingdom (n=4557; 8.29%), Italy, (n=3546; 6.45%), France (n=2781; 5.06%) and the Netherlands (n=2471; 4.5%). Spain takes 6th place (n=1542; 2.81%) (Table 1). Other countries in addition to the United States that contributed over 1% of worldwide output are: Japan (n=5680; 10.33%), Canada (3268; 5.95%), Australia (n=1115; 2.03%), China (n=1057, 1.92%), Russia (n=775; 1.41%), and Brazil (n=640; 1.16%). Spain therefore holds 9th place overall in the world rankings. Figure 1 shows the annual progress in the number of articles published by the EU's most productive nations. The majority of countries maintain a steady output for the whole period, and significant increases in the number of articles can only be seen for Italy (from 595 articles

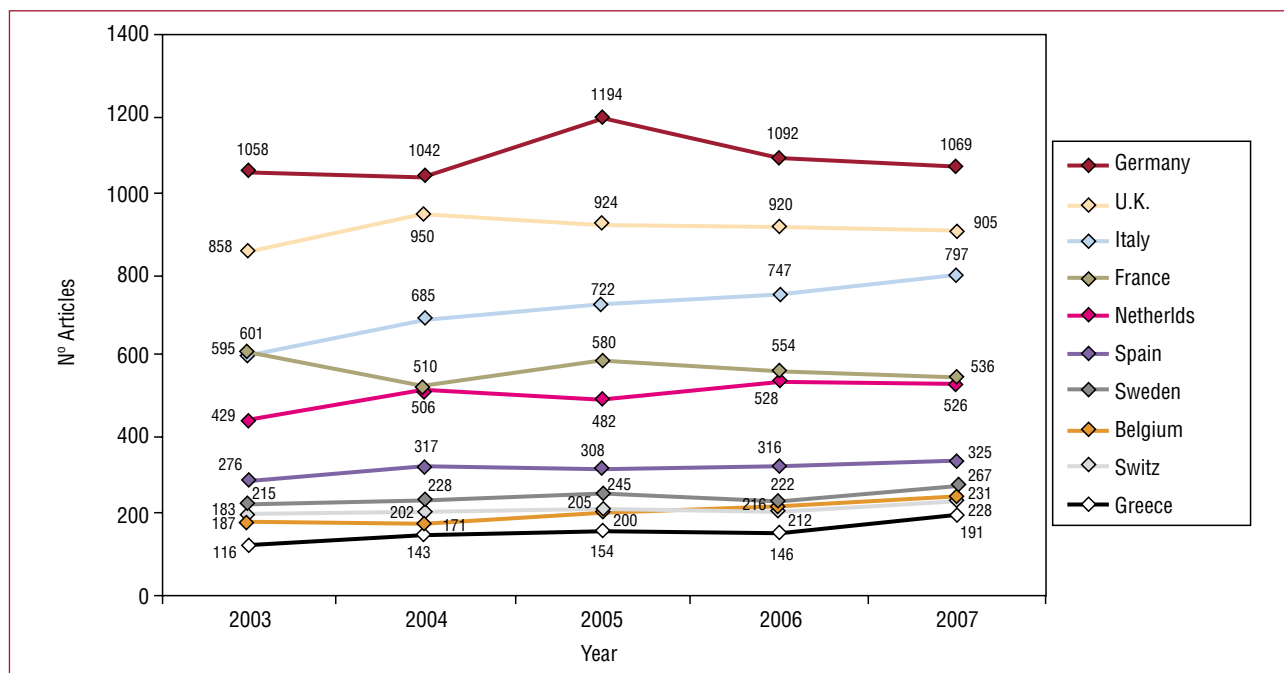


Figure 1. Annual development of EU-27 countries with the highest contribution to the CCS category.

TABLE 1. Articles Published by European Countries in the Cardiac and Cardiovascular Systems Category and Citations Received Since Date of Publication

Countries	Total CCS					First Quartile CCS				
	2003-2007					2003-2007				
	Total Articles	Articles of Total CCS, %	Total Citations	Citations of Total CCS, %	Average Citations/Article	Total Articles	Articles of Total CCS, %	Total Citations	Citations of Total CCS, 5	Average Citations/Article
Germany	5455	9.92%	70 679	12.29%	12.96	2541	9.45%	58 486	12.58%	23.02
Austria	597	1.09%	7561	1.31%	12.66	310	1.15%	6094	1.31%	19.66
Belgium	1007	1.83%	13 586	2.36%	13.49	602	2.24%	11 935	2.57%	19.83
Bulgaria	17	0.03%	121	0.02%	7.12	6	0.02%	101	0.02%	16.83
Cyprus	10	0.02%	163	0.03%	16.30	5	0.02%	133	0.03%	26.60
Denmark	675	1.23%	10 005	1.74%	14.82	396	1.47%	8601	1.85%	21.72
Slovakia	48	0.09%	444	0.08%	9.25	17	0.06%	202	0.04%	11.88
Slovenia	53	0.10%	309	0.05%	5.83	16	0.06%	149	0.03%	9.31
Spain	1542	2.81%	15 359	2.67%	9.96	640	2.38%	11 998	2.58%	18.75
Estonia	21	0.04%	109	0.02%	5.19	4	0.01%	49	0.01%	12.25
Finland	532	0.97%	7928	1.38%	14.90	288	1.07%	6753	1.45%	23.45
France	2781	5.06%	33 121	5.76%	11.91	1277	4.75%	28 038	6.03%	21.96
Greece	750	1.36%	5631	0.98%	7.51	268	1%	3508	0.75%	13.09
Hungary	237	0.43%	2450	0.43%	10.34	109	0.41%	1976	0.42%	18.13
Ireland	255	0.46%	4115	0.72%	16.14	147	0.55%	3694	0.79%	25.13
Italy	3546	6.45%	43 281	7.53%	12.21	1834	6.82%	35 702	7.68%	19.47
Latvia	9	0.02%	130	0.02%	14.44	6	0.02%	122	0.03%	20.33
Lithuania	54	0.10%	275	0.05%	5.09	12	0.04%	227	0.05%	18.92
Luxembourg	11	0.02%	178	0.03%	16.18	3	0.01%	141	0.03%	47
Malta	3	0.01%	1	0	0.33	0	0	0	0	0
Netherlands	2471	4.50%	39 781	6.92%	16.10	1635	6.08%	35 279	7.59%	21.58
Poland	471	0.86%	5778	1.00%	12.27	198	0.74%	4749	1.02%	23.98
Portugal	98	0.18%	1099	0.19%	11.21	54	0.20%	894	0.19%	16.56
United Kingdom	4557	8.29%	62 751	10.91%	13.77	2708	10.07%	54 308	11.68%	20.05
Czech Republic	200	0.36%	2205	0.38%	11.03	85	0.32%	1674	0.36%	19.69
Romania	26	0.05%	309	0.05%	11.88	14	0.05%	275	0.06%	19.64
Sweden	1171	2.13%	15 704	2.73%	13.41	577	2.15%	12 399	2.67%	21.49
Norway	484	0.88%	6,706	1.17%	13.86	271	1.01%	5729	1.23%	21.14
Switzerland	1034	1.88%	12 039	2.09%	11.64	565	2.10%	11 014	2.37%	19.49
Total EU-27	22 389	40.73%	252 408	43.90%	11.27	10 834	40.29%	204 674	44.02%	18.89
Total EU-27 (+Norway/Sweden)	23 331	42.44%	262 049	45.57%	11.23	11 305	42.05%	212 424	45.68%	18.79
Industrialised nations										
Australia	1115	2.03%	16 169	2.81%	14.50	719	2.67%	14 367	3.09%	19.98
Brazil	640	1.16%	6343	1.10%	9.91	287	1.07%	4998	1.07%	17.41
Canada	3268	5.95%	41 497	7.22%	12.70	1994	7.42%	35 975	7.74%	18.04
United States	20 625	37.52%	285 914	49.72%	13.86	13 672	50.85%	253 273	54.47%	18.52
India	374	0.68%	1474	0.26%	3.94	57	0.21%	514	0.11%	9.02
Japan	5680	10.33%	44 773	7.79%	7.88	2048	7.62%	29 312	6.30%	14.31
Mexico	163	0.30%	1223	0.21%	7.50	75	0.28%	912	0.20%	12.16
New Zealand	257	0.47%	3563	0.62%	13.86	185	0.69%	3255	0.70%	17.59
People's Republic of China	1057	1.92%	9169	1.59%	8.67	448	1.67%	6816	1.47%	15.21
Russia	775	1.41%	1138	0.20%	1.47	31	0.12%	897	0.19%	28.94
Total EU-29 and industrialised nations	50 164	91.26%	552 109	96.02%	11.01	25 704	95.60%	452 112	97.23%	17.59
Rest of world	4804	8.74%	22 884	3.98%	4.76	1183	4.40%	12 879	2.77%	10.89
Total CCS category	54 968		574 993		10.46	26 887		464 991		17.29

in 2003 to 797 in 2007), and a minor decrease for France (from 601 articles in 2003 to 536 in 2007). *Revista Española de Cardiología* (Spanish Journal of Cardiology), which published 460 original articles

during the 5-year period, contributed 30% of the total articles published by Spanish institutions in CCS-JCR journals, this being 0.84% of worldwide contributions.

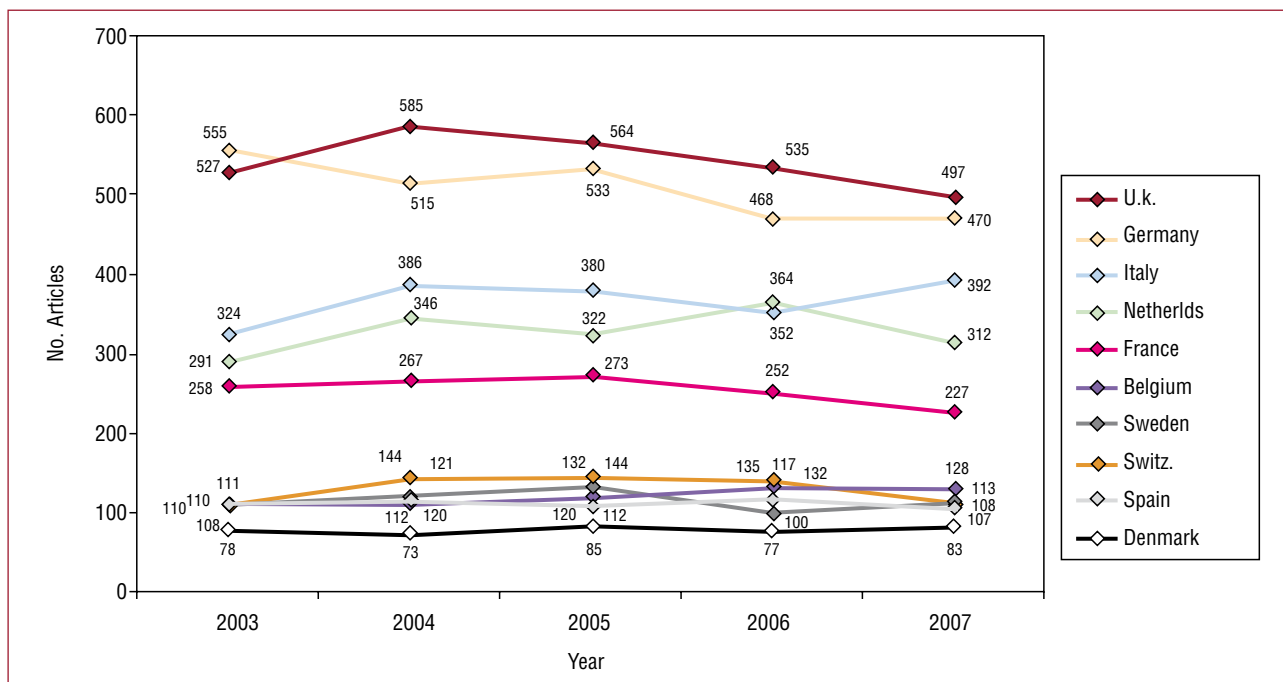


Figure 2. Annual production of EU-27 countries with the highest contribution to journals in the first quartile of the Cardiac & Cardiovascular Systems category.

Scientific Contributions to All First-Quartile CCS-JCR Journals

The total number of original articles published by all countries in first-quartile journals was 26 887, this being 48.91% of total contributions. Of this number, the United States published 13 672 articles (46%), the EU-27 10 834 (37%), and other countries published 4905 (17%). It should be noted that the sum of original articles from the EU-27, United States and rest of the world is greater than the total number of first quartile articles. This is because some articles were collaborations between countries in different groups.

Those European countries which published the largest number of articles are as follows: United Kingdom (n=2708; 10.07%), Germany (n=2541; 9.45%), Italy, (n=1834; 6.82%), the Netherlands (n=1635; 6.08%), and France (n=1277; 4.75%). Spain again holds 6th place, but with approximately half the number of articles published by its predecessor (n=640; 2.38%). Besides the United States, countries whose participation exceeded 1% of worldwide output are as follows: Japan (n=2048; 7.62%), Canada (n=1994; 7.42%), Australia (n=719; 2.67%), China (n=448; 1.67%), and Brazil (n=287; 1.07%). Spain holds 10th place in the world ranking (Table 1).

Figure 2 shows the annual progress in the number of articles published in this selection of journals by the EU's most productive nations. Again we see an increase in articles from Italy (rising from

324 articles in 2003 to 392 in 2007), and a minor decrease in articles from Germany (from 555 in 2003 to 470 in 2007), United Kingdom, and France.

Table 2 shows the number of articles published by each of the 27 EU countries (including Norway and Sweden) in those journals included in the first quartile of the JCR, as well as a comparison between the EU-27 and the United States, Japan, Canada, Australia, Brazil, China, New Zealand, Mexico, India, and Russia. Of the 13 journals included in this selection, 9 are edited in the United States (US) and 4 in the United Kingdom (UK). The number of articles published in US journals was 19 941, while the number published in European (EU) journals was 4003. The number of US articles published in all US journals exceeds that of EU articles except in the case of the *Journal of Thoracic and Cardiovascular Surgery* (440 US articles compared with 537 EU), while EU articles exceed US articles in EU journals except in the case of the *Journal of Molecular and Cellular Cardiology* (392 US articles compared with 234 EU). Figure 3 compares the number of first-quartile US and EU articles with the total overall number published in the first quartile of each journal. In overall figures, the percentage of EU articles published in US journals (35.13%) exceeds that of US articles published in EU journals (28.18%).

Those journals containing the largest number of articles by Spanish authors were *American Journal*

TABLE 2. Distribution by Country of Number of Articles Published in First-Quartile Journals in Cardiac and Cardiovascular Systems Category (2003-2007)

Countries	Circulation (US)	Journal of The American College of Cardiology (US)	Circulation Research (US)	European Heart Journal (UK)	Cardio-vascular Research (UK)	Journal of Molecular And Cellular Cardiology (UK)	Heart (UK)	American Journal of Physiology-Heart and Circulatory Physiology (US)	American Heart Journal (US)	Journal of Cardio-vascular Electrophysiology (US)	Journal of Thoracic and Cardio-vascular Surgery (US)	American Journal of Cardiology (US)	Journal of Heart and Lung Transplantation (US)
Impact factor 2007	12.755	11.054	9.721	7.924	6.127	5.246	4.141	3.973	3.716	3.475	3.354	3.296	3.087
Germany	387	247	266	269	196	70	119	142	121	90	146	191	87
Austria	50	24	21	27	14	3	10	24	17	14	35	20	23
Belgium	72	64	43	110	29	7	36	35	51	19	24	63	27
Bulgaria	—	—	2	1	—	1	—	1	—	—	—	—	1
Cyprus	—	—	1	2	—	—	—	—	—	1	—	1	—
Denmark	51	36	30	61	10	2	37	42	31	4	5	37	7
Slovakia	1	2	2	2	—	1	1	2	3	1	—	1	—
Slovenia	—	1	1	—	—	—	1	2	4	1	—	2	—
Spain	59	68	45	80	54	9	42	29	44	20	15	91	20
Estonia	—	—	—	—	—	—	—	—	1	—	1	—	—
Finland	49	28	25	51	6	9	9	26	7	6	12	30	7
France	165	128	117	152	70	32	56	112	70	54	69	105	39
Greece	13	29	5	29	4	3	30	3	27	5	8	70	7
Hungary	10	2	3	11	17	2	4	24	6	6	3	11	1
Ireland	27	7	11	18	4	3	16	13	8	3	5	11	2
Italy	214	239	128	210	45	24	96	73	128	55	112	294	38
Latvia	2	1	—	1	—	—	—	—	1	—	—	1	—
Lithuania	—	2	—	1	—	2	—	1	—	1	1	2	—
Luxembourg	1	—	1	—	—	—	—	—	1	—	—	—	—
Malta	—	—	—	—	—	—	—	—	—	—	—	—	—
Netherlands	227	199	117	197	82	24	97	99	118	48	43	232	21
Poland	33	21	9	28	7	1	12	9	28	2	6	27	1
Portugal	6	4	3	5	3	—	5	6	4	—	2	3	—
United Kingdom	328	262	224	240	132	69	398	142	138	54	100	223	91
Czech Republic	3	7	6	11	1	3	9	6	7	11	1	5	1
Romania	1	2	—	3	—	—	2	1	2	—	—	3	—
Sweden	64	51	36	114	12	13	39	38	57	11	19	40	7
Norway	40	24	17	35	15	11	13	31	19	1	8	34	2
Switzerland	81	57	57	62	21	15	32	50	25	14	36	43	22
Australia	79	71	65	45	35	17	31	69	57	13	35	70	61
Brazil	33	27	14	16	9	2	15	36	29	17	7	53	7
Canada	281	182	165	75	116	64	37	297	227	49	115	180	66
United States	1984	1372	1218	281	303	392	152	2237	1046	431	440	2263	575
India	2	5	1	—	2	2	5	6	10	1	11	8	—
Japan	255	171	185	45	136	102	56	262	72	84	222	231	49
Mexico	12	10	3	1	2	—	2	20	7	2	1	10	—
New Zealand	19	29	10	25	2	—	12	15	22	2	1	27	4
People's Republic of China	40	31	38	9	42	29	23	72	23	25	28	41	9
Russia	5	2	2	5	—	2	2	4	2	—	1	5	—
EU-27	1301	1030	845	1062	579	234	854	729	652	351	537	1202	359
Total 2003-2007	3953	2,478	1392	1200	939	767	1097	3313	1774	916	1351	3707	1057

of Cardiology (n=91), *European Heart Journal* (n=80) and *Journal of the American College of Cardiology* (n=68), while those with the fewest number of Spanish articles were the *Journal of Molecular and Cellular Cardiology* (n=9) and the *Journal of Thoracic and Cardiovascular Surgery* (n=15) (Table 2).

Comparison Between Articles Published in First-Quartile Journals and Those Published in the Entire CCS-JCR Category

Those countries with the highest percentage of articles published in first-quartile journals were: Latvia (66.67%), Netherlands (66.17%), Belgium

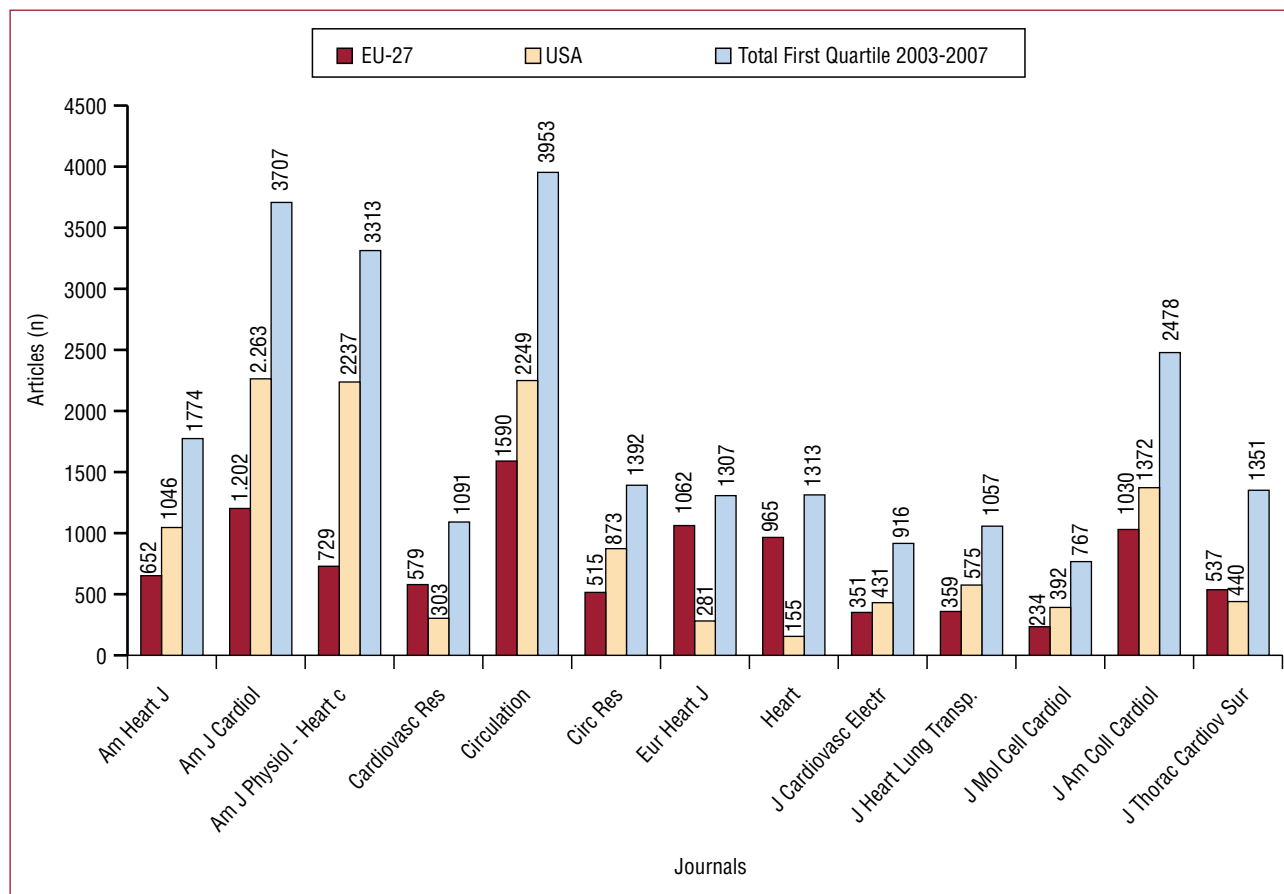


Figure 3. Comparison of original articles from the EU-27/US/rest of world published in journals in the first quartile of the Cardiac & Cardiovascular Systems category.

The EU-27 data originates from information from all countries combined using the Boolean operator OR, which identifies as a single document any collaboration between different countries.

Am Heart J indicates American Heart Journal; Am J Cardiol, American Journal of Cardiology; Am J Physiol-Heart C, American Journal of Physiology-Heart and Circulatory Physiology; Cardiovasc Res, Cardiovascular Research; Circulation, Circulation; Circ Res, Circulation Research; Eur Heart J, European Heart Journal; Heart, Heart; J Cardiovasc Electr, Journal of Cardiovascular Electrophysiology; J Heart Lung Transpl, Journal of Heart and Lung Transplantation; J Mol Cell Cardiol, Journal of Molecular and Cellular Cardiology; J am Coll Cardiol, Journal of the American College of Cardiology; J Thorac Cardio Sur, Journal of Thoracic and Cardiovascular Surgery.

(59.68%), United Kingdom (59.43%), and Denmark (58.67%) (Table 3). If no correction factor were applied, Germany would hold 16th place, France 18th, and Spain 21st. However, some of the countries leading this table published very few articles (for example, Latvia published only 9 during the 5-year period). If a minimum threshold of 500 articles were applied, the table would be led by the Netherlands, followed by Belgium, United Kingdom, Switzerland, Italy, Sweden, Germany, France, and Spain, which held 9th place with 41.5% of articles (24.67 percentage points below the Netherlands and 6.89 percentage points below the EU-27 average). Worldwide, the EU-27, with 48.39%, came behind the United States (66.29%), Australia (64.48%), and Canada (61.02%). Figure 4 illustrates the proportion of articles published in first-quartile journals by the

EU-27, United States and rest of the world compared to those published in the entire CCS category.

Citations Received by Articles Published in CCS-JCR Category Journals

Journals in this category received 574 993 citations, of which 285 914 correspond to the United States (49.72%) and 252 408 to the EU-27 (43.90%). The number of citations received by the main European countries was as follows: Germany (n=70 679; 12.29%), United Kingdom (n=62 751; 10.91%), Italy, (n=43 281; 7.53%), Netherlands (n=39 781; 6.92%) and France (n=33 121; 5.76%). Five countries received much fewer citations but still exceeded 10 000: Sweden (n=15 704; 2.73%), Spain (n=15 359; 2.67%), Belgium (n=13 586;

TABLE 3. Activity and Impact of European Countries on First-Quartile Journals and on Total CCS Category (2003-2007)

Countries	Total Category			First Quartile			First-Quartile Articles and Citations of Total Category, %	
	Total Articles	Total Citations	Average Citations/Articles	Total Articles	Total Citations	Average Citations/Articles	1st-Quartile Articles, %	1st-Quartile Citation, %
Germany	5455	70 679	12.96	2541	58 486	23.02	46.58%	82.75%
Austria	597	7561	12.66	310	6094	19.66	51.93%	80.60%
Belgium	1007	13 586	13.49	602	11 935	19.83	59.78%	87.85%
Bulgaria	17	121	7.12	6	101	16.83	35.29%	83.47%
Cyprus	10	163	16.30	5	133	26.60	50.00%	81.60%
Denmark	675	10 005	14.82	396	8601	21.72	58.67%	85.97%
Slovakia	48	444	9.25	17	202	11.88	35.42%	45.50%
Slovenia	53	309	5.83	16	149	9.31	30.19%	48.22%
Spain	1542	15 359	9.96	640	11 998	18.75	41.50%	78.12%
Estonia	21	109	5.19	4	49	12.25	19.05%	44.95%
Finland	532	7928	14.90	288	6753	23.45	54.14%	85.18%
France	2781	33 121	11.91	1,277	28,038	21.96	45.92%	84.65%
Greece	750	5,631	7.51	268	3508	13.09	35.73%	62.30%
Hungary	237	2450	10.34	109	1976	18.13	45.99%	80.65%
Ireland	255	4115	16.14	147	3694	25.13	57.65%	89.77%
Italy	3546	43 281	12.21	1834	35 702	19.47	51.72%	82.49%
Latvia	9	130	14.44	6	122	20.33	66.67%	93.85%
Lithuania	54	275	5.09	12	227	18.92	22.22%	82.55%
Luxembourg	11	178	16.18	3	141	47.00	27.27%	79.21%
Malta	3	1	0.33	0	0	0	0	0
Netherlands	2471	39 781	16.10	1635	35 279	21.58	66.17%	88.68%
Poland	471	5,778	12.27	198	4,749	23.98	42.04%	82.19%
Portugal	98	1099	11.21	54	894	16.56	55.10%	81.35%
United Kingdom	4557	62 751	13.77	2708	54 308	20.05	59.43%	86.55%
Czech Republic	200	2205	11.03	85	1674	19.69	42.50%	75.92%
Romania	26	309	11.88	14	275	19.64	53.85%	89.00%
Sweden	1171	15 704	13.41	577	12 399	21.49	49.27%	78.95%
Norway	484	6706	13.86	271	5729	21.14	55.99%	85.43%
Switzerland	1034	12,039	11.64	565	11 014	19.49	54.64%	91.49%
Total EU-27	22 389	252 408	11.27	10 834	204 674	18.89	48.39%	81.09%
Total EU-27 (+NORWAY/SWEDEN)	23 331	262 049	11.23	11 305	212 424	18.79	48.45%	81.06%
Industrialised nations								
Australia	1115	16 169	14.50	719	14 367	19.98	64.48%	88.86%
Brazil	640	6343	9.91	287	4998	17.41	44.84%	78.80%
Canada	3268	41 497	12.70	1994	35 975	18.04	61.02%	86.69%
United States	20 625	285 914	13.86	13 672	253 273	18.52	66.29%	88.58%
India	374	1474	3.94	57	514	9.02	15.24%	34.87%
Japan	5680	44 773	7.88	2048	29 312	14.31	36.06%	65.47%
Mexico	163	1223	7.50	75	912	12.16	46.01%	74.57%
New Zealand	257	3563	13.86	185	3255	17.59	71.98%	91.36%
People's Republic of China	1057	9169	8.67	448	6816	15.21	42.38%	74.34%
Russia	775	1,138	1.47	31	897	28.94	4.00%	78.82%
Total EU-29 and industrialised nations	50 164	552 109	11.01	25 704	452 112	17.59	51.24%	81.89%
Rest of world	4804	22 884	4.76	1183	12 879	10.89	24.63%	56.28%
Total category doc.	54 968	574 993	10.46	26 887	464 991	17.29	48.91%	80.87%

2.36%), Switzerland (n=12 039; 2.09%), and Denmark (n=10 005; 1.74%), meaning that Spain holds 7th place in the EU for number of citations received. *Revista Española de Cardiología* received 1936 citations during the 5-year period, this being

0.34% of the total citations received by CCS-JCR category journals.

Worldwide, those countries which received over 1% of citations are as follows: Canada (n=41 497; 7.22%), Japan (n=44 773; 7.79%), Australia

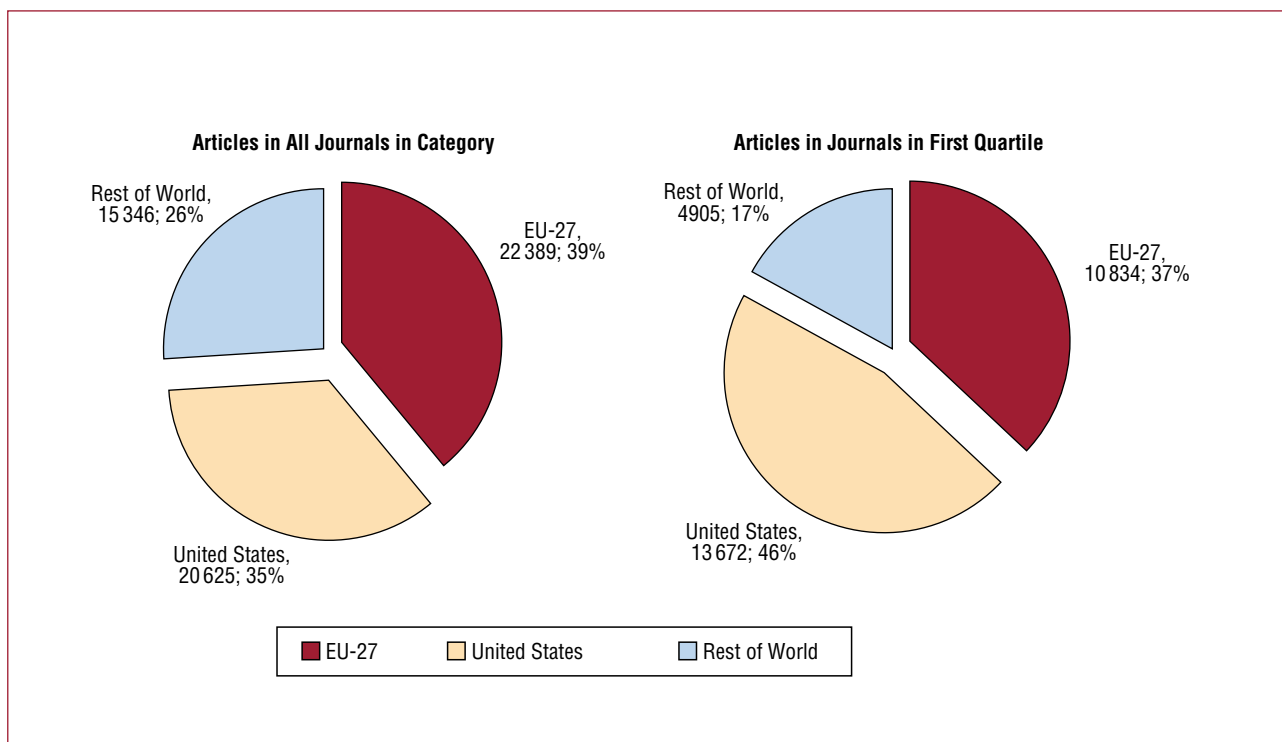


Figure 4. Contribution of the EU-27, US and rest of the world to the total contributions in the CCS category (left) and to contributions in first-quartile journals (right).

(n=16 169; 2.81%), China (n=9169; 1.59%), and Brazil (n=6343; 1.1%). Spain therefore holds 11th place overall in the world rankings (Table 1).

Citations Received by Articles Published in First-Quartile CCS-JCR Category Journals

First-quartile journals received 464 991 citations, of which 253 273 correspond to the United States (54.47%) and 204 674 to the EU-27 (44.02%). With regard to the number of citations received by European Union countries, in first place was Germany (n=58 486; 12.58%), followed by the United Kingdom (n=54 308; 11.68%), Italy (35 702; 7.68%), Netherlands (n=35 279; 7.59%), and France (n=28 038; 6.03%). Four countries received much fewer citations but still exceeded 10 000: Sweden (n=12 399; 2.67%), Spain (11 998; 2.58%), Belgium (11 935; 2.57%), and Switzerland (11 014; 2.37%), meaning that Spain holds 7th place in the EU for number of citations received.

Worldwide, other countries which received over 1% of citations are similar to those mentioned above: Canada (n=35 975; 7.74%), Japan (n=29 312; 6.3%), Australia (14 367; 3.09%), China (n=6816; 1.47%), and Brazil (n=4 998; 1.07%). Spain again holds 11th place in the world ranking (Table 1).

Comparison of the Number of Citations Received for First-Quartile Journals and That Received for the Entire CCS Category

If a minimum threshold of 500 articles is established, the largest percentage of citations corresponding to first-quartile journals is that of Switzerland (91.49%), followed by the Netherlands (88.68%), Belgium (87.85%), United Kingdom (86.55%), and Denmark (85.97%). Australia leads worldwide (88.86%), followed by the United States (88.58%), Canada (86.69%), and the EU-27 (81.09%). Spain holds 12th place in Europe and 19th place worldwide (78.12%) (Table 3).

Average Citations per Article

The distribution of European nations in all CCS-JCR category journals according to the “average number of citations received by published articles” indicator (av) should be observed with caution, as this figure is again distorted by the leadership of countries which have published very few articles. If only countries with a minimum of 500 published studies are taken into account, the ranking is led by the Netherlands (av=16.10), followed by Finland (av=14.90), Denmark (av=14.82), United Kingdom (av=13.77), Belgium

(av=13.49), Sweden (av=13.41), and Germany (av=12.96). Spain holds 12th position (av=9.96), with a European average of 11.27 (Table 1).

Note that, at worldwide level, New Zealand has the same rate as the United States (av =13.86); however, this is due to the fact that New Zealand made very few contributions (257 articles over the entire 5-year period, compared with 20 625 from the United States). Using the same criteria as mentioned above (minimum of 500 published articles), Australia leads the ranking (av=14.50), followed by the United States (av=13.86), and Canada (av=12.70). According to this indicator, Spain holds 15th place in the ranking, ahead of Japan, Russia, and China (Table 1).

The distribution of the European countries according to the “average citations per article in first-quartile CCS-JCR category journals” indicator again appears distorted by nations which have published very few articles, such as Ireland (av=25.13), Poland (av=23.98), and Finland (av=23.45). If only countries with a minimum of 500 published studies are taken into account, the ranking is led by Germany (av=23.02), followed by France (av=21.96), Netherlands (av=21.58), Sweden (av=21.49), and the United Kingdom (av=20.05). Spain holds 9th position (av=18.75), 14 hundredths below the European average (av=18.89). Russia hold the highest worldwide rate (av=28.94), but again this is due to the country’s very low number of contributions (31 articles during the whole 5-year period). Using the same threshold as before, Australia leads the ranking (av=19.98), followed by the European Union (av=18.89), United States (av=18.52), and Canada (av=18.04). According to this indicator Spain holds 10th place in the ranking, surpassed only by Australia among the non-European nations, and above the United States and Japan.

Productivity Relative to Population and Gross Domestic Product (GDP)

Table 4 shows the productivity of each EU-27 country relative to its population. The Netherlands leads, with 15.11 articles per 100 000 inhabitants, followed by Switzerland (n=13.77), Sweden (n=12.85) and Denmark (n=12.39). Spain takes 15th place with 3.47 articles. The average for EU-27 countries was 4.52, below Canada (n=9.79), the United States (n=6.85), New Zealand (n=6.24) and Australia (n=5.46), and roughly equal with Japan (n=4.46).

Productivity relative to gross domestic product (GDP) is led by the Netherlands (n=43.58), followed by Sweden (n=35.35), Switzerland (n=33.17), Greece (n=32.87), and Belgium (n=30.07). In this case Spain holds 18th place (n=14.68), with a rate similar to that of France (n=14.70), this being below both the EU-27 and US averages (n=18.14

and 19.69, respectively). Outside the EU, Canada leads with 34.73 articles, followed by New Zealand (n=30.13) and Australia (n=20.70) (Table 5).

DISCUSSION

Cardiovascular medicine has garnered considerable success in recent years, developing therapies for the prevention and treatment of numerous diseases, substantially reducing their morbidity and mortality.¹¹ Despite these diseases being the principal cause of death in the United States, their mortality rate has decreased by 63% thanks to significant investments made over the last 30 years.¹² However, an increase in life expectancy, together with socioeconomic changes in industrialised countries over recent decades, means there has been an increase in the prevalence of CVDs. This high prevalence has meant that cardiovascular research arouses the greatest amount of interest in our society and has become a priority biomedical research field in a large number of developed nations.⁵

The publication of original Spanish articles in the CCS-JCR category has moderately increased since the end of the 5-year period analysed in this study, with an annual increase of ten articles from 2003 to 2007. Spain holds 6th place in the EU-27, behind Germany, the United Kingdom, Italy, France and the Netherlands, and 9th place worldwide, behind the United States, Japan, and Canada. This gives the country an advantage in the Essential Science Indicators world rankings, published by Thomson Reuters in the ISI Web of Knowledge¹³: Spain holds 10th place in the Clinical Medicine category but, taking into account all scientific categories, maintains 9th position overall. It is interesting to note that those countries most recently incorporated into the EU are at the bottom of the table, with only Poland notable for its contribution. The EU-27 outperforms the United States in the total number of original articles published in CCS-JCR category journals (39% compared with 35%). However, if only those articles with the highest level of scientific excellence are considered, ie, those published in journals included in the first quartile of the CCS-JCR category, the United States outperforms the EU-27 (46% of all articles compared with 37%) (Figure 4). It is noteworthy that the United Kingdom outperforms Germany, and that Spain maintains 6th position in the European rankings even though the country published approximately half the number of articles of the preceding country, France, and one third of the number produced by Italy. Spain drops one position at world level, taking 10th place and once more being surpassed by Australia. As we have seen, the highest percentage of articles published in first-quartile

TABLE 4. Productivity Relative to Population per EU-27 Country

Country	Documents 2003-2007, No.	Population 2007, No.	Documents/100 000 inhab.
EUROPEAN UNION 27			
Germany	5455	82 314 906	6.63
Austria	597	8 298 923	7.19
Belgium	1007	10 584 534	9.51
Bulgaria	17	7 679 290	0.22
Cyprus	10	778 684	1.28
Denmark	675	5 447 084	12.39
Slovakia	48	5 393 637	0.89
Slovenia	53	2 010 377	2.64
Spain	1542	44 474 631	3.47
Estonia	21	1 342 409	1.56
Finland	532	5 276 955	10.08
France	2781	63 392 140	4.39
Greece	750	11 171 740	6.71
Hungary	237	10 066 158	2.35
Ireland	255	4 312 526	5.91
Italy	3546	59 131 287	6.00
Latvia	9	2 281 305	0.39
Lithuania	54	3 384 879	1.60
Luxembourg	11	476 187	2.31
Malta	3	407 810	0.74
Netherlands	2471	16 357 992	15.11
Poland	471	38 125 479	1.24
Portugal	98	10 599 095	0.92
United Kingdom	4557	60 816 701	7.49
Czech Republic	200	10 287 189	1.94
Romania	26	21 565 119	0.12
Sweden	1171	9 113 257	12.85
Norway	484	4 681 134	10.34
Switzerland	1034	7 508 739	13.77
No. EU-27 documents	22 389	495 090 294	4.52
Other countries			
Australia	1115	20 434 176	5.46
Brazil	640	190 010 647	0.34
Canada	3268	33 390 141	9.79
United States	20 625	301 139 947	6.85
India	374	1 129 866 154	0.03
Japan	5680	127 433 494	4.46
Mexico	163	108 700 891	0.15
New Zealand	257	4 115 771	6.24
People's Republic of China	1057	1 321 851 888	0.08
Russia	775	141 377 752	0.55

Source: CIA World Factbook.

Source: European Commission — Eurostat.

journals, compared with the category as a whole, corresponds to the Netherlands. Spain remains in 9th place. In the world rankings, the EU-27 is behind the United States, Australia, and Canada. As we have detailed previously, a minimum publication threshold of 500 articles was applied in generating these rankings. Without this, countries such as Latvia and Ireland would hold leading positions as a result of having published very few articles, although the majority of these were in first-quartile journals.

The fact that EU-27 researchers lead in terms of number of articles published, surpassing even the

United States, is also seen in other areas; as is the fact that Canada leads the ranking for scientific productivity relative to population and GDP.¹⁴ This position for Canada is logical, since Canada has a high level of scientific and technological development but a small population and GDP in comparison with other developed countries. This can also be seen in Europe, where small countries such as the Netherlands, Sweden, Switzerland, Greece and Belgium are high in the rankings, and Spain holds an unfavourable 18th position, although similar to France, and comes below

TABLE 5. Productivity Relative to Gross Domestic Product (GDP) per EU-27 Country

Country	Documents 2003-2007, No.	2007 GDP, Million Euros	Documents/100 Million Euros
European Union 27			
Germany	5455	2 422 900	22.51
Austria	597	270 836	22.04
Belgium	1007	334 917	30.07
Bulgaria	17	28 898	5.88
Cyprus	10	15 667	6.38
Denmark	675	226 544	29.80
Slovakia	48	34 470	13.93
Slovenia	53	54 856	9.66
Spain	1542	1 050 595	14.68
Estonia	21	15 270	13.75
Finland	532	179 659	29.61
France	2781	1 892 243	14.70
Greece	750	228 180	32.87
Hungary	237	101 130	23.44
Ireland	255	190 602	13.38
Italy	3546	1 535 540	23.09
Latvia	9	21 111	4.26
Lithuania	54	28 422	19.00
Luxembourg	11	36 277	3.03
Malta	3	5447	5.51
Netherlands	2471	567 066	43.58
Poland	471	308 638	15.26
Portugal	98	163 119	6.01
United Kingdom	4557	2 049 007	22.24
Czech Republic	200	127 142	15.73
Romania	26	123 846	2.10
Sweden	1171	331 225	35.35
Norway	484	284 053	17.04
Switzerland	1034	311 768	33.17
No. EU-27 documents	22,389	12 342 257	18.14
Other countries			
Australia	1115	538 608	20.70
Brazil	640	1 321 260	4.84
Canada	3268	941 006	34.73
United States	20 625	10 473 480	19.69
India	374	3,316 190	1.13
Japan	5680	3 365 730	16.88
Mexico	163	917 048	1.78
New Zealand	257	85 298	30.13
People's Republic of China	1057	8 120 000	1.30
Russia	775	1 392 820	5.56

the average for EU-27 countries. The situation is similar when productivity is analysed as relative to population: again small countries lead, such as the Netherlands, Switzerland, Sweden and Denmark, and Spain holds 15th position, again below the EU-27 average.

The difference in scientific productivity observed between countries is due to a number of different factors, including availability of resources, existence of consolidated research centres, even differing individual and scientific traditions. That cardiovascular research is predominant in Northern and Western Europe and North America

is logical, as these are developed countries with strong economies, and the amount of funds spent on cardiovascular research and patient care is very high. It is well known that small countries such as the Netherlands, Sweden and Belgium hold significant positions with regard to certain indicators. Their long-standing research traditions and high level of competency in English could explain these positions,¹⁵ as well as a high level of investment in R&D. On the other hand, it should not be forgotten that, for some countries, having only one cardiology journal in the cardiovascular category of the JCR can prove to be a disadvantage

TABLE 6. Position of Spanish Output in Cardiac & Cardiovascular Systems Category (2003-2007) According to Range of Indicators

Indicator	Position in EU-27	Worldwide Position
No. articles in CCS-JCR category journals	6th	9th
No. articles in first-quartile CCS-JCR category journals	6th	10th
Articles in first-quartile journals as percentage of total CCS-JCR category ^a	9th	12th
No. citations received	7th	11th
Percentage of citations of articles published in first-quartile CCS-JCR category journals	7th	11th
Citations of articles in first-quartile journals as percentage of total CCS-JCR category ^a	12th	19th
Average citations per article in CCS-JCR category journals	12th	15th
Average citations per article in first-quartile CCS-JCR category journals	9th	10th
No. articles per 100 000 inhabitants	15th	20th
No. articles per €100 million GDP	18th	23rd

CS-JCR indicates *Cardiac & Cardiovascular Systems of Journal Citation Reports*; GDP, gross domestic product.

^aApplying a minimum threshold of 500 articles.

when compared with other more highly represented countries, such as the United States (which produced 42 of the 75 journals in the category in 2007), the United Kingdom (with 11 journals), Germany (5 journals), the Netherlands (5 journals), Japan (3 journals), and Italy (2 journals). Spain is among those countries with only 1 cardiovascular journal in the JCR, *Revista Española de Cardiología*, whose impact has increased significantly in recent years¹⁶ and which came in 28th among the 78 journals in the category in 2008. Other countries with just one journal include France, Belgium, Canada, Switzerland, Russia, and Norway, although none of these can be found in the first quartile. However, it should be noted that *Revista Española de Cardiología* plays an important role in the international circulation of high-quality cardiological science: almost one third of articles by Spanish authors published in CCS-JCR journals can be found in this bilingual journal.

With regard to the citing of cardiological studies, the United States dominates with 49.7% of all citations, and the European Union amasses 43.9%. Spain holds 7th place among the EU-27, behind Germany, United Kingdom, Italy, Netherlands, France, and Sweden, and 11th in the world rankings, behind the United States, Canada, Japan and Australia. In the index of citations received per article, Spain comes 12th in Europe and 15th worldwide. Table 6 allows us to see the place held by Spanish cardiovascular research in Europe and the world, according to each of the indicators mentioned in this paper.

The predominance of the United States, garnering the highest percentage of citations and outperforming the EU-27, has also been seen in other biomedical categories, such as intensive-care medicine,¹⁵ clinical oncology,¹⁷ microbiology,¹⁸ and radiology.¹⁹ Conversely, a previous study which analysed worldwide contribution in cardiovascular

medicine during the period 1995-2002 also showed a higher global output from the EU compared with the United States, although the average impact of the European articles was less than that of US articles.²⁰ It is worth mentioning the bias found in the SCI-E database coverage, which favours US journals, as well as other factors affecting citations described in other studies.^{5,7} There is also the belief, on the part of some authors, that any study published in English and with only English citations will receive a higher level of scientific recognition, even though foreign language citations may be of a high quality and great scientific relevance.¹⁶

Furthermore, there is a pressure to publish as many articles as possible in many particular groups and nations. This can reduce the average number of citations received for articles by certain authors or groups, when compared with other authors or groups who publish only the most significant results.^{5,7,21}

CONCLUSIONS

Despite the positive data expressed here, some reports and commentaries published in the scientific literature give cause for concern, in that they question the advantages of cardiovascular research given its negligible economic benefits when compared with research into other diseases.¹¹ Promoting high-quality cardiology research in Europe should be an important goal, both for the European Society of Cardiology and national societies.²² To improve research and overcome the differences between countries, it would be necessary to push certain activities, including encouraging communication between researchers in order to establish multinational programmes, promoting English tuition in order to improve efficiency of communication, exploring in full the possibilities of funding from the EU, providing

the necessary technology for young researchers lacking resources,²³ and promoting adequate academic understanding of the merits of scientific publication. With regard to the cardiovascular field, it is necessary to promote economic support and resources in order to maintain adequate levels of research,¹² strengthening and reinforcing research networks of excellence.²³ Studies analysing the scientific activities of publications provide data which allows the creators and managers of research to evaluate the impact of their policies, adopting measures to correct identified weaknesses and reinforce strong points.^{21,24,25}

Methodological Limitations

Among the limitations of this study, it is worth mentioning that only the production and impact of cardiological articles published in CCS-JCR category journals have been analysed, in spite of the fact that cardiologists also publish articles in journals from other categories, such as general and internal medicine, medical imaging, paediatrics, nephrology, etc. as well as multidisciplinary journals. On the other hand, numerous professionals from other specialities complement the professional exercise and research provided by cardiologists, thus improving production in terms of scientific results.¹² However, calculation and analysis of journals specific to distinct biomedical fields is the routine method used for bibliometric studies in the SCI-E database, since this gives the most reliable picture of the research carried out in these fields, and this database has been widely used in previous studies.^{4,5,7,26} Another limitation is that the SCI-E database does not cover several national cardiological publications. However, it was decided that this database would best serve the needs of this study, since it involves the so-called “science mainstream” and allows us to identify and compare the contributions of every country in the world to this trend. The decision to select SCI-E as opposed to Medline, in spite of its wider biomedical coverage, was based on the fact that only the former allows the examination of citations and impact of the included publications.

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