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Bibliometric Analysis of the United Kingdom's Contribution to Scientific Literature in the Field of Optometry

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Abstract

History: Optometry is a young discipline undergoing expansion, in which English-speaking countries predominate in this scientific field.

Purpose: We have conducted a bibliometric analysis of scientific publications of British researchers in the field of Optometry beginning from 1972 (date of first publications) until 2013, to compare its production with other countries.

Methods: For this study, the EMBASE database was used using "optomtr*", "optic*", "visual", "vision", "eye*" and "ophthalm*" as search terms. To the selected publications, we applied a series of bibliometric indicators such as Price's law on the increase of scientific literature, the doubling time of production, Lotka's law of scientific productivity, Price's transience index, and Bradford's Law of scattering of scientific literature, and the degree of collaboration among authors was also analysed. Furthermore, the scientific output was correlated with socio-medical data (per capita income and Health expenses).

Results: The number of published articles retrieved for the period 1972–2013 was 3,331. The UK ranks second in optometric production. The growth of publications was more linear (r = 0.9093) than exponential (r = 0.8434). The doubling time of scientific production was 4.97. The level of productivity corresponded to medium-size producers (81.70%) and a transience index of 9.75%. %. The collaboration index is 87% and the degree of collaboration is 0.88. The collaboration index was 3.78. The Bradford core was formed by three journals with an impact factor greater than 2, in which Ophthalmic and Physiological Optics with 20.38% accumulated the greatest number of articles.

Conclusions: English-speaking countries account for the majority of the production in Optometry. Research in the UK is in an established phase that shows linear growth in scientific output, as demonstrated by the low transience index and the high percentage of authors found to be medium-size producers. We found a high concentration of publications in a small number

of journals.

Keywords: Bibliometrics; Optometry; Vision Science; United Kingdom; Price's Law

Introduction

Optometry is a relatively young discipline that has undergone major developments in recent decades, with English-speaking countries predominating in this scientific field, particularly the United States and the United Kingdom.

There has been some controversy with regard to the origin of the word "optometry," which seems to have first appeared in 1759 in the work "Treatise on the Eye, the Manner and Phaenomena of Vision." by William Porterfield. The first university studies were conducted in the United States at the Illinois College of Optometry, founded in 1872, and at the New England College of Optometry in 1894 (then the Klein School of Optics) [1]. In 1886, E. Landolt, in his book "*The refraction and accommodation of the eye and their anomalies*", began to use the term "optometry" to describe refractive procedures, leading to the generalization of this term in the first decades of the twentieth century.

The first European records in the field date from 1895 when the first professional organization, *The British Optical Association* (BOA), was founded. At the start of the late 19th century, visual tests and their dispensations were performed by ophthalmic opticians. The first schooling in the discipline was given in the early 20th century by the pioneering Northampton Institute, the Manchester College of Technology and Glasgow and West of Scotland Technical College [2].

According to the World Council of Optometry (WCO) Congress in Kyongju, Korea (April 25, 1997), optometry is defined as "*a health profession that is autonomous, educated, and regulated (licensed/registered), dedicated to eye and vision care, that understands refraction and dispensing, detection/diagnosis and management of disease in the eye, and the rehabilitation of conditions of the visual system*" [3].

Although this discipline has become stronger from a scientific perspective, there is no objective data to support this claim, thus making it necessary to establish a set of parameters to prove the growth of optometry. Another factor to consider is the continued restriction of resources earmarked for scientific research, making it imperative to establish the best way in which to allocate funds. It is therefore necessary to begin an evaluation of scientific activity to identify the centres, groups, and researchers that conduct productive and high-quality work. The promotion of scientific quality will be one of the main purposes of this assessment activity [4].

The scientific process is analogous to the economic model created by Leontief, [5] which takes into account a cost-benefit analysis, which we will call the "input", and the investment result, which we will call "output" [6-8]. Both the input and output are quantifiable. The input makes reference to the materials and human resources available to the investigation, such as financial resources, human resources, scientific knowledge, infrastructure and equipment, and materials and products used, [9] regardless of the results obtained. The output indicators refer to results originating from scientific activity, such as articles, conferences, and patents, which may be quantitative if the productivity or number of publications is measured, or qualitative if the quality of the productivity is assessed. This measure is complicated because the results are intangible, as they involve measurements of the knowledge generated during the research process, as well as its impact and influence.

The results of scientific research are difficult to assess, therefore making necessary the use of analytical methods that allow us to examine different aspects of research capacity. The parameters used for the evaluation process of any activity can be defined as "indicators." A set of indicators are used to highlight each and every aspect of the object being evaluated [10]. Currently, revisions to science policy would not be understood without resorting to the existing indicators.

Bibliometrics, through its indicators, focuses on calculating and analysing the quantifiable values of consumption and scientific production [11,12]. It can be defined as the science of the nature and course of a discipline, with regards to publications, through the computation and analysis of various aspects of written communication.12 Bibliometrics encompasses the acquisition, treatment, and handling of quantitative bibliographical data from scientific publications [13].

The Organisation for Economic Co-operation and Development (OECD) refers to bibliometrics as a tool by which one can observe the state of science and technology through the global production of scientific literature in a given level of specialisation [14].

Our group has studied, using a bibliometric approach, the evolution of scientific literature in different areas (i.e., psychiatry, neurology, gynaecology, and phytotherapy) that pertain to different aspects of various disorders and specific therapeutic modalities [15-21]. In this study, we analysed the evolution of British scientific output in the area of optometry. Other objectives were to study the productivity of authors and their degrees of collaboration, and to identify the choices of journals for publication.

Materials and Methods

The databases used in this bibliometric study were MEDLINE (Index Medicus, U.S. National Library of Medicine, Bethesda, Maryland, USA) and Excerpta Medica (Elsevier Science Publishers, Amsterdam, Netherlands), considered to be the two most exhaustive biomedical literature databases that participate in EMBASE Biomedical Answer web (Elsevier B.V.). EMBASE Biomedical Answer web has over 25 million indexed records from 1947, including articles, reviews, conferences, notes, letters, and communications, and covers over 8,400 biomedical journals from 90 countries.

Using remote downloading techniques, we chose papers containing the following descriptors: in the AD (author address) section: *United Kingdom*; in any field of record: *optometr*, visual, vision, eye*, or ophthalm**; in the field AD: optic*, and those published from 1972 (the first British publications) to 2013.

For the purposes of this study, we considered all original articles, brief articles, reviews, editorials, letters to the editor, etc., and all duplicate papers were omitted. The database used thus by its very nature allows for the elimination of items that may be duplicated in each of the other databases (MEDLINE and EMBASE).

In the present study, we applied the following bibliometric indicators: Price's index, doubling time and annual growth rate, Lotka's law of scientific productivity, Price's transience index, Bradford's zones, and the co-authorship index.

Among the bibliometric indicators of production, we applied Price's law [22]. This law is the indicator most widely used to analyse the productivity of a specific discipline or a particular country, and to reflect the fundamental aspect of scientific production, which is its exponential growth. To assess whether the growth of scientific production in optometry follows Price's law of exponential growth, we made a linear fit of the data obtained, according to the equation $y = 4.8738x - 25.476$, and another adjustment to an exponential curve, according to the equation $y = 6.9378e0^{.0905x}$.

Other quantities related to growth are doubling time and annual growth rate. The first is the amount of time required for the subject matter to double its production; the annual growth rate represents how the magnitude has grown over the previous year, expressed as a percentage. The equation used for calculating the doubling time (D) is:

$$D = \frac{Ln2}{b}$$

Here, *b* represents the constant that relates growth rate to the size of the science acquired. To calculate the annual growth rate, we used the following equation:

$$R=100(e^{b} -1)$$

Lotka formulated the frequency distribution of scientific productivity according to the number of published articles, also known as the "inverse square law of scientific production" [23]. It analysed authors' publication volume, stating that the number of authors who publish fewer papers is greater than the number of authors who publish many papers [24]. In mathematical terms, the original law is expressed by the formula:

$$A(n) = \frac{A(1)}{n^2}$$

According to this index, authors are distributed into three levels of productivity: small producers: those who publish one article; medium-size producers: those who publish between 2–9 articles; and large-scale producers: those who publish 10 or more articles.

The productivity index or level of productivity (PI) is one of the key indicators, corresponding to the logarithm of the number of author publications

It is also interesting to determine the number of authors with a single publication. This is known as the transience index or Price's law. Its calculation is given as the percentage ratio of authors with one publication to the total. Mathematically, it would be expressed as:

$$IT = \frac{Authors\ with\ a\ single\ publication}{Total\ number\ of\ authors} * 100$$

The last indicator that we will use is the scattering index known as Bradford's zone. Samuel C. Bradford explained that the highest percentage of bibliographical output in a particular subject tends to concentrate in a small number of journals. This observation implies a rapid decrease in the usefulness of expanding the reference search away from its core [25]. The most common way to represent this law is through a semi-logarithmic plot, which represents the calculated number of articles, R(r), versus the cumulative number of journals, r. In this semi-logarithmic diagram, the logarithm of the cumulative number of journals is used as the abscissa and the cumulative number of articles is used as the ordinate. In this way, once the data are graphed, the articles are distributed into approximately three equal parts. One is the nucleus or core, and the other two are the peripheral zones (linear zone). In the core, the number of articles increases slowly, giving rise to a curve, defined as the Groos droop[26]. This model allows the identification of the journals most widely used or with greatest weight in a given field of scientific output.

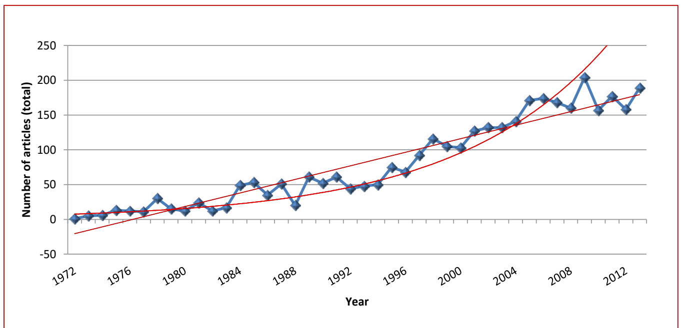
As an indicator of the publications' influence, we used the impact factor (IF). This indicator, developed by the Institute for Scientific Information (Philadelphia, Pennsylvania, USA), is published annually in the *Journal Citation Reports* (JCR) section of the *Science Citation Index* (SCI). The IF of a journal is calculated based on the number of times the journal is cited in source journals of the SCI during the previous 2 years and the total number of articles published by that journal in those 2 years. The JCR lists scientific journals by specific areas, ascribing to each of them their corresponding IF and establishing a ranking of "prestige"[27]. In this study, we used the IF data from 2013, published in the JCR in 2014.

Another indicator included in this analysis was per capita income and investment in health related to the production generated in this scientific field. This data was obtained from the Department of Health Statistics and Informatics of the World Health Organization [8].

Results

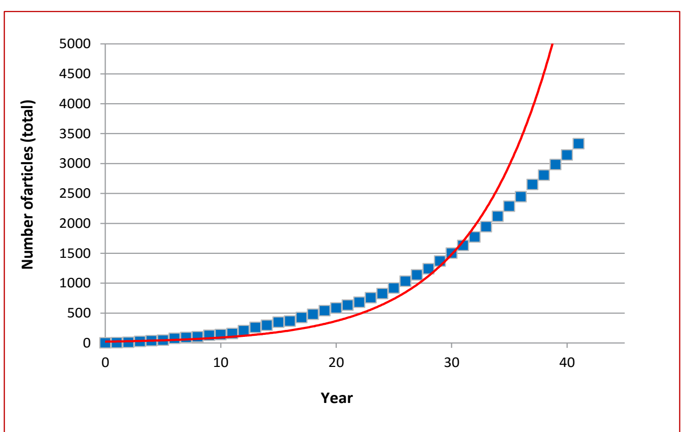
Based on the search criteria used, we retrieved 3,331 original documents (articles, reviews, letters to the editor, etc.) for the period between 1972 and 2013. Figure 1 shows their chronological distribution

Figure 1. Chronological distribution of scientific publications in optometry in the United Kingdom.



To assess whether the growth of scientific production follows Price's law of exponential growth, we made a linear fit of the data obtained and an adjustment to the exponential curve. According to these mathematical expressions, the r value (correlation coefficient) is greater for the linear adjustment, with a value of 0.9093, which reveals the quality of the representative power of the function against the exponential curve, which is r = 0.8434. It can be concluded that optometry research in the UK is going through a lineal growth phase. The annual growth rate for the entire study period was 29.78%.

Figure 2. Temporal evolution of British scientific output in optometry



To calculate doubling time, the scatter plot in Figure 2 shows the temporal production of publications along the trend line, which was fitted to the equation $y = 22.645e^{0,1394x}$, with a correlation coefficient of 0.8615. This production corresponds to 42 years and a doubling time of 4.97.

The total number of documents compiled for the field of optometry was 25,280, with the US and UK showing the highest productivity, as seen in Table 1. This data was obtained using the search criteria previously described and pairing each specific country.

Table 1. Distribution of documents on optometry from the world's most productive countries.

Country	No. of Documents	%
USA	8,755	34.63%
UK	3,331	13.18%
Australia	2,606	10.31%
Canada	1,651	6.53%
Spain	1,055	4.17%
China	1,035	4.09%
Germany	647	2.56%
New Zealand	279	1.10%
Italy	245	0.97%
Total Optometry	25,280	100.00%

The productivity indices (IP, logarithm of the values of n for each author) allow us to establish three levels of productivity, corresponding to those described by Lotka,23 and are shown in Table 2. The largest group consists of medium-size producers (0<PI<1) with 81.70%, whereas the transience index (authors with a single publication) is 8.55%.

Table 2. Author dispersion according to productivity level.

Productivity index	Number of authors	Authors (%)	Number of articles	Articles (%)
PI=0 (1 article)	195	9.75%	195	3.47%
0 < PI < 1 (2–9 articles)	1,634	81.70%	1,634	29.11%
PI ≥ 1 (10 or more articles)	171	8.55%	3,785	67.42%
Total	2,000		5,614	

Table 3 shows author classification based on level of productivity. The most productive author had 114 publications, which means that 0.05% of authors contribute to 3.84% of publications, whereas 171 authors, 8.55% of the total, contributed only one publication each.

Of the 3,331 documents generated in the UK included in this study, there were 12,594 co-authors (Table 4). This means that the co-authorship index, indicative of author collaboration in the production of articles, is rather low, with an average of 3.78 co-authors per article.

Table 3. Productivity of British authors.

CONTRIBUTIONS	AUTHORS	AUTHORS (%)	PI of LOTKA (lg10 n)	CUMULATIVE AUTHORS
1	195	9.75%	0.000	2000
2	829	41.45%	0.301	1805
3	361	18.05%	0.477	976
4	176	8.80%	0.602	615
5	117	5.85%	0.699	439
6	53	2.65%	0.778	322
7	50	2.50%	0.845	269
8	22	1.10%	0.903	219
9	26	1.30%	0.954	197
10	20	1.00%	1.000	171
11	15	0.75%	1.041	151
12	8	0.40%	1.079	136
13	14	0.70%	1.114	128
14	9	0.45%	1.146	114
15	9	0.45%	1.176	105
16	8	0.40%	1.204	96
17	7	0.35%	1.230	88
18	6	0.30%	1.255	81
19	9	0.45%	1.279	75
20	3	0.15%	1.301	66
21	4	0.20%	1.322	63
22	3	0.15%	1.342	59
23	8	0.40%	1.362	56
24	4	0.20%	1.380	48
25	4	0.20%	1.398	44
26	2	0.10%	1.415	40
27	1	0.05%	1.431	38
28	3	0.15%	1.447	37
30	4	0.20%	1.477	34
32	1	0.05%	1.505	30
33	2	0.10%	1.519	29
35	2	0.10%	1.544	27
36	2	0.10%	1.556	25
37	3	0.15%	1.568	23
38	1	0.05%	1.580	20
39	3	0.15%	1.591	19
40	1	0.05%	1.602	16
41	2	0.10%	1.613	15
42	1	0.05%	1.623	13
43	1	0.05%	1.633	12
48	1	0.05%	1.681	11
53	2	0.10%	1.724	10
55	1	0.05%	1.740	8
61	1	0.05%	1.785	7
62	1	0.05%	1.792	6
72	1	0.05%	1.857	5
73	2	0.10%	1.863	4
105	1	0.05%	2.021	2
114	1	0.05%	2.057	1

The collaboration index proposed by Lawani [29] would result in:

$$IC = \frac{\sum_{j=1}^{k} jf_j}{N} x100 = \frac{2899}{3331} x100 = 87\%$$

Where IC is the collaboration index, jf_j is the number of publications in collaboration in a given period of time and N is the number of documents published during that time.

Table 4. Number of co-authors per first-author publication.

Number of signing authors	Number of publications	Cumulative number of authors	Publications (%)
107	1	107	0.85%
106	1	106	0.84%
94	1	94	0.75%
67	1	67	0.53%
59	1	59	0.47%
44	1	44	0.35%
41	1	41	0.33%
35	1	35	0.28%
35	1	35	0.28%
24	1	24	0.19%
22	1	22	0.17%
20	1	20	0.16%
20	1	20	0.16%
17	1	17	0.13%
16	3	48	0.38%
15	6	90	0.71%
14	4	56	0.44%
13	7	91	0.72%
12	19	228	1.81%
11	11	121	0.96%
10	22	220	1.75%
9	39	351	2.79%
8	60	480	3.81%
7	218	1526	12.12%
6	187	1122	8.91%
5	286	1430	11.35%
4	473	1892	15.02%
3	716	2148	17.06%
2	834	1668	13.24%
1	432	432	3.43%
TOTAL	3331	12594	100.00%

To quantitatively determine the degree of collaboration, we used the formula expressed by Subramanyan: [30]

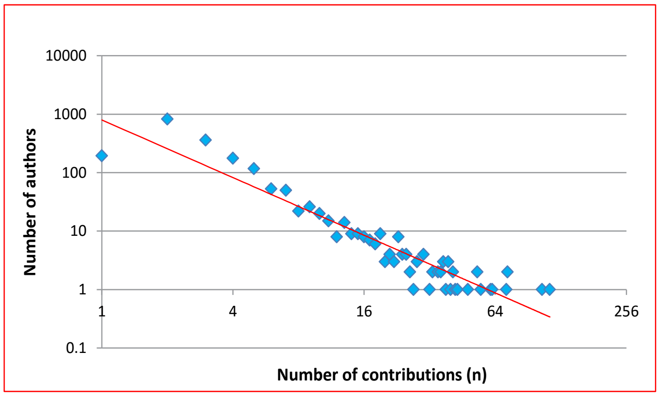
$$C = \frac{N_m}{N_m + N_s} = \frac{3331}{3763} = 0.88$$

Where C is the degree of collaboration, N_m is the number of research articles by multiple authors during a determined amount of time, and N_s are articles published by a single author in that period.

To represent the number of authors and their publications, we used a logarithmic graph (Figure 3), which adjusts to the equation $y = 797.32x^{-1.638}$ with a correlation coefficient of 0.8875.

The journals used by British researchers in our sample number 408. The first zone or core is composed of three journals, accounting for 37.02% of all articles published. Table 5 shows the division by Bradford zones, the average number of articles (1,110.33) and the multiplication factor.

Figure 3. Number of author publications.



The graphical distribution of Bradford's zones for the entire set of journals is represented in Figure 4. It should be taken into account that it is a semi-logarithmic diagram that represents the cumulative number of articles against the cumulative number of journals (r). The straight zone has been considered for *r = 5* and was fitted to the equation $y = 452.13\ln(x) + 926.89$, with a high correlation coefficient (0.9927). The Gross droop was observed for r = 90.

Figure 4. Bradford's distribution of global data.

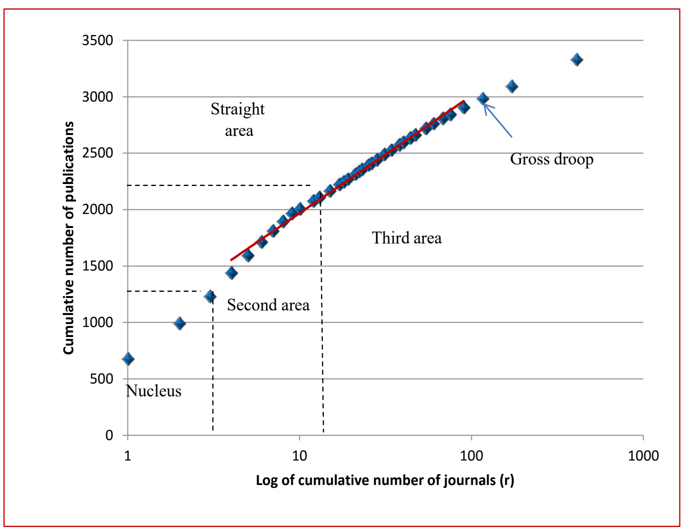


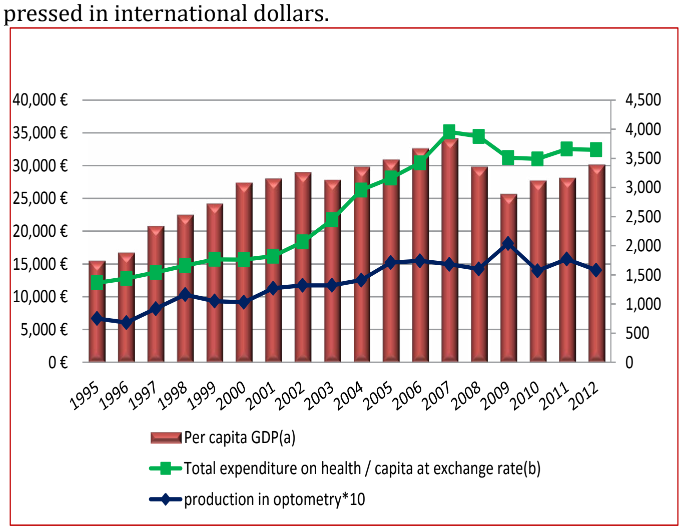
Table 5 shows the core journals, their abbreviated names and their country of origin. We can see that of the three journals, two are published in the United States and one is published in the UK, where *Ophthalmic and Physiological Optics* amassed the greatest number of publications.

In terms of social and health parameters, if we correlate the scientific production per capita income and investment in health (GDP *per capita*, the total *per capita* expenditure on health), we see that from 1995 to 2012 production grew at a rate of 5.65%, the per capita income increased at 4.32%, and health expenditure grew at 6.22% (Figure 5).

Table 5. Bradford's zones, showing distribution of journals

Zones	Number of journals	Journals (%)	Number of articles	Articles (%)	Bradford´s constants
1	3	0.74%	1,233	37.02%	
2	20	4.90%	1,124	33.74%	6.7
3	385	94.36%	974	29.24%	19.3
Total	408	100.00%	3,331	100.00%	13

Figure 5. Relationship between scientific production, total expenditure on health and gross domestic product. Economic data is expressed in international dollars.



(a) *The World Bank.* The per capita GDP is obtained by dividing GDP by the number of inhabitants
(b) *The World Health Organization. (http://apps.who.int/nha/database/ViewData/Indicators/es).*

Table 6. Core journals found in Bradford's distribution.

Journal	Number of publications	(%)	Impact factor	Journal title abbreviation	Country of origin
Ophthalmic and Physiological Optics	679	20.38%	2.664	Ophthalmic Physiol. Opt.	UK
Optometry and Vision Science	315	9.46%	2.038	Optom. Vis. Sci.	U.S.
Investigative Ophthalmology and Visual Science	239	7.18%	3.661	Invest. Ophthalmol. Vis. Sci.	U.S.

Discussion

Bibliometric studies have become essential tools for evaluating scientific activity, allowing a global vision of the growth, size, and distribution of the scientific literature associated with a particular discipline [31-33]. As reliable and universal methods of measuring the productivity of a sector, these tools will be increasingly required in countries with greater scientific development [34].

However, the limitations of this sociometric approach should also be noted, along with its benefits. For instance, bibliometric studies do not take into account either the quality of the publications or the fact that the results of scientific activity are measured only according to publication. Some aspects that are not considered are teaching, applied research, scientific dissemination, specific investigators, and the highlighting of particular publications by different authors [35,36].

One of the strengths presented in this analysis is the use of an exhaustive database to minimize methodological limitations arising from the retrieval of records, thus allowing the correct use of bibliometric indicators and reducing the relativity of the data as much as possible [31,32]. Taking this into account, the design of this study allows us to assess certain aspects of British research in the field of optometry.

Most optometry research in the world is produced in English-speaking countries (the United States, the United Kingdom, Australia, Canada, and New Zealand), accounting for 65.75% of scientific production. The UK ranked second in research output in this field, the same ranking it obtained in other biomedical fields such as medicine, nursing (source: SCImago Journal & Country Rank), and primary care [37]. When compared to the total production volume, the UK is in third position in the world ranking (source: SCImago Journal and Country Ranking).

Our studies found that the volume of scientific literature produced in the UK has significantly increased, with an average growth of around 30% since 1972, and a doubling time of close to five years (4.97). This increase is higher when compared to production in other areas. For instance, primary care had an average increase of 7.28% between 2001 and 2006; the medical area had an average increase of 3.76%; and research output in general had an average increase of 4.13% for the period between 1996 and 2013 (source: SCImago Journal & Country Rank). To this effect, the decade of 1981–1990 produced a higher increase (256.19% over the previous period) but slowed in the following decades. This strong growth may be due to the impetus given by the creation in 1980 of *the College of Optometrists*, resulting from the merger of *The British Optical Association* (BOA) and *The Worshipful Company of Spectacle Makers* (SMC). This finding indicates a strengthening of research in this field, showing linear growth in production, as observed in the mathematical adjustment of the trend line in Figure 1.

Another piece of data that supports the strengthening of research in this area is the low rate of transience and the fact that most authors are classified as medium-size producers, unlike other indicated areas, which show a more elevated transience index [38,39].

The overall rate of collaboration is high at 87%. Cooperation between authors is an indicator that reflects the importance of teamwork and reveals a trend on the increase in the number of authors in the experimental sciences. This is due to the high cost, complexity and specialization of the research [40,41]. With regard to the degree of collaboration, this is set at 0.88, which represents a value greater than that produced in other areas [41-43]. The mean value obtained for co-authorship index is 3.78, with the majority representing articles with 2 and 3 co-authors (close to half of the documents [46.54%]). However, this index is below that indicated for other biomedical disciplines, which is set at around five [44-48].

We observed that a high volume of articles are published in just a few journals, with only three journals accounting for 37.02% of publications. Moreover, it should be noted that the core journals used by researchers have an IF greater than two. The journal *Ophthalmic* and *Physiological Optics* accounted for the highest number of publications with 679 articles overall, representing 20.38% of all publications. The selection of this journal as the journal of choice was similar to those indicated by other authors [49].

Another aspect of interest is the correlation between the scientific output, health expenditure, and per capita income, keeping in mind that greater health expenditure does not necessarily equal greater scientific output. The scientific output of a country in a particular field reflects research policy, without being dependent on a specific economic circumstance [17,18]. In this case, despite observing an increase in health expenditure, the number or articles published did not increase at the same rate, a situation that has already been noted in other areas of study [50]. On the other hand, the growth in the number of publications is greater in relation to per capita income.

Readers are warned against over-interpreting the findings of this study, because it has several limitations, inherent to its bibliometric nature [51]. First, not all papers on optometry from the United Kingdom were included. This bibliometric study includes papers from the EMBASE Biomedical Answer web. The criteria set by the databases themselves determine the subsequent development of the studied materials [34,52]. Papers from national or local journals that were not included in MEDLINE and Excerpta Medica, and those contributions at scientific conferences and meetings were excluded. Additionally, we included only those papers with British corresponding authors in this study.

The originality of this research lies in the absence of relevant publications, which will allow the comparison of these data with those obtained in the future and substantiate its evolution.

Taking into account the limitations and strengths set out above, we have been able to provide an overview of the representativeness and evolution of international research on optometry in the United Kingdom, confirming its high standing. The originality of this research project is reflected by the absence of other publications on the subjects. It means our findings will be able to be compared with those obtained in the future and that possible future changes can be monitored, since at present British optometrists have varying aspirations, such as for example the use of medications to treat certain eye conditions.

Disclosure

The authors do not have any conflicts of interest, including financial support.

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