Academic Productivity of Neurosurgeons Working in the United Kingdom: Insights from the H-Index and Its Variants

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■ OBJECTIVES: **Academic metrics can be used to compare the productivity of researchers. We aimed to use a variety of bibliometric parameters to assess the productivity of neurosurgeons working in the United Kingdom.**

■ METHODS: **Neurosurgical consultants working in the United Kingdom were identified using the Society of British Neurosurgeons' Audit Programme website. Baseline data collected included year of entry to specialist register, academic position and award of higher degree. Google Scholar was used to compute a range of academic metrics for each consultant including the h-index, hi-norm, e-index and g-index. Non-parametric tests were used to compare median results.**

■ RESULTS: **Median metrics for the whole cohort were: h-index (5), hi-norm (3), g-index (10.4) and e-index (9). The top 3 units based on h-index were Addenbrookes (13), Great Ormond Street (12.5) and Queen's Square (11.5). The h-index correlated with academic position [Prof (17.5), Senior Lecturer (10.5) and non-academic (5); $P < 0.0001$], higher degree [PhD (10), MD (6) and none (4.5); $P < 0.0001$] and consultant experience [> 10 year (7), < 10 years (4); $P < 0.0001$]. No difference was found based on gender [male (5), female (4); $P = 0.12$]. The same trends were seen across the following other metrics: hi-norm, e-index and g-index.**

■ DISCUSSION: **This study details the academic impact of United Kingdom-based neurosurgeons through the analysis of a number of citation metrics. It provides a benchmark bibliometric profile and we advocate future comparative assessments as a means to assess impact of and guide academic policy.**

INTRODUCTION

Publications are widely regarded as a key indicator of academic performance. Analysis of citation trends is playing an increasingly important role in assessing the impact of individual academics. These analyses are being used to facilitate funding allocation and comparison between individuals and institutions.[1,2] The most common metric is the Hirsch index (h-index), which was devised in 2005.[3] It is calculated where "h publications received at least h citations or more," so an academic with 20 publications with at least 20 citations each would have an h-index of 20. The h-index is one of the most widely used metrics; however, it has a number of weaknesses. In particular, it is weighted toward older researchers who have had more time to accumulate citations throughout their career. Furthermore, it does not take into account highly cited articles and has therefore been suggested as favoring quantity over quality. It may also lose reliability for researchers with common names or fields of high coauthorship.[1] To compensate for these methodological issues, various modifications of the h-index have been developed. These include the m-quotient[3] and hi-annual, which aim to provide a temporal profile to the h-index and are meant to level the playing field between researchers with differing years of experience. Similarly, the hc-index provides an age-related weight to articles, which favors more recent publications.[4] While the g-index[5] provides more weight toward articles with high citation counts, the hi-norm takes into account the number of

Key words
- Bibliometrics
- h-index
- Neurosurgery
- United Kingdom

Abbreviations and Acronyms
BNTRC: British Neurosurgical Trainee Research Collaborative
GMC: General Medical Council
NNAP: Neurosurgical National Audit Programme
SBNS: Society of British Neurological Surgeons
SPSS: Statistical Package for the Social Sciences

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authors per publication. These variants provide context for the h-index and allow for a more robust interpretation of an individual's academic output.

A number of studies have assessed the h-index in a neurosurgical population.[6–10] Khan et al. examined the h-index of 188 neurosurgeons working in the United States and found a mean h-index of 20.3 based on Google Scholar.[10] Khan went on to further assess the productivity of 1225 academic neurosurgeons in the United States.[6] The study found that the median h-index, g-index, hc-index, and m-quotient were 11, 20, 8, and 0.62, respectively. Wilkes assessed the h-index and m-quotient of neurosurgeons working in the United Kingdom and found results of 6 and 0.41.[9] The observed differences between the 2 national cohorts are partly driven by the populations assessed, with Khan's studies focusing on academic neurosurgeons. Though these studies provided useful insights into the academic output of neurosurgeons, they either concentrated on part of a national cohort of neurosurgeons or only used a limited number of metrics to measure academic output in a full national cohort. In this study, we aimed to quantitatively analyze the scientific output of all neurosurgeons working in the United Kingdom. By using a broad portfolio of metrics, we aimed to address the major shortcomings of the h-index including bias toward more experienced researchers, lack of weighting toward highly cited articles, and limited differentiation between authorship patterns. We therefore aim to provide a robust assessment of the academic productivity of neurosurgeons working in a single country and create a bibliometric profile to guide academic policy and for future comparative assessments.

MATERIALS AND METHODS

Neurosurgical consultants working in the United Kingdom were identified using The Society of British Neurological Surgeons Neurosurgical National Audit Programme (NNAP) website. From this we sourced the consultant's units, General Medical Council (GMC) number, and higher degrees (Ph.D., M.D., or none). In the United Kingdom, an M.D. is a postgraduate qualification normally awarded after 2 years of original research and submission of a thesis. The GMC's medical register was then interrogated for consultant's date of entry to the Specialist Neurosurgery Register. Online and departmental website searches were then used to identify consultant academic positions (professor, senior clinical lecturer, or none). University rankings were identified from the University League table, which ranks institutions on the basis of an aggregate score of their research quality (as indicated by the university Research Excellence Framework),[11] student satisfaction (measured by the National Student Survey of final year undergraduates),[12] graduate prospects (employability of first-degree graduates based on data from the Higher Education Statistics Agency),[13] and entry criteria (average university entrance tariff for undergraduate students). Following the collection of baseline demographic data, 2 search engines (Scopus and Google Scholar) were used to gather a range of academic metrics for each consultant. These included the metrics defined later, as well as the number of papers published by each consultant and the total number of citations received.

Academic Metric Engines

A number of engines are available for tracking and analyzing citation patterns. Bakkalbasi compared 3 engines (Google Scholar, Scopus, and Web of Science) across a range of disciplines and in 2 different years.[14] The study showed that no one resource provided a superior performance across disciplines or timeframes. We opted to use the following 2 search engines:

Scopus. Scopus (www.scopus.com) uses an author-identifying algorithm to match author names on the basis of their affiliation, address, subject area, source title, dates of publication citations, and coauthors. A list of publications for each consultant was generated, as well as the number of coauthors and the total number of citations. Scopus automatically generates an h-index, but it is inaccurate for authors with papers published before 1996 as Scopus has incomplete citation data before this date.

Google Scholar. Publish or perish (PoP) is a free program available to download from Anne-Wil Harzing's website (www.harzing.com) that searches Google Scholar to calculate a wider range of citation metrics than Scopus.[15] Google Scholar had a number of documented drawbacks at its inception in 2004 including poor indexing of publications and variability in citation counts. However, a number of recent longitudinal studies have identified a significant improvement in Google Scholar's stability and coverage in the past few years.[16,17] PoP has been tested by assessing the publication record of 20 Nobel Laureates across a range of disciplines.[18] It showed comprehensive coverage of 800 of their most cited publications except in 4 cases. PoP has also been used for citation analysis across a range of disciplines including economics and the social sciences.[19] There is no author-matching algorithm, so lists of publications were manually checked to ensure that only papers pertaining to the author in question were included. This was achieved by assessing the author's initials and article title. Names that generated >1000 hits were excluded from analysis. Once the author publication list was finalized, POP automatically generated a range of citation metrics including the h-index, hi-norm, hi-annual, hc-index, e-index, g-index, and m-quotient.

Citation Metrics

We opted for a portfolio of 7 metrics that were calculable using the search engines used and addressed the major shortcomings of the h-index. These include:

h-index: h is defined as the highest number such that the academic has h publications with at least h or more citations.[8]

hi-norm: instead of dividing the total h-index, it first normalizes the number of citations for each paper by dividing the number of citations by the number of authors for that paper. The hi-norm is then calculated as the h-index of the normalized citation counts. This metric is meant to mitigate the effect of differing authorship numbers that is seen across disciplines and provides a per-author measure.[15]

hi-annual: the individual, average annual increase of the h-index. This metric is designed to allow comparisons between researchers with differing years of experience.[15]

hc-index: The contemporary h-index adds an age-related weighting to each cited article, giving less weight to older articles. It is derived by multiplying the citation count of article by 4, then dividing by the number of years since publication.[15]

e-index: The e-index is the (square root) of the surplus of citations in the h-set beyond h^2. The aim of the e-index is to differentiate between scientists with similar h-indices but different citation patterns.[15]

m-quotient: The m-quotient is the h-index divided by the number of years since the author's first publication. This metric, much like hi-annual, is designed to level the playing field between researchers of differing career lengths.

g-index: gives more weight to articles with a large number of citations. With articles ranked in decreasing order based on number of citations, the g-index is the largest number such that the top x articles received collectively at least x^2 citations.[6]

Statistical Analysis

All identified articles linked to an author were included for the generation of an individual's academic metric portfolio. A single article could be linked to authors from different neurosurgical units within the country. Nonparametric tests were applied to the data to compare for differences in the academic metrics based on consultant parameters. We used the Mann Whitney U test to compare differences between 2 groups: gender, university ranking (top vs. bottom 25) and years since joining specialty register (> or <10 years). For comparison of 3 groups (higher degrees and academic position) we used the Kruskal-Wallis test. We also calculated correlation coefficients for departmental ranking between the h-index and other metrics. Statistical Package for the Social Sciences (SPSS) version 19 was used for analysis, and the P value was set at <0.05.

RESULTS

A total of 334 consultants were included in the study. From this cohort, 17 did not have any identifiable data on either search engine, leaving a total of 317 consultants for analysis. Of this cohort, 26 consultants had data available on Scopus only and 2 consultants had data only from Google Scholar (Figure 1). We found consultants published a median of 12 articles with a range 0–457 papers. We compared the number of publications and total citations between neurosurgeons with < or >10 years' experience. We found that junior consultants had a median of 9 publications (0–118) and 80 citations (0–5699). Senior consultants had a median of 16 publications (0–457) and 319 citations (0–13105). We found the median h-index differed between the 2 search engines with Google Scholar, calculating it as 5 and Scopus as 6. There was a positive correlation between the h-indices of the two search engines with a coefficient of 0.76. Table 1 highlights the median academic metrics across the whole consultant cohort.

Departmental Differences in Academic Metrics

We ranked the units across the United Kingdom according to the median Google Scholar indices. On the basis of the h-index, we found that the top 5 units were Addenbrookes (13), Great Ormond Street (12.5), Queen's Square (11.5), John Radcliffe (10), and Frenchay, Bristol (9) (Table 2). Addenbrookes held the top rank across all the metrics except the m-quotient and hi-annual. A number of units, outside of the top 5 based on the h-index, showed strong m-quotient and hi-annual metrics. These units included the Walton Centre in Liverpool (0.51), the Queen Elizabeth Hospital in Birmingham (0.47), Leeds General Hospital (0.45), and Western General Hospital in Edinburgh (0.4). The correlation coefficients in the departmental rankings between the h-index and the other metrics were as follows: hi-norm (0.94),

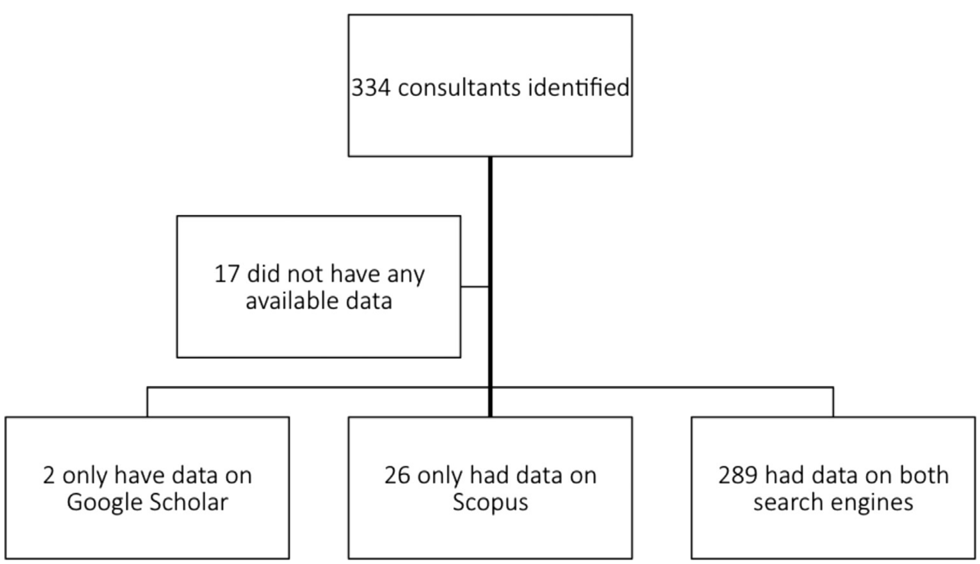

Figure 1. Scheme of consultant inclusion and data availability in search engine.

Table 1. Summary of Academic Metrics for Whole Consultant Cohort

Scopus	Google Scholar						
h-index	h-index	hi-norm	hi-annual	hc-index	g-index	m-quotient	e-index
6	5	3	0.23	4	10.4	0.3	9

hi-annual (0.61), hc-index (0.91), g-index (0.88), m-quotient (0.69), and e-index (0.92).

Parameters Associated with Academic Metrics

We found statistically significant differences between all metrics when we compared consultants on the basis of their academic degree and academic position (Table 3). There was no statistically significant difference between consultant academic metrics based on their gender. We also assessed the significance of consultant seniority on their calculated metrics based on their time since joining the specialist register. We found that consultants with more than 10 years of experience had significantly higher metrics except for the m-quotient and hi-annual; both of which take into account change over time. Consultants linked to the top 25 universities had a significantly higher h-index (7) compared with those linked to the bottom 25 institutions (4) ($P < 0.0001$). This trend was seen across all the other metrics.

DISCUSSION

There has been a significant expansion in the use of bibliometric parameters to profile academic productivity in recent years. The h-index has been the primary metric used; however, a range of variants has been devised to address its shortcomings. In this article we detail the application of a wide portfolio of metrics to neurosurgeons working in the United Kingdom. A previous study by Wilkes et al. assessed the United Kingdom neurosurgical community using the h-index and m-quotient.[9] The study used Scopus only for their analysis and calculated the h-index as 6 and the m-quotient as 0.41. Reassuringly, we calculated the h-index as 6 on the basis of our Scopus analysis demonstrating a good interobserver concordance. Our primary analysis using Google Scholar returned an h-index of 5 and an m-quotient

Table 2. Comparison of Median Academic Metrics for the Top 20 Units Based on the h-index

No.	Unit	h-index	hI norm	hI annual	hc-index	g-index	m-quotient	e-index
1	Addenbrooke's, Cambridge	13	8	0.39	11	28.6	0.71	29
2	Great Ormond Street, London	12.5	7.5	0.44	9.5	24.3	0.86	23
3	NHNN, Queens Square, London	11.5	7	0.33	10.5	20.3	0.49	23.5
4	John Radcliffe, Oxford	10	5.5	0.34	8	17	0.63	18.5
5	Frenchay Hospital, Bristol	9	4.5	0.29	4.5	17.6	0.41	12
6	St. Georges, London	9	6	0.18	5	17.8	0.3	16
7	SW Neurosurgery, Plymouth	9	6	0.23	6	19	0.29	17
8	Walton Centre, Liverpool	8.5	5	0.29	6.5	14.8	0.51	16
9	Charing Cross, London	8	4	0.23	6	18.7	0.4	10
10	Queen Elizabeth, Birmingham	7	4	0.28	6	13.6	0.47	11
11	Romford, Essex	6.5	5	0.23	5	11.9	0.35	13
12	King's College, London	6	4	0.25	5	14.6	0.38	16
13	Queen's Medical Centre, Nottingham	6	5	0.23	4	12.1	0.31	10
14	Western General, Edinburgh	6	4	0.29	5	10.8	0.4	14
15	James Cook, Middlesbrough	6	3	0.16	4.5	8.8	0.26	10.5
16	Southampton General Hospital	5	3	0.18	4	10	0.24	9
17	General Infirmary, Leeds	5	3	0.21	4	7.2	0.45	7
18	North Staffordshire	5	3	0.18	4	8.9	0.25	10
19	St. Barts and Royal, London	4.5	3.5	0.24	3.5	15.4	0.3	5
20	University Hospital, Cardiff	4	3	0.17	3	9.1	0.21	7.5

Table 3. Comparison of Median Academic Metrics Based on Range of Parameters

	h-index	hI norm	hI annual	hc-index	g-index	m-quotient	e-index
Gender							
Female	4	3	0.21	3	9.7	0.27	9
Male	5	3	0.23	4	10.6	0.33	10
P value	0.12	0.26	0.46	0.15	0.32	0.2	0.55
Academic position							
Professor	17.5	9.5	0.35	13	28.1	0.53	36
Senior Clinical Lecturer	10.5	6	0.32	8.5	19.2	0.5	19.5
None	5	3	0.21	4	9.6	0.31	8
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Higher degree							
Ph.D.	10	6.5	0.35	7.5	20	0.6	19
M.D.	6	3	0.24	4	11.2	0.33	9.5
None	4.5	3	0.2	4	8.7	0.3	8
P value	<0.0001	<0.0001	0.001	<0.0001	0.001	0.005	<0.0001
Consultant seniority							
<10 years	4	2	0.22	3.5	7	0.3	7
>10 years	7	5	0.23	5	15.4	0.3	15
P value	<0.0001	<0.0001	0.86	<0.0001	<0.0001	0.56	<0.0001
University ranking							
Top 25	7	4	0.27	6	12.7	0.4	13
Bottom 25	4	3	0.2	3	9	0.3	7
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

of 0.3. Two studies by Khan applied citation metrics to neurosurgeons working in the United States.[6,8] These studies described median h-indices between 11 and 16 in their assessed cohort. In part, the studied population drives this difference with Khan's studies focusing on neurosurgeons working in major academic centers. This approach omits a large number of non-academically orientated surgeons. Comparatively, our approach aimed to analyze the whole consultant cohort in the United Kingdom, giving a broader and more representative view of the neurosurgical community. A subanalysis of the top 10 units in our study found that the median h-index was 10; this is closer to the Khan's findings demonstrating that there is a less apparent difference between comparable cohorts of neurosurgeons in the United States and United Kingdom.

Within our analysis, metrics that took years of experience into account (m-quotient and hi-annual) showed no significant difference between surgeons of different seniority. This highlights that junior consultants are maintaining similar academic productivity rates compared with their senior colleagues. The introduction of defined clinical academic training pathways and the recent establishment of the British Neurosurgical Trainee Research Collaborative (BNTRC) should have an important impact on the long-term productivity of British neurosurgery.[20] The collaborative is a network of neurosurgical trainees in the United Kingdom that aims to undertake trainee-led multicenter research projects. So far, the BNTRC has embarked on 2 prospective multicenter studies focusing on chronic subdural hematoma management and infection rates following external ventricular drainage.[21,22] Trainee participation in collaborative research should further ingrain an academic culture within the community and increase the number of high-impact publications emerging from the United Kingdom.

Our findings highlighted that neurosurgical units linked to higher-ranking universities (top 25 vs. bottom 25) have significantly higher academic metrics. This trend was seen across all metrics showing a broad-reaching academic benefit to be linked to major research centers. This was also reflected in the ranking of the units with links to major United Kingdom universities in the top 10. The reason for this is likely driven by 2 synergistic fronts: the draw of academically active neurosurgeons to these units coupled with the available infrastructure and support for research and funding acquisition. As with previous studies, our analysis reinforced the impact of academic position and higher degrees on academic metrics.[6,10,23,24] Our project analyzed a variety of additional metrics, which allowed us to glean a more nuanced interpretation of academic neurosurgery in the United Kingdom. Both the m-quotient and hi-annual were significantly greater based on higher degree status. This finding indicates that the effect of undertaking a higher degree is continued throughout the surgeon's career as he or she maintains citation acquisition, which may point toward continued academic productivity. This trend is not seen when we compared these metrics on the basis of consultant seniority, indicating that higher degree uptake by trainees should have a positive effect on the future of academic neurosurgery in the United Kingdom. The significantly higher hi-norm (citations normalized to number of authors) in more senior consultants is partly explained with increasing number of citations over time but may also indicate a shift to greater collaborative research and larger authorship numbers among younger consultants. The academic rank and higher degree differences in the g-index show that achieving professorship and obtaining a Ph.D. have an important link to producing highly cited articles during a neurosurgeon's career.

Comparison of the academic metrics provides useful insights into the landscape of regional academic variability across the United Kingdom. Cambridge emerged as the dominant academic unit across almost all the metrics. This was also reflected in Wilkes' study; however, those results placed St. George's in the top 5 while ours included Bristol.[9] The moderate correlation between the h-index and m-quotient and hi-annual departmental rankings demonstrates a variation in rate of h-index changes per unit time throughout the country. This highlights potential differences in the changing pace of academic output and points toward increasingly active units such as the Walton Center in Liverpool, Western General Hospital in Edinburgh, and Leeds General Infirmary. A study by Knight comparing the h-index of U.K. neurosurgical units found similar trends with Addenbrookes taking top rank and the Western General Hospital showing an improvement in h-indices.[25] However, the results were not completely identical due to differing search strategies and engine choice. Knight took a unit-centric search strategy using Thomson's Institute for Scientific Information Web of Science to calculate h-indices across 3 time periods (64, 10, and 3 years). Using Addenbrooke's as an example, Knight found h-indices of 75, 53, and 12 over the 3 time periods compared with a result of 14 and 13 in Wilkes' and our articles, respectively.[9] Using a unit-specific approach compared with our and Wilkes' consultant-specific strategy captures more publications and over wider time periods, therefore generating much higher h-indices.

Despite our efforts to provide an accurate assessment of the productivity of British neurosurgeons, the project has a number of limitations. These stem, in the most part, from the databases used. It has been demonstrated that different databases produce qualitatively and quantitatively different citation trends.[26] This is driven by the differing algorithm approaches and the use of manual assessment in Google Scholar. We attempted to mitigate these effects with the use of 2 databases to ensure we provided as robust a picture as possible.

CONCLUSIONS

In this project we provide the most up-to-date and robust picture of academic productivity of all neurosurgeons working in a single country. The differences across academic rank, higher degree status, and university ranking demonstrate an internal validity for the metrics in our studied cohort. Our use of a wide range of h-index variants has provided a more comprehensive insight into the productivity status of neurosurgeons working in the United Kingdom. It highlighted the value of higher degrees on career-long academic activity and indicated a potential shift toward higher authorship numbers, reflecting a potential increase in collaborative research. This portfolio of metrics provides a benchmark of British neurosurgical academic productivity, and we advocate future comparative assessments to help guide academic policy.

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