SPECIAL ARTICLE

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Medical School and Residency Influence on Choice of an Academic Career and Academic Productivity Among US Neurology Faculty

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Objective: To evaluate the effectiveness of medical schools and neurology training programs in the United States by determining their contribution to academic neurology in terms of how many graduates choose academic careers and their respective influence on current medical knowledge through bibliometric analysis.

Design, Setting, and Participants: Biographical information from current faculty members of neurology training programs in the United States was obtained through an Internet-based search of departmental Web sites. Collected variables included medical school attended, residency program completed, and current academic rank. For each faculty member, ISI Web of Science and Scopus *h*-indices were also collected.

Results: Data from academic neurologists from 120 training programs with 3249 faculty members were collected. All data regarding training program and medical school education were compiled and analyzed by the institution from which each individual graduated. The 20 medical schools and neurology residency training programs producing the greatest number of graduates remaining in academic practice and the mean *h*-indices are reported. More medical school graduates of the Columbia University College of Physicians and Surgeons chose to enter academic neurology practice than the graduates of any other institution. Analyzed by residency training program attended, New York Presbyterian Hospital (Columbia University), Mayo Clinic (Rochester, Minnesota), and Mount Sinai Medical Center (New York, New York) produced the most graduates remaining in academics.

Conclusions: This retrospective, longitudinal cohort study examines through quantitative measures the academic productivity and rank of academic neurologists. The results demonstrate that several training programs excel in producing a significantly higher proportion of academically active neurologists.

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MEDICAL SCHOOLS AND residency programs share the common objective of producing competent physicians and future academicians.[1] At some point during training, all physicians must decide whether to pursue an academic career or seek employment in a nonacademic setting. The factors motivating physicians to pursue careers in academics or the private sector are complex, with many financial, personal, and geographic factors contributing.[2] Attracting physicians into academic medicine is important for the continued advancement of medicine; many medical schools and residency training programs excel at this task, while others languish.[3-5]

Given the wide range of possible goals, productivity within academic medicine is difficult to quantify. Within the clinical arena, the relative value unit is often appropriated as a surrogate for clinical activity. Thus, by way of summation of relative value units, the total activity of an institution, department, or individual can be measured and analyzed.[6] Another established measure of departmental academic success has been the amount of National Institutes of Health funding secured.[7] Other metrics to evaluate the academic productivity of a specific department include the number of peer-reviewed scholarly articles published, number of faculty members, and academic degrees held by the faculty.[8] The strongest indicator that a faculty member will be promoted is the number of published first-author peer-reviewed papers, thus making the generation of manuscripts essential to career advancement of academic physicians.[9] Recently, Hirsch[10] proposed a measurement called the *h*-index (which stands for "highly cited" index) that is based on an author's most cited articles and the number

Table 1. Results Available After Internet-Based Analysis of 120 Neurology Programs

Search	Total Available, No.	Collected, No. (%)
Programs	125	120 (96.0)
Faculty		3249
Rank/position	3249	2846 (87.6)
Medical school	3249	3119 (96.0)
Residency completed	3249	3061 (94.2)

of citations each of these articles receive. This metric has been recently used to provide an estimate of the importance, significance, and broad impact of a scientist's cumulative research contributions. While these measures have typically been compared in aggregate to assess the contribution of each center to the academic atmosphere, little attention has been directed toward individual centers' ability to inspire graduates to choose a career in academic medicine and to subsequently enrich themselves and other academic institutions with productive faculty members.

Residency training programs and medical schools often claim to seek trainees with the greatest potential for an academic contribution. However, to our knowledge, a systematic appraisal of the contribution of individual centers' graduates to academic medicine has not been previously reported. Our analysis attempts to assess the impact of the medical school and residency training program on the decision to pursue a career in academic neurology as well as an estimation of the most productive medical schools and residency programs based on the academic productivity of their respective graduates. To this end, *h*-index–based metrics and the endowment of human capital generated by each center are considered in order to provide an appraisal of the contribution of all medical schools and US training programs to academic neurology.

METHODS

Residency training programs were identified through a register of 125 neurology programs in the United States and Puerto Rico accredited by the Accreditation Council on Graduate Medical Education obtained from the Fellowship and Residency Electronic Interactive Database Access System Web site (http://www.ama-assn.org/go/freida). Biographical information on individual faculty members was identified from each program by an Internet-based search of departmental Web sites conducted during January 2010. Faculty members were included for analysis if listed on institutional Web sites. All research faculty and faculty specializing in pediatric neurology were excluded from evaluation. Additionally, any individual designated as a nonneurologist, resident, fellow, or professor emeritus was excluded from this analysis. Institutions without an established residency Web site (5 programs) were excluded from analysis. Based on these Web pages, academic rank was cataloged as instructor, assistant professor, associate professor, professor, and/or chairman. The sites where faculty members completed medical school and residency training were also recorded. To a great extent, this was available from the departmental Web sites; if missing, a second search was performed at http://www.drscore.com.

An individualized measure of each faculty member's *h*-index score was performed using 2 citation-tracking databases. Using the Scopus database (http://www.scopus.com), first and last names were entered into the author search function to create a search string. If incomplete information was obtained from the Web site search, the Scopus results were then used to refine each faculty member's full name, including middle initial and preferred variations of the author's name used in published articles. The title of the most recent published article of inexact matches was surveyed to determine whether the corresponding result should be included in the author's publications, regardless of institutional affiliation. The citation tracker function was then used to generate the *h*-index for each author. The ISI Web of Science (WoS) database (http://www.isiknowledge.com) was also used to gather *h*-indices. Using WoS, a search was performed using the surname and the author's preferred initials in reported peer-reviewed literature (typically first and middle initial) to obtain the citation report of the individual. This was performed because the WoS identifies authors by surnames and initials rather than by surnames and full given names.[11] Citation results for this engine were not processed further. The citation report function provided a summary of standard bibliometrics including *h*-indices. Searches were conducted randomly by program in a single week of May 2010 by a single data collector (Y.H.L.) in an attempt to minimize bias.

Analysis of variance was performed to determine whether an overall difference existed between average *h*-indices across academic ranks. The Tukey range test, with significance defined as $P \leq .05$, was used to identify significantly different pairs of ranks. All statistical analyses were performed using the SAS-based statistical software package JMP version 7.0 (SAS Institute, Inc, Cary, North Carolina). Statistical significance was defined as $P < .05$.

RESULTS

One hundred twenty of 125 programs (96.0%) had departmental Web sites individually identifying their faculty (**Table 1**). The institutions where each neurologist completed medical school and residency were identified with 96.0% and 94.2% effectiveness, respectively. Faculty rank was available for 87.6% of the sample. Within this group, 128 (4.5%) were instructors, 1160 (40.8%) were assistant professors, 657 (23.1%) were associate professors, and 900 (31.6%) were full professors.

The program in which each faculty member completed medical school and residency was recorded. All medical schools (including foreign institutions) and Accreditation Council on Graduate Medical Education–accredited residency programs were tabulated using an institution-specific notation. These results were further analyzed to determine which medical schools and residency programs are most effective at producing academic neurologists. Residency programs produced from 1 to 134 academic neurologists. The median program produced 3 faculty members; centers in the 25th percentile produced 1 academic attending and those in the 75th percentile generated 15 academic attendings. In the interest of brevity, only the top 20 medical schools and residency programs are described in this article (**Table 2** and **Table 3**). The 3 US medical schools most effective at producing academic neurologists were Columbia University College of Physicians and Surgeons, University

Table 2. Top 20 Most Productive Residency Programs by Graduates Entering Academic Neurology and Mean Scopus and ISI Web of Science *h*-Indices of Graduates

Rank	Program	Graduates in Academic Neurology, No.	ISI Web of Science Mean *h*-Index	Scopus Mean *h*-Index
1	Columbia University	134	22.500	12.6493
2	Mayo Clinic, Rochester, Minnesota	112	21.179	12.6071
3	Mount Sinai Medical Center, New York, New York	106	10.792	4.8774
4	University of Pennsylvania	104	22.231	13.5865
5	Johns Hopkins University	93	23.333	14.2903
6	University of California, San Francisco	78	24.192	15.9231
6	Washington University	78	17.410	9.1026
8	University of California, Los Angeles	75	16.013	9.5600
9	Massachusetts General Hospital	71	26.296	17.9859
10	Cornell University	67	24.821	13.3582
11	University of Michigan	66	15.197	9.0758
12	Albert Einstein College of Medicine	64	13.547	7.2188
13	Boston University	58	23.793	12.7414
14	University of Virginia	58	19.172	10.6034
15	New York University	54	15.185	5.9444
16	Yale University	51	14.745	8.1961
17	Brigham and Women's Hospital	48	19.188	13.5106
18	University of Rochester	47	18.128	10.2766
19	University of Iowa	44	20.159	9.8182
20	Duke University	43	17.628	7.4651

Table 3. Top 20 Most Productive Medical Schools by Graduates Entering Academic Neurology and Mean Scopus and ISI Web of Science *h*-Indices of Graduates

Rank	Program	Graduates in Academic Neurology, No.	ISI Web of Science Mean *h*-Index	Scopus Mean *h*-Index
1	Columbia University	79	18.722	9.6203
2	University of Pennsylvania	68	23.485	12.9265
3	Harvard Medical School	63	27.714	17.2419
4	Johns Hopkins University	54	24.037	14.2037
4	Northwestern University	54	18.963	12.6481
6	New York University	53	17.906	9.6604
7	Albert Einstein College of Medicine	50	20.420	10.0200
8	Indiana University	48	13.208	6.5000
9	Cornell University	47	24.723	13.7234
10	Washington University	42	22.095	13.2381
11	University of Chicago	39	22.846	13.9231
12	Baylor University	38	19.105	10.4474
12	University of Michigan	38	19.684	12.3421
13	Yale University	35	30.029	17.3143
14	University of Miami	32	16.688	9.3438
15	Boston University	31	19.935	9.6452
16	Ohio State University	30	18.933	9.1000
16	State University of New York at Buffalo	30	10.500	5.6000
18	Tulane University	29	16.724	7.0690
18	University of Virginia	29	34.724	18.5862
20	Case Western Reserve University	28	20.714	12.7500
20	Rush University	28	21.929	11.2500

of Pennsylvania School of Medicine, and Harvard Medical School. When analyzed by residency training program attended, New York Presbyterian Hospital (Columbia University), Mayo Clinic (Rochester, Minnesota), and Mount Sinai Medical Center (New York, New York) produced the most graduates remaining in academics at the time of data collection.

The top 3 training programs were responsible for 10.8% of the academic neurologists identified by this survey. Correspondingly, the top 3 medical schools graduated 6.5% of currently practicing academicians. Furthermore, the graduates of the top 20 residency programs and medical schools accounted for 44.7% and 29.1% of the entire population of university neurologists, respectively.

The WoS and Scopus *h*-indices were additionally evaluated in an attempt to assess the scholarly contribution of a center's graduates to peer-reviewed literature. These values were summated to provide a mean *h*-index for the graduates of individual training programs and medical schools. All mean *h*-indices for the top 20 centers have

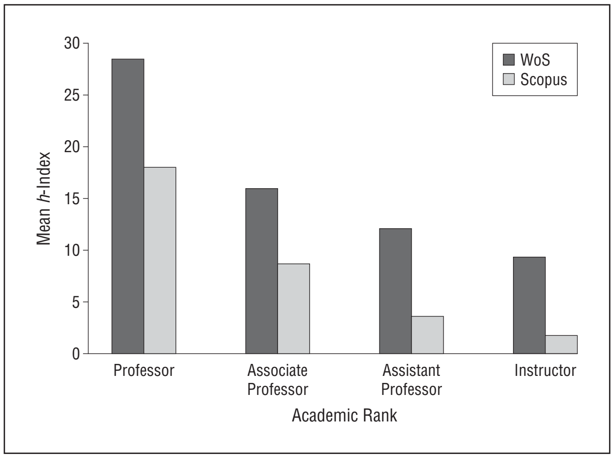

Figure. The mean *h*-indices of academic neurologists derived from the ISI Web of Science (WoS) and Scopus statistically significantly increased in comparison with academic rank.

been reported (Table 2 and Table 3). By medical school, graduates of the University of Virginia, Yale University, and Harvard University medical schools had the highest mean WoS *h*-indices; the assessment performed using the Scopus database also identified University of Virginia, Yale University, and Harvard University medical school graduates as having the highest academic output. Within neurology residency programs, mean WoS *h*-indices showed that the graduates of the Massachusetts General Hospital program, Cornell University, and the University of California, San Francisco have the highest scholarly output, while Scopus recognized graduates of the Massachusetts General Hospital program, the University of California, San Francisco, and Johns Hopkins University to be the most prolific authors.

Mean *h*-indices were statistically analyzed in an attempt to evaluate their correlation with academic rank (**Figure**). The mean WoS *h*-indices were 9.4 for instructors, 12.1 for assistant professors, 15.9 for associate professors, and 28.5 for professors. The mean Scopus *h*-indices were 1.7 for instructors, 3.6 for assistant professors, 8.7 for associate professors, and 18.1 for professors. There were statistically significant decreases in *h*-indices associated with decreases in academic rank for professors, associate professors, and assistant professors in both the WoS and Scopus values ($P < .05$) (Figure). Assistant professors and instructors did not have statistically significant differences in *h*-index by either database.

COMMENT

Determining which elements attract physicians to choose an academic career and what factors may predict eventual success in academics would be beneficial to both applicant selection and mentoring medical students and residents. It is likely that medical school and residency experiences are important factors in the choice of an academic career in neurology.[12,13] Several longitudinal studies have identified some of the early predictors of an academic career choice in medical students, pediatric residents, family medicine faculty, radiology faculty, and neurology faculty.[13-17] Strong mentorship and publishing early and often were the most consistent variables associated with future academic inquiry. Accordingly, by evaluating the academic productivity of graduates of all medical schools and neurology residency training programs accredited in the United States, this study seeks to determine the influence of the academic center with regard to academic productivity.

MEDICAL SCHOOL AND RESIDENCY IMPACT

If asked, most academic neurologists would be able to provide a rough appraisal of the strengths and weaknesses of specific departments. Most commonly, reputations are abbreviated, with programs identified as research powerhouses or possessing a strong clinical bent. Some programs are believed be less robust in their research and clinical productivity.[18] Evaluation of individual departmental characteristics has been difficult and subjective.

When attempting to evaluate the scholarly contribution of a certain department, outcome measures such as total publications, number of citations, grant award rates and amounts, professional society leadership posts, and editorial board membership have most frequently served as indicators of academic achievement in the past.[19] In the recent pathology, neurosurgery, and radiation oncology literature, bibliometric analysis of *h*-indices has been adopted to serve as a comparative measure of both qualitative and quantitative research activity on an interdepartmental basis.[8,11,18]

Individually collected *h*-indices of practicing academic neurology attendings were captured at a specific time in an attempt to estimate the mean scholastic output of the graduates of medical schools and Accreditation Council on Graduate Medical Education–accredited neurology residency training programs who currently work in an academic center. Rather than using these metrics to compare the aggregate departmental output as has been done previously in other disciplines, this study aims to compare the gross total academic output of the graduates of these medical schools and training programs regardless of their current institutional affiliation.[8,18-21]

This analysis of the academic impact of medical schools and their affiliated institutions was designed with the intention to objectively evaluate both the overall scholarly output and the sum of their graduates who select careers in academic medicine. The exact determinants of an individual's medical school and training program experience on his or her decision to embrace academic medicine (thereby endowing the entire field with continued knowledge, skill, and creativity) are not understood.[22] Our study seeks to use the production of academic neurologists as an important metric in evaluation of medical schools and neurology training programs.

RESULTS OF THIS STUDY

Many factors contribute to an individual's decision to pursue an academic career. Commonly cited facilitators include completion of a graduate degree or fellowship, research interests, the desire to teach, intellectual stimulation, and the influence of a mentor.[23,24] Experiences in certain medical schools or residency programs may provide a stronger academic influence on future career decision making than experiences in others. To our knowledge, assessment of the impact of medical school or residency training on the choice of an academic career in neurology has not been reported in the literature.

Overall, neurology residencies have a median of 3 graduates in academic practice per program, with a range of 1 to 134. Four centers have produced more than 100 academicians active at the time of our assessment (Table 2). The distribution of academicians in neurology and the distribution of medical school and residency training programs seem to show that medical school and residency program experiences may significantly contribute to career choice.

While many factors likely contribute to an individual's choice of an academic career in neurology, it is possible that the influence of medical school and residency program experiences is significant. In the current assessment, 44.7% of all academic neurologists completed training at one of the 20 programs listed in Table 2. Furthermore, the top 3 programs in our assessment accounted for 10.8% of all academicians; future study may help to elucidate the underlying factors that explain the inclination of these programs to successfully produce academicians.

h-INDEX SCORING

The assessment of an academician's scientific contribution often plays a significant role in academic promotion, tenure determination, and grant funding.[25] While first introduced for use in evaluating physics professors, the *h*-index was proposed in 2005 to estimate both the quantitative output and the broader impact of a scientist's cumulative research contributions.[10] The use of the *h*-index has recently been applied to the medical subspecialties, including pathology, neurosurgery, radiation oncology, radiology, urology, and otolaryngology.[8,11,20,21,26] However, this metric is growing in popularity given its availability and has recently been used as justification for allocation of research funding.[27]

Citation counts are used to measure the impact of articles, journals, and researchers. Prior to 2004, WoS was the only search engine capable of determining citation data.[28] As a result, nearly all citation analysis of the medical literature was performed through this portal.[29] Since this time, 2 alternatives to WoS have become available for bibliometric analysis: Scopus and Google Scholar. The WoS database contains citation data from 1900 to the present, Scopus contains data from 1996 to the present, and Google Scholar does not disclose its time coverage.[30] However, if there is disagreement in these databases with regard to citation counts, this could create an inherent bias for citation analysis studies. To this end, Bar-Ilan[28] compared the *h*-indices of the publications of several highly cited Israeli researchers induced by the citation counts reported by WoS, Scopus, and Google Scholar and found a high similarity between Scopus and WoS results but fewer similarities between these engines and Google Scholar. While Google Scholar consistently retrieves even the most obscure citations, it has been criticized for being unreliable, being antiquated, containing grossly inflated citation counts, and reporting phantom authors and citations.[31,32] Based on these reports, we chose to query both the WoS and Scopus databases to evaluate our *h*-indices. In our assessment, we found higher *h*-indices using WoS, which was likely secondary to the required use of the author's first initials as opposed to first name in Scopus. However, both Scopus and WoS were able to detect a statistically significant increase in mean *h*-indices and increased academic rank (Figure).

SOURCES OF BIAS

To our knowledge, this study is the first attempt to classify academic success as it relates to the graduates of medical schools and training programs of currently practicing neurology faculty. This study possesses several limitations. All faculty members were identified by a search of the publicly available departmental Web sites, which may not have been up to date or may not include all faculty members at satellite institutions. Also, given the multiple training pathways to some of the pediatric subspecialties, pediatric specialists were excluded to ensure that the entire sample had completed a neurology residency training program. Academic neurologists not involved in residency training programs were omitted from the assessment.

Large institutions producing more graduates are likely disproportionately favored through their increased number of residents completing training. The study defines an academic neurologist as one remaining active in resident education, and hence only reviews Accreditation Council on Graduate Medical Education–accredited training programs. During the course of this study, some residency training programs combined and others significantly enlarged their resident complement. For the purposes of this evaluation, graduates were evaluated separately based on the institution at which they completed training.

Given the cumulative nature of the *h*-index, it is a lagging indicator. More senior faculty members are expected to enjoy a greater *h*-index, likely due to their academic contributions being available for citation for a longer time (Figure). Our primary outcome measure, production of academic neurologists, is also a lagging indicator reflecting the experiences of neurology faculty members today even though they were residents and medical students perhaps many years prior. This past performance may not reflect the current environment and experiences of trainees at these institutions.

Centers producing the most graduates with the highest bibliometric indicators were ranked prominently; however, neither of these metrics assesses clinical experience. We are unaware of any consistently collected, nonproprietary estimates of case volume that would allow for a meaningful interdepartmental comparison. This study does not examine graduates' effectiveness in patient care, teaching ability, involvement in medical societies, or the curriculum of specific medical schools or training programs. This assessment of bibliometrics and individual productivity provides an indirect and durable estimate of institutional impact on academic outcome.

CONCLUSIONS

This study seeks to evaluate the academic productivity of medical schools and neurology residency programs based on the contribution of their graduates as active faculty members in residency training programs as well as the productivity of these graduates as measured by their mean *h*-indices. The top 3 residency training programs were responsible for 10.8% of all academic neurologists at the time of this assessment. The experiences in medical school and residency training may be one factor influencing the choice of an academic career in neurology.

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