Physician-scientists in neurology

Research contributions of a cohort of neurologists

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Neurology® 2018;91:508-514. doi:10.1212/01.wnl.0000544243.58941.11

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Abstract

Objective

The objective of this study was to evaluate the methods by which neurology physician-scientists are quantified through applying author-level metrics to commonly used definitions when discussing funding efforts aimed at the attrition of the physician-scientist workforce.

Methods

Neurology residency alumni from institutions with the highest National Institute of Neurological Disorders and Stroke funding were identified for 2003–2005, and their funding records, publishing history, and impact factor (*h*-index) were obtained via the NIH Research Portfolio Online Reporting Tools and Scopus Author Profile. The group differences of total publications, yearly publication rate, and *h*-index between R01-funded, non-R01-funded, and nonfunded individuals were analyzed via analysis of variance models, and a publications-per-research hour rate was calculated and similarly compared across groups.

Results

From 15 programs, and from a total of 252 neurologists, 186 were identified as having demonstrated an interest in research. The mean *h*-index, yearly publication rate, and cumulative number of publications were significantly higher in those who eventually received an R01 grant compared to those without R01 funding and those with no research funding. Within the top 50 performers by yearly publication rate, there was an equal mix of the 3 groups of neurologists: R01 (19, 38%), non-R01 (15, 30%), and nonfunded (16, 32%). Those who were nonfunded (10% research effort) had an estimated 4.9 publications per 1,000 research hours compared to 3.0 for those with non-R01 (40% research effort) funding and 3.2 for those with R01 funding (80% research effort).

Conclusions

While eventual R01 grant and early career funding pathways were confirmed as important components of higher *h*-index and larger publication numbers, the classic definition of a physician-scientist was questioned through these findings. Those presumed to be without funding and generally excluded from the physician-scientist pool because of lack of protected research time, in some instances, outperformed their R01-funded colleagues and had a higher publications-per-research hour than those with an R01 and those with non-R01 funding, when estimating a 10% research effort. This reflects a potentially erroneous assumption and indicates the important contribution of these neurologists.

From the NIH, National Institute of Neurological Disorders and Stroke, Office of the Clinical Director, Medical Education Unit (W.P.B., A.K.H., O.I.K.), and Clinical Trials Unit (G.N.), Bethesda; and NIH, National Institute of Neurological Disorders and Stroke, Surgical Neurology Branch (J.D.H.), and Office of the Clinical Director (A.N.), Bethesda, MD.

Go to Neurology.org/N for full disclosures. Funding information and disclosures deemed relevant by the authors, if any, are provided at the end of the article.

Glossary

h-index = impact factor; **NINDS** = National Institute of Neurological Disorders and Stroke; **RePORT** = Research Portfolio Online Reporting Tools.

Physician-scientists have long been recognized as an “endangered species” whose loss threatens the future of clinical and translational research and subsequent advances in the treatment of neurologic conditions.¹ Lack of protected time and funding during training periods has been identified as a major cause of attrition, with efforts to slow this mainly focused on increasing support for young investigators during the graduate and postgraduate training pipeline toward research independence.² In 2016, the National Institute of Neurological Disorders and Stroke (NINDS) invested \$20 million solely for training awards such as the K08 and K23.³ However, despite this support, data indicate only approximately 40% of grantees go on to receive an R01, which has been considered the pinnacle of independent research, and thus earning the perceived qualification of a physician-scientist.⁴ Despite significant funding efforts, the current number of physician-scientists seems to be stagnant or declining.⁵

One challenge to determining the physician-scientist workforce is accurately qualifying, and thus in effect quantifying, physician-scientists and what attributes allow a neurologist to be counted as one. This challenge was highlighted in the NIH Physician-Scientist Workforce Report of 2014, a landmark report that identified the concerning situation of this shrinking workforce.⁵ One classic approach has been identifying those physicians with independent research funding, often the R01 grant, and classifying them as physician-scientists. This approach has almost become the gold standard for the definition of a scientist; however, this may not be reliable as it does not capture the research contributions of non-R01 and nonfunded physicians.

Acknowledging the need for a reliable methodology to measure any given neurologist’s contribution to neuroscience research as the first step in identifying physician-scientists, we used author-level metrics for early career neurologists to evaluate the research contributions of classically defined physician-scientists vs those without an R01 grant.

Methods

Standard protocol approvals, registrations, and patient consents

This study was exempted from institutional review board review by the NIH Office of Human Subjects Research Protections.

Neurology physicians cohort

The population of interest for this study comprised those neurologists who were best positioned to contribute to research. To identify these individuals, institutions with the

most funding from the NINDS were identified for the 2016 fiscal year, via the publicly available NIH Research Portfolio Online Reporting Tools (RePORT), and the institutions’ websites were searched for publicly available neurology residency alumni information, including both adult and pediatric neurology residents. Previous research has indicated approximately a 10-year difference between the average age of graduating residents and the average age of their first R01.^{6,7} From this, it was determined that 2003, 2004, and 2005 graduates would be the most appropriate to use as it would capture the age difference and still be recent enough to account for changes in the research environment and funding models. Data collected from the institutional website included name, degree(s), and graduation year. Current practice data for these alumni were not available. If no alumni list was publicly available, the institution was excluded from further analyses. Every neurologist included in the publication and *h-index* analyses had a Scopus account.

Funding history, publications, and *h-index*

The publicly available RePORT system was searched to find the history of all NIH and other Department of Health and Human Services and Department of Veterans Affairs research funding for individual alumni. Alumni were also searched in the Scopus Author Profile to ascertain their number of post-residency publications as well as their *h-index*. The *h-index*, also known as the *Hirsch-index*, is a measure of an individual’s research publication impact by finding the number of papers with a number of citations greater than or equal to *h*.⁸ These data from Scopus were recorded as a point-in-time measure on September 28, 2017, the date the data collection was performed. The data identified 3 distinct groups: those with an NIH R01 (termed “R01-funded”); those with another form of federal funding (“non-R01 funded”); and those with no history of funding in the RePORT database (“nonfunded”).

Publications-per-research hour

A publications-per-research hour rate, different than the yearly publication rate, was calculated for the 3 groups after assigning a percentage of research time to each group. For those with R01 grants, it was assumed that they dedicated 80% of their time to research, as this is often regarded as the adequate amount of protected time to promote research success.⁹ Those with other grants were assigned an estimated value of 40% of research time because of the variable nature of commitments during training periods captured in this category, and those without grants were assigned a varying estimate of 10%, 15%, and 20% of research time. These estimates were determined from previously published self-reported

survey data of neurologists, where a majority reported less than 25% of their time was devoted to research/teaching.^{10,11} Based on additional surveys of the neurology workforce, the total work hours of all groups was conservatively estimated to be 2,500 hours per year (50 work hours per week for 50 weeks of the year).¹² The average publications per year for each group was then weighted by that group's estimated number of annual research hours.

Statistics

An α level of 0.05 was used for significance, and analyses were conducted in R (version 3.4.2). Cohort characteristics were described quantitatively using percents, means/SDs, and medians/interquartile ranges, as appropriate. Funding group differences in yearly publication rate, total number of publications, and h -index were tested using analysis of variance, and visualized using boxplots. Yearly publication rate was defined as the average number of publications per year for each subject, which was then used to calculate a group average; t tests were also used to compare group differences between degree type, for those with R01 funding. Kruskal-Wallis rank sum test was used to test funding group differences in the ranks of yearly publication rates of the top 50 publishers. Cumulative numbers of publications were further visualized by institution, stratified by funding group. Longitudinal plots were used to describe cumulative publications over time and the time of first R01 in the R01-funded group.

Results

Of the top 110 institutions with funding from NINDS, 15 had publicly available information on their neurology residency graduates from 2003, 2004, and 2005. From these 15 programs, 252 neurologists were identified. Eight individuals were excluded, as 4 were deceased and 4 could not be isolated in Scopus, resulting in an overall cohort of 244. One individual had a Scopus account, but an unavailable h -index, and remained in the cohort with a recorded h -index of "Not Applicable (NA)." Several individuals had no publications during the postresidency years but a nonzero h -index because of earlier publications, and were included in analysis. The final analysis cohort of interest comprised neurologists who had demonstrated an interest in research, as ascertained by the presence of a Scopus account, which was determined to be 186 individuals (figure 1).

Funding and degree demographics

Of the overall cohort of 244, 26 (11%) had an R01 grant; 31 (13%) had another form of federal funding but non-R01; and 187 (77%) had no federal funding. Furthermore, 43 (18%) of the overall cohort had a K award, with 22 of them in the non-R01-funded group (71%), and overall, 19 (44%) of the individuals with a K award went on to later receive an R01. Fifty (21%) had both a doctor of medicine (MD) and doctor of philosophy (PhD) and 12 (5%) were doctors of osteopathic medicine (DO), with the remaining

Figure 1 Methodology flow diagram

NINDS = National Institute of Neurological Disorders and Stroke.

182 (75%) having an MD degree. Of the R01-funded investigators, 15 (58%) had MD-PhDs and 11 (42%) had an MD only.

Status of R01-possessing physicians

Using the analysis cohort of interest of 186 neurologists, the mean h -index ($F_{2, 182} = 62.2$, $p < 0.001$), yearly publication rate ($F_{2, 183} = 52.6$, $p < 0.001$), and cumulative number of publications ($F_{2, 183} = 49.0$, $p < 0.001$) were significantly higher in those who eventually received an R01 grant, compared to those without R01 funding and those with no funding (table and figure 2).

Within those who were R01 funded, those with MD-PhD compared to those with MD without a PhD had non-significant differences in average h -index (29.0 vs 28.0, $p = 0.85$), mean yearly publication rate (6.7 vs 5.9, $p = 0.69$), and mean cumulative number of publications (94.0 vs 84.2, $p = 0.71$).

Among the top 50 performers by yearly publication rate, there was an equal mix of the 3 groups of neurologists: R01 (19, 38%), non-R01 (15, 30%), and nonfunded (16, 32%). However, an analysis of the cohorts indicates that the ranks of yearly publication rates still differ among these groups ($p =$

Table Mean values and analysis of variance *p* values for all 3 groups, across outcome indicators

	R01-funded (n = 26)	Non-R01-funded (n = 31)	Nonfunded (n = 129)	<i>p</i> Value
<i>h</i>-Index	28.6 (13.6)	15.9 (7.1)	8.0 (7.9)	<0.001
Yearly publication rate	6.4 (4.7)	3.0 (2.1)	1.2 (1.6)	<0.001
No. of publications	89.9 (70.4)	41.8 (28.1)	17.4 (23.6)	<0.001

All values are mean (SD).

0.01). Within the top 10, 8 were neurologists with R01 funding.

Median time from completion of residency training to first R01 funding was 7.0 years (interquartile range 6.0–8.8), and time of first R01 funding appears to be similar regardless of publication activity (figure 3). Individuals with an R01 had a mean of 3.8 grants (SD = 2.1), compared to 1.5 (SD = 0.9) for non-R01-funded individuals.

Institution

Funded individuals had similar success across institutions, but nonfunded individuals from institutions with more NINDS funding were somewhat more likely to be high publishers than those from institutions with less NINDS funding (figure 4).

Publications-per-research hour

Those who were nonfunded (10% research effort) had an estimated 4.9 publications per 1,000 research hours, compared to 3.0 for those with non-R01 funding (40% research effort), and 3.2 for those with R01 funding (80% research effort). However, given the above findings that some individuals in the nonfunded group have high publication activity, it is likely that 10% effort underestimates the average behavior

of this group. Using 15% and 20% effort instead results in 3.3 and 2.4 publications per 1,000 research hours, respectively, for the nonfunded group.

Discussion

Several of the findings from this early career cohort were unsurprising since they confirmed the effect of funding on one's research trajectory. The data showed that those individuals with funding had a higher *h*-index, cumulative number of publications, and yearly publication rate, confirming previous work of the value of an R01 and research funding.^{13–15} However, these data also elucidated the contribution to research of non-R01-funded physician-scientists. The significant differences that exist in *h*-index, yearly publication rate, and cumulative publications were expected, and possibly explained by the fact that those who have R01 grants will spend most of their time focused on publishing while also having the capabilities and resources to produce peer-reviewed publications that are more impactful. This explanation was supported by the finding that on average those with an R01 had a higher number of grants, which further contributes to the ability to focus primarily on publishing. However, there was no noticeable difference in the

Figure 2 Boxplots of 3 outcome indicators for each of the 3 identified groups of the cohorts

(A) *h*-Index; (B) publication rate; (C) number of publications.

Figure 3 Longitudinal publishing trajectories for those who received R01 funding

The marked point indicates first R01 funding.

longitudinal publishing trajectories before receiving the first R01, questioning the pathway that one takes to achieving an R01.

While the differences in yearly publication rate, cumulative publications, and *h*-index were proven to be statistically significant, understanding the data in context is important. The boxplots highlight that there is a nonnegligible number of individuals without R01s who are outperforming those who do have R01s in all 3 outcome measures (yearly publication

rate, cumulative number of publications, *h*-index). While those nonfunded individuals who are performing well do not discount the important research being conducted by those individuals with an R01, it highlights that there are many physicians who are heavily participating in research, and producing meaningful results, without an R01. Achieving an R01 grant does not simply provide resources for research; it can drastically alter an individual's career by guaranteeing protected research time and reduced clinical and teaching duties. While an R01 affects an individual's work balance, as the data highlight, it does not necessarily guarantee more publications than nonfunded individuals produce. This group of nonfunded physicians are those who are not captured in existing definitions and methodology to understand the physician-scientist workforce, yet demonstrate their importance to the workforce.

Physicians who are not funded are presumed to have less protected time for research and scholarly activities and therefore less of an ability and opportunity to contribute to research endeavors. Recent surveys indicate that approximately 80% of neurologists spend between 0% and 25% of their time in "research/teaching."¹¹ When weighted by these standards of presumed dedicated research time, those with no funding were more productive (measured as publications per 1,000 research hours) compared to those with non-R01 funding and R01 funding. However, after considering the observed publication rates and using slightly inflated percent efforts of 15% or 20%, the nonfunded group produced either equal or slightly lower numbers of publications per 1,000 hours than the other 2 groups. This implies that while the research contributions through publications may be on average less in overall quantity, those without federal funding are still able to use their limited time to engage with and conduct research at a level comparable to funded individuals. This also

Figure 4 Institutional breakdown of the number of publications

Rank indicates funding rank in our dataset, not overall funding rank.

illustrates that a single percent effort may not accurately summarize the research behavior of the nonfunded group and highlights the importance of examining those neurologists not traditionally defined as physician-scientists.

Some trends became apparent when investigating yearly publication rates and *h*-indices by institution. It appeared that institutional resources or philosophy during training may influence future scientific contributions, regardless of funding status. Conversely, overvaluing the amount of NINDS funding a training institution receives to predict potential success for a research career can be a pitfall because many successful individuals train at institutions with less NINDS funding.

Potential limitations of this study include a selection bias, protected time assumptions, the use of the *h*-index as an impact measure, and utilization of raw publication numbers. Using only NINDS funding is unable to account for whether individual residents were selected based on research background, or whether they were exposed to and encouraged to participate in research during their training. However, we posit that it can be used as a measure of the institution's infrastructure and opportunities to conduct research, and that institutions with greater NINDS funding will have more of these opportunities. Similarly, relying solely on NIH and other US Department of Health and Human Services funding meant those with industry or other institutional funding were likely to be included in the "nonfunded" category. Furthermore, in the analysis of publications-per-research hour, a value for protected time was assigned to neurologists in each category. This value was based on the best available data for estimating protected time, yet protected time may vary based on individual situations and thus a blanket value may not accurately capture specific situations. Another limitation to this study was using *h*-index as a measure of an individual's research impact. While it has gained popularity in recent years as a measure of scientific impact, there is debate over its usefulness and accuracy. The 2 most relevant limitations are (1) it is a reliable measure if calculated across platforms and (2) it is an ever-evolving value as more papers are identified by the platform.¹⁶ However, by relying on one platform and collecting the data as a point-in-time measure, the effect of both limitations was minimized. The last limitation to the study was using the raw number of publications without differentiating the types of publications that were included in the values provided by Scopus. By taking the cumulative number, there was no differentiation between an article that may have been a leading piece of research vs a short case report. This limitation was partially mitigated by concurrently using the *h*-index, but was also an important consideration in our study design and development. Although some publications contributing toward an individual's high publication numbers may be shorter case reports or clinical observations, they nonetheless indicate an individual's participation and engagement in scholarly efforts and research.

Conclusions

Physician-scientists have classically been measured by possession of an NIH-funded R01 grant; yet, this definition has often been challenged as being too narrow. By measuring the research contributions and funding outcomes of a sample of neurologists, it was found that several individuals, without possessing an R01 grant or other federal funding, contribute to research just as regularly and effectively as those with the coveted R01. While this study confirmed that those with R01 funding have a higher *h*-index, yearly publication rate, and cumulative number of publications, it also provided evidence that those without R01 funding also produced significant contributions to research. These results underscore that physicians of all research-funding levels meaningfully contribute to science and research endeavors, and support expanding and evaluating funding opportunities to a broader range of physicians.

Author contributions

Wyatt Bensken: study concept and design, authoring of manuscript. Gina Norato: analysis and interpretation of data. Alexandra Hansen: acquisition of data. John Heiss: critical revision of manuscript. Avindra Nath: critical revision of manuscript. Omar Khan: study concept and design, critical revision of manuscript, project oversight.

Acknowledgment

The authors express their gratitude to the NINDS Clinical Neurosciences Program Fellowship Committee for their guidance, support, and energetic contributions to strengthening the physician-scientist workforce. Further, the authors acknowledge and thank Devera Schoenberg for her thorough editing of this manuscript.

Study funding

This research was supported by the Intramural Research Program of the National Institute of Neurological Disorders and Stroke, NIH.

Disclosure

The authors report no disclosures relevant to the manuscript. Go to Neurology.org/N for full disclosures.

Received December 18, 2017. Accepted in final form May 25, 2018.

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