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Original Research

Evaluation of Adult Reconstruction and Arthroplasty Fellowships in the United States Based on Academic Productivity

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ABSTRACT

Background: Institutional academic productivity varies on an individual level. This study aims to analyze the research output of adult reconstruction and arthroplasty fellowship programs in the United States.
Methods: The American Association of Hip and Knee Surgeons Fellowship Directory was used to evaluate 112 adult reconstruction and arthroplasty fellowships in the United States. Publication data and Hirsch index (h-index) were collected from the Scopus Database. All of each author's total publications were analyzed with their current institution, regardless of their affiliation at the time of publication. Multivariate logistic regressions were performed to determine the effect of program size on research productivity.
Results: The total number of publications per institution ranged from 2 to 3743, with a mean of 289 and a median of 135. The h-index of individual faculty members ranged from 0 to 103, with a mean of 16 and a median of 11. The number of faculty ($P < .001$) and number of fellows ($P = .003$) per program had a significant effect on the total number of publications. The number of faculty did not have a significant effect on the median number of publications ($P = .12$) or the median h-index ($P = .31$). The number of fellows had a significant effect on the median number of publications ($P < .001$) and the median h-index ($P < .001$).
Conclusions: Academic productivity in adult reconstruction and arthroplasty fellowships within the United States varies widely, with the top few institutions responsible for a majority of the overall output.

Introduction

The field of orthopaedic surgery has become more popular since the 1970s, and over the past decade, orthopaedic residents have become increasingly subspecialized [1]. Horst et al. [1] reported that 90% of orthopaedic residency graduates in 2013 planned to complete fellowship training, which is a 14% increase from the percentage of applicants in 2003 [1]. Fellowship candidates consider many factors when deciding where to pursue their fellowship, including location, program reputation, academic productivity, and career outcomes [2]. Many often assess the quality of training that they will receive at each institution using online rankings such as US News & World Report or Doximity. However, these criteria are not well-defined and may not be applicable to all fellowship training programs. With more orthopaedic residents pursuing subspecialties, there has been an increased interest in developing objective measures to evaluate the quality of education at each institution.

Although research output is just one small aspect of the overall fellowship training experience, there has been a recent push to develop objective measures to evaluate research productivity in academic medicine. The Hirsch index (h-index) of a researcher is the number of papers co-authored by the researcher with at least *h* citations each, and it has been shown to be a better predictor of future achievement than number of citations, number of papers, or mean citations per paper [3]. For example, an h-index of 10 means that an author has published 10 papers that were each cited at least 10 times. Thus, evaluating the academic productivity of clinical faculty using the h-index has become popular as an objective

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measure of program quality. This study aims to provide an overview of academic productivity within the field of adult reconstruction and arthroplasty fellowships and to identify the effect of program size on overall research productivity.

Material and methods

Data collection

The American Association of Hip and Knee Surgeons Fellowship Directory was searched (May 2022-December 2023) to identify orthopaedic surgery, adult reconstruction, and arthroplasty fellowship programs in the United States. Programs were excluded if they were not in the American Association of Hip and Knee Surgeons directory or were located outside of the United States. In total, 112 programs were identified that met these criteria. The fellowship program websites were screened by three authors (A.G., C.S., and R.H.) to assure each program was an active fellowship and to determine adult reconstruction and arthroplasty faculty and the number of fellows accepted into each program annually. For programs that did not have a list of active faculty members on their website, the main hospital or institution's website was searched, and all surgeons who completed fellowship training in adult reconstruction were considered to be faculty members. Musculoskeletal oncology surgeons were excluded from faculty of adult reconstruction and arthroplasty fellowship programs. The Scopus Database (Elsevier BV) was used to search for each faculty member's total number of publications and h-index. All of each author's total publications were analyzed with their current institution, regardless of their affiliation at the time of publication.

Statistical analysis

Data were pooled, and statistical analyses were performed using Microsoft Excel 2021 (Microsoft Corporation, Redmond, WA). Multivariate logistic regressions were performed to evaluate the effect of the number of faculty and number of fellows on the total number of publications, median h-index per faculty, and the median number of publications per faculty. One-way analysis of variance tests were performed to investigate if the number of faculty and fellows differed between each quartile. The significance for all analyses was set at $P \leq .05$.

Results

Within the 112 programs that were analyzed, 540 associated faculty members and 226 fellowship positions were identified. The total number of publications per institution ranged from 2 to 3743, with a mean of 289 and a median of 135. The number of publications per faculty member ranged from 0 to 935, with a mean of 61 and a median of 28. The h-index of individual faculty members ranged from 0 to 103, with a mean of 16 and a median of 11. The mean number of faculty per program was 4.8 (range 1 to 26, median 4). The mean number of fellows per program was 2.0 (range 1 to 6), with an average faculty-to-fellow ratio of 2.8. The top 10 programs based on total number of publications were identified, and the results are listed in Table 1.

Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the total number of publications. A summary of these results is shown in Table 2. The overall regression was statistically significant ($R^2 = 0.58$, $F[2, 109] = 77.5$, $P < .001$). The number of faculty ($t = 7.39$, $P < .001$) and the number of fellows ($t = 2.96$, $P = .0038$) were both significant predictors.

Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the median number of publications. A summary of these results is shown in Table 3. The overall regression was statistically significant ($R^2 = 0.27$, $F[2, 109] = 20.3$, $P < .001$). The number of faculty ($t = -1.56$, $P = .12$) was not a significant predictor, but the number of fellows ($t = 5.75$, $P < .001$) was a significant predictor.

Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the median h-index. A summary of these results is shown in Table 4. The overall regression was statistically significant ($R^2 = 0.24$, $F[2, 109] = 17.2$, $P < .001$). The number of faculty ($t = -1.01$, $P = .31$) was not a significant predictor, but the number of fellows ($t = 5.09$, $P < .001$) was a significant predictor.

Programs were divided into quartiles based on their total number of publications by current faculty members. The cutoff for the first quartile was 330 publications (mean 829.7, median 442.5). The cutoff for the second quartile was 135 publications (mean 219.0). The cutoff for the third quartile was 51 publications (mean 82.5). The fourth quartile included programs with fewer than 51 publications (mean 21.6). The total number of adult reconstruction and arthroplasty faculty present at each institution increased in

Table 1
Top 10 adult reconstruction and arthroplasty fellowships based on total number of publications.

Program	Total number of publications	Median number of publications per faculty	Mean h-index of faculty	Median h-index of faculty	Number of faculty	Number of fellows
Hospital for Special Surgery Adult Reconstruction and Joint Replacement Fellowship	3743	119.5	38	29.5	26	6
Mayo Clinic Minnesota Adult Reconstruction Fellowship	2258	233	42.7	45	10	3
Rothman Orthopedics at Thomas Jefferson University Adult Reconstruction Fellowship	1965	135	35	24	9	4
Rush University Adult Joint Reconstruction Fellowship	1814	170	43.3	38	10	6
Stanford University Adult Reconstruction Fellowship	1356	167	46.2	38	5	3
Washington University, St. Louis, Adult Reconstruction Fellowship	1121	105	33.6	27	7	4
James A. Dickson Fellowship in Adult Reconstructive Surgery at Cleveland Clinic	1083	38	14.5	12.5	18	6
NYU Langone Health Orthopedic Adult Reconstruction Fellowship	999	95	22.4	17	7	5
Joint Preservation and Adult Reconstruction at Lenox Hill Hospital	965	195	34	39	7	6
Joint Implant Surgeons, Inc. Adult Reconstruction Hip and Knee Fellowship	736	64.5	25.2	16.5	6	2

Table 2
Effect of the number of faculty and fellows on the total number of publications for all programs.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	−326.37	59.33	−5.50	2.52E-07	−443.96	−208.78
Number of faculty	90.70	12.27	7.39	3.12E-11	66.38	115.01
Number of fellows	88.47	29.91	2.96	.0038	29.19	147.75

each consecutive quartile with means of 2.9, 3.8, 4.9, and 7.5, respectively ($P < .001$). The total number of adult reconstruction and arthroplasty fellows present at each institution also increased in each consecutive quartile with means of 1.3, 1.7, 1.7, and 3.4, respectively ($P < .001$).

Additional analysis was performed on only those programs in the first quartile based on the total number of publications. Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the total number of publications. A summary of these results is shown in Table 5. The overall regression was statistically significant ($R^2 = 0.53$, F [2, 25] = 14.1, $P < .001$). The number of faculty ($t = -4.21$, $P < .001$) was a significant predictor, but the number of fellows ($t = 0.319$, $P = .75$) was not a significant predictor.

Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the median number of publications. A summary of these results is shown in Table 6. The overall regression was statistically significant ($R^2 = 0.22$, F [2, 25] = 3.43, $P = .048$). The number of faculty ($t = -1.69$, $P = .10$) was not a significant predictor, but the number of fellows ($t = 2.61$, $P = .015$) was a significant predictor.

Multiple linear regression was used to test if the number of faculty and number of fellows significantly predicted the median h-index. A summary of these results is shown in Table 7. The overall regression was not statistically significant ($R^2 = 0.10$, F [2, 25] = 1.44, $P = .26$). The number of faculty ($t = -0.88$, $P = .38$) and number of fellows ($t = 1.69$, $P = .10$) were not significant predictors.

Discussion

This study investigated the academic productivity of orthopaedic surgery, adult reconstruction, and arthroplasty fellowships throughout the United States. Our results demonstrate that most academic productivity in adult reconstruction and arthroplasty is attributed to a relatively small number of fellowship programs. The top 10 programs account for 49% of the total number of publications, whereas the bottom 50% of programs account for only 9% of the total.

When analyzing all fellowship programs together, the number of fellows had a significant effect on the total number of publications, median number of publications per faculty member, and median h-index of faculty members. However, even though programs in the first quartile had a significantly greater number of fellows than those outside of the first quartile, within the first quartile, the number of fellows did not have any effect on the total number of publications or median h-index of faculty members. These results suggest that overall, much of the research productivity in the field of adult reconstruction and arthroplasty is fellow-driven; however, there are additional factors at play within the first quartile, one of which is likely the amount of funding available for research.

In 2017, Khan et al. [4] published the first study using h-indices to evaluate the academic productivity of adult total joint reconstruction surgeons. They identified 375 faculty members associated with 66 different fellowship programs. Our study builds upon this existing data set and includes 540 faculty members associated with 112 different programs. Khan et al. [4] reported an average of 50.1 publications per faculty and a mean h-index of 12.8 within their study population, compared to the average of 60.6 publications and mean h-index of 16.0 that we found. Similarly, they also found that the number of fellows per program had a direct effect on both total number of publications and faculty h-index. As expected, the average number of publications and mean h-index have increased over time, and we believe that they should continue to be evaluated periodically to provide the most complete and up-to-date data as new programs emerge and aspiring faculty members accept new positions to better align with their academic career goals.

When contrasted with the mean h-index of faculty members in other orthopaedic surgery subspecialties, our results are comparable. A summary of the reported mean h-index of faculty members in other orthopaedic surgery subspecialties is presented in Table 8. To our knowledge, data on the mean h-index of faculty in the subspecialties not listed have not been published yet at this time. Our results suggest that the research productivity of academic adult reconstruction and arthroplasty surgeons may be slightly more robust than their other orthopaedic surgery counterparts, however, most of these reported data were published years ago and may not account for the trend in growth of mean h-indices over recent years due to the increased number of total publications and cumulative citations of faculty members.

Other authors have researched additional factors that may impact the research productivity of orthopaedic surgeons. Khan

Table 4
Effect of the number of faculty and fellows on the median h-index for all programs.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	6.17	1.48	4.17	6.07E-05	3.24	9.10
Number of faculty	−0.31	0.31	−1.01	.32	−0.91	0.30
Number of fellows	3.79	0.75	5.09	1.53E-06	2.31	5.27

Table 3
Effect of the number of faculty and fellows on the median number of publications for all programs.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	6.09	7.79	0.78	.44	−9.35	21.53
Number of faculty	−2.51	1.61	−1.56	.12	−5.70	0.68
Number of fellows	22.57	3.93	5.75	8.37E-08	14.79	30.35

Table 5
Effect of the number of faculty and fellows on the total number of publications for programs in the first quartile.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	−101.00	247.53	−0.41	.69	−610.80	408.80
Number of faculty	112.34	26.69	4.21	.00029	57.37	167.32
Number of fellows	24.53	76.84	0.32	.75	−133.74	182.79

Table 6
Effect of the number of faculty and fellows on the median number of publications for programs in the first quartile.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	42.15	31.49	1.34	.19	−22.69	107.00
Number of faculty	−5.75	3.40	−1.69	.10	−12.74	1.25
Number of fellows	25.47	9.77	2.61	.015	5.34	45.61

Table 8
Summary of mean h-indices among other orthopaedic surgery subspecialty faculty members.

Specialty	Mean h-index	Reference
Foot and ankle	11.9	Sherman et al. (2022) [5]
Hand	10.2	Lopez et al. (2015) [6]
Joint replacement	12.8	Khan et al. (2017) [4]
Musculoskeletal tumor	12.9	Martinez et al. (2015) [7]
Spine	13.6	Schoenfeld et al. (2015) [8]

et al. [4] found that joint replacement faculty with formal fellowship training or an academic title of Associate Professor or Professor were significantly associated with total publications and mean h-index per faculty. Furthermore, they found that practicing at an Accreditation Council for Graduate Medical Education-approved program was not shown to be significantly associated with faculty total number of publications or h-index. Interestingly, both Khan et al. [4] and Schoenfeld et al. [8] reported that there is a negative correlation between programs with a mandated research requirement and the mean h-index of those institutions' faculty members. A potential explanation for this, as proposed by Schoenfeld et al. [8], is mandated fellow research requirements at programs with faculty who are less established in an attempt to boost research productivity. Additionally, Cvetanovich et al. [9] reported geographical differences in academic productivity, with higher mean h-indices among sports medicine faculty in the Northeast and Midwest compared to other regions throughout the United States.

It is important to note that the data acquisition methods for this study and the utility of h-index measures do present some limitations. We used website information to identify faculty members at each program, which may have been incomplete or out-of-date at the time of our search. Additionally, all of the faculty members listed for each program may not be directly involved with the training of fellows. This study did not account for other measures of academic productivity such as grant funding or national presentations and lectures, and relied only on h-index, which has its own inherent biases as well. The h-index is a cumulative rather than a dynamic metric that is skewed toward more established faculty, given the increased time for them to produce publications and for their publications to accumulate citations. As surgeons progress in their careers, some may accept positions at more prestigious institutions. When evaluating individual authors, all of an author's publications were analyzed with their current institution, regardless of their affiliation at the time of publication. Furthermore, author self-citation is unable to be accounted for but is believed to only play a minor role in the overall h-index results [10]. The Scopus database that was searched for this data collection does not include publications prior to 1995, so the total number of publications and mean h-index may have been undercounted for more senior faculty members. Despite these limitations, the h-index is still a validated measure of research productivity and provides an objective measure to guide residents and faculty members in their career decision-making [3]. Looking forward, additional analyses may be performed to identify the effect of variables such as grant funding, region, gender, academic vs nonacademic, and fellowship founding year on the overall research output in the field of reconstruction and arthroplasty.

Table 7
Effect of the number of faculty and fellows on the median h-index for programs in the first quartile.

Variable	Coefficients	Standard error	t Stat	*P*-value	Lower 95%	Upper 95%
Intercept	19.56	5.24	3.73	.00098	8.77	30.36
Number of faculty	−0.50	0.57	−0.88	.39	−1.66	0.67
Number of fellows	2.75	1.63	1.69	.10	−0.60	6.11

Conclusions

Within our study population, the average number of publications per faculty member was 61, with a mean h-index of 16.0 and median h-index of 11. Although program size has a significant effect on research productivity, there are additional factors that affect it as well. However, research productivity is only one metric used in the evaluation of fellowship programs. Therefore, h-index should not be the only factor used to assess the quality of an orthopaedic surgeon's career. Clinical expertise, technical skill, teaching ability, and leadership are equally important aspects that should also be considered by fellowship applicants; however, these are all inherently difficult to measure objectively. The data presented above are just one tool, among many, for prospective applicants and faculty members to identify and evaluate institutions that align with their career goals.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101475.

CRediT authorship contribution statement

Nicholas R. Williams: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Alvarho J. Guzman:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Therese Dela Rueda:** Methodology, Investigation, Data curation. **Raia Francisco:** Writing – original draft, Investigation. **Caleb Shin:** Methodology, Investigation, Data curation, Conceptualization. **Ryan Haratian:** Methodology, Investigation, Data curation, Conceptualization. **Patrick J. McGahan:** Supervision, Methodology, Investigation, Conceptualization. **James L. Chen:** Supervision, Methodology, Investigation, Conceptualization.

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