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Workforce Analysis of Spine Surgeons Involved with Neurological and Orthopedic Surgery Residency Training

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■ OBJECTIVE: **Spinal surgery is taught and practiced within 2 different surgical disciplines: neurological surgery and orthopedic surgery. We have provided a unified analysis of spine-focused faculty at U.S. residency programs.**

■ METHODS: **A total of 278 Accreditation Council for Graduate Medical Education training programs were assessed to identify 923 full-time faculty members with a spinal surgery designation, defined by spine fellowship training or surgeon case volume >75% spine surgeries. Faculty were assessed with respect to parent discipline, years of fellowship training, academic rank, gender, and academic productivity (*h*-index).**

■ RESULTS: **The spine-teaching workforce contains 55% orthopedic surgeons and 45% neurosurgeons with wide gender asymmetry overall and at all faculty ranks. Of the female spine surgeons, those with neurosurgical training (64.44%) nearly doubled the number with orthopedic training (35.56%). Academic productivity increased with academic rank similarly for both genders and subspecialties. Orthopedic spine surgeons had a greater mean fellowship number compared with the neurological spine surgeons. Fellowship time of completion (intraresidency/infolded vs. postresidency) did not significantly affect the *h*-indexes. Addition of fellowship conferred academic productivity benefit for orthopedic surgeons only.**

■ CONCLUSIONS: **Neurological and orthopedic spine surgery showed similar patterns for the spread of faculty across academic ranks and trends in academic productivity. Marked gender disparity was seen in both neurosurgical and orthopedic surgery, with fewer female spine surgeons seen at every academic rank. Orthopedic spine surgeons had a greater mean fellowship number than did their neurosurgical counterparts, and a lack of fellowship correlated with lower academic productivity in orthopedic, but not neurological, spine surgery.**

INTRODUCTION

In 2008, the Institute of Medicine projected a healthcare workforce gap unable to meet the needs of >70 million "Baby Boomers," born between 1946 and 1964, who will begin turning 65 years old in 2011 and all of whom will surpass age 65 years by 2029. The report expected that the U.S. population aged >65 years would increase from 12%, in 2005, to 20%, by 2030 and that the gap between healthcare supply and demand would rapidly become evident.[1] This has been supported by more recent projections from the Association of American Medical Colleges (AAMC),[2] suggesting that by 2030, new surgeon graduation will be roughly equal to future surgeon attrition and that an overall shortfall of 40,800–104,900 physicians will exist, with a deficit of 19,800–29,000 providers in surgical specialties. They projected the growth of the U.S. population by 12%, from 321 million to 359 million, the growth of the population aged <18 years by 5%, and the growth of those aged ≥65 years by 55%.

Key words
- Academic neurosurgery
- Academic orthopedic surgery
- Bibliometrics
- Gender
- *h*-Index
- Spine surgery
- Workforce analysis

Abbreviations and Acronyms
AAMC: Association of American Medical Colleges
AANS: American Association of Neurological Surgeons
AAOS: American Academy of Orthopedic Surgeons
ABNS: American Board of Neurological Surgeons
ANOVA: Analysis of variance
FTE: Full time equivalent
SNS: Society of Neurological Surgeons

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According to the 2016 Physician Specialty Data Report by the AAMC,[3] 5346 neurosurgeons were active, of whom 4920 were involved in active patient care with an estimated ratio of 60,123 people per neurosurgeon. The demographic breakdown showed the neurological spine surgeons to be 92.2% male, 7.8% female, 55.5% aged <55 years, and 44.5% aged ≥55 years. Of 19,145 active orthopedic surgeons, 18,292 were actively involved in patient care, with an estimated ratio of 16,789 people per orthopedic surgeon. The demographic breakdown showed orthopedic spine surgeons to be 95% male, 5% female, 45.9% aged <55 years, and 54.1% aged ≥55 years. The 5% female workforce in orthopedics represented the lowest percentage of 43 surgical and nonsurgical specialties. Examination of the Accreditation Council for Graduate Medical Education residents in 2015 noted 1323 neurosurgical residents and fellows (1097 male [82.9%], 226 female [17.1%]) and 3534 orthopedic residents and fellows (3012 male [85.2%] and 522 female [14.8%]).

Paralleling a population that is increasing in number as well as aging, the usage of spine services has also increased. Martin et al.[4] examined the Medical Expenditure Panel Survey and noted an overall increase in patients seeking treatments for spine problems (from 14.8 million in 1997 to 21.9 million in 2006), with the 49% increase in patients seeking outpatient, spine-related care (from 12.2 million in 1997 to 18.2 million in 2006) the largest contributing factor toward increased outpatient expenditure.[4] From 1999 to 2009, the number of lumbar epidural steroid injections increased by 900,000 procedures and physical therapy evaluations increased by 1.4 million visits annually.[5] Haralson and Zuckerman[6] noted that "musculoskeletal conditions cost society more in money and disability than any other condition" and reported that 60% of all injuries involved the musculoskeletal system, with 3% of those injured requiring admission to hospitals. Also, they reported that the total estimated costs of musculoskeletal injury care increased from $93 billion in 1998 to $127.4 billion in 2004.[6] With a declining orthopedic workforce, they also called for additional resources to meet the demands of musculoskeletal care.

Patients currently receive spine-based treatment by neurological or orthopedic surgeons according to patient desire, surgeon availability or density, hospital or trauma call schedule, and/or local referral patterns. It is reasonable to believe that the use of spine-related resources will continue to increase and that an appropriate number of qualified, spine-specific surgeons will need to be trained through neurosurgical and orthopedic residency programs. Many previous subspecialty workforce studies, including those of pediatric neurosurgery,[7,8] pediatric orthopedic surgery,[9,10] hip and knee replacement surgeons,[11] and orthopedic trauma surgery,[12] have examined subsets of the neurosurgical and orthopedic workforce separately. To the best of our knowledge, our study is the first to examine the combined academic spine workforce, noting that it bridges 2 different surgical disciplines yet produces surgeons who will serve similar, if not identical, patient populations.

METHODS

Selection of Programs and Surgeons

Public searches of the Accreditation Council for Graduate Medical Education website were performed to identify 110 neurological surgery and 168 orthopedic surgery residency training programs active through 2016–2017.

Faculty members with spine expertise were identified by examining the department websites (faculty lists, subspecialty section lists, faculty biographies) and hospital websites (faculty lists, "spine section" or "spine team" lists). The faculty members included in the present study were surgeons with neurosurgery or orthopedic surgery listed as their primary specialty. Furthermore, we included faculty who had undergone fellowship training in spine surgery or had a surgeon case volume of >75% in spine surgery. The surgeon case volumes were self-reported, and only programs and practitioners who self-reported could self-designate. Adjunct faculty with a primary specialty other than neurological or orthopedic surgery (e.g., radiology, otolaryngology, rehabilitation medicine) and nonsurgeons (e.g., neurologists, radiologists, physiatrists, nonsurgical Ph.D.s [Doctor of Philosophy]) were excluded from this study.

Once spine faculty were identified, the departments were contacted separately by electronic mail or telephone, or both. The departments were asked to verify the accuracy of the lists created using the publicly available data and to augment with data available within the department. In select cases, surgeons were contacted directly. Unresponsive departments were approached ≥5 times before being marked as unverified. After determining that verified and publicly available data containing unverified programs were not significantly different statistically, we used publicly available data for all further analyses. Board certification data were also assessed through the American Board of Neurological Surgery and American Board of Orthopedic Surgery websites.

Faculty members were assessed by academic rank (i.e., instructor, assistant professor, associate professor, professor), although a number of faculty had no verifiable academic rank. Some residency training programs had not yet officially conferred academic rank on new or junior faculty members, some did not confer academic rank on any of their faculty members, and some had chosen to not publicly list academic rank. After demographic reporting, the faculty with no academic rank were excluded from subsequent analysis. Data were collected regarding gender, year of graduation from medical school, years of graduation from residency, years of graduation from fellowship, and board eligible status or year of initial board certification. Fellowship analysis included both intraresidency (infolded) and postresidency fellowships.

h-Index

Hirsch's *h*-index, for an individual, is defined as the number of papers (h) with citation number $\geq h$.[13] An automated *h*-index was calculated for each faculty member from the Scopus abstract and citation database using the "Author Search" feature with the author's surname (last name) and given (first) and middle initials as search input strings. Author identification included evaluation of the author's name (with variations), location, site of academic affiliation, affiliations with other authors, journal and manuscript titles, and known publications by the author. Once the author had been appropriately identified, an automated calculation of the *h*-index was performed via the Scopus platform.

Statistical Analysis

The following *a priori* comparisons were performed:

- Surgical discipline versus academic rank

- Surgical discipline versus gender
- Academic rank versus gender
- Surgical discipline versus number of fellowships
- *h*-Index versus fellowship number
- *h*-Index versus fellowship type (intraresidency vs. postresidency)

In addition to descriptive statistics, analysis of variance (ANOVA) and Welch's *t* tests were used. Tukey's multiple comparisons post hoc test was used after ANOVA. Statistical analyses were performed using GraphPad Prism, version 6 (GraphPad Software, San Diego, California, USA). An α level of <0.05 was considered significant for all test results. The mean ± standard error of the mean are presented.

RESULTS

Independent verification of the publicly collected data was possible for 65% of the neurosurgical programs and 41% of the orthopedic programs, accounting for 63.0% of the 416 neurological spine surgeons and 48.1% of the 507 orthopedic spine surgeons. The comparison between the verified and publicly available data showed no statistically significant differences.

Demographic Data

Using the publicly available data, 416 neurosurgical spine (45.07%) and 507 orthopedic spine (54.93%) surgeons were identified (Table 1 and Figure 1A). Of the neurosurgeons and orthopedic surgeons, 65 (15.63%) and 106 (20.91%) had no verifiable academic rank (either through publicly available data or after direct verification with their department). Of the 351 neurological spine surgeons with verifiable academic rank, 4 were instructors (1.14%), 162 were assistant professors (46.15%), 89 were associate professors (25.36%), and 96 were professors (27.35%).

Of 401 orthopedic spine surgeons with verifiable academic rank, 23 were instructors (5.74%), 181 were assistant professors (45.14%), 83 were associate professors (20.70%), and 114 were professors (28.43%; Table 1 and Figure 1B). Of all the spine surgeons, 45 were female (4.88%) and 878 were male (95.12%). Of the 416 neurological spine surgeons, 29 were female (6.97%) and 387 were male (93.03%). Of the 507 orthopedic spine surgeons, 16 were female (3.16%) and 491 were male (96.84%). The proportion of females for each faculty rank was lower than that of males for each faculty rank (Table 1 and Figure 2A, B).

Academic Productivity

The men and women were separated by faculty rank for both neurosurgical spine and orthopedic spine. Using 2-way ANOVA, no significant difference was found in academic productivity with respect to the *h*-index between the men and women for both neurosurgical spine and orthopedic spine ($P = 0.4378$ and $P = 0.4277$, respectively). Using Welch's *t* tests, we also found no statistically significant differences between male and female academic productivity within the same faculty rank for both specialties (Figure 2C, D).

Fellowship

Examination of the fellowship data showed no statistically significant differences when comparing the mean *h*-index and the number of fellowships for both neurological and orthopedic spine surgery (Table 2). No statistically significant differences in the mean *h*-index were found between neurological and orthopedic spine surgeons with the same number of fellowships. The *h*-index still correlated with academic rank for both intraresidency (infolded) and postresidency fellowships (Table 3 and Figure 3A, B). Orthopedic surgeons without fellowship training showed a statistically significant decrease in the mean *h*-index relative to the mean *h*-index for all orthopedic spine surgeons. This effect was not seen among the neurological surgeons (Figure 3C, D).

Orthopedic spine surgeons had a significantly greater mean number of fellowships (0.78 ± 0.03) compared with their neurosurgical counterparts (0.68 ± 0.04; $P = 0.0355$; Figure 4A). Neurological spine surgeons had a greater percentage of their number with no fellowships and orthopedic surgeons had a greater percentage of their number with ≥1 fellowships (Figure 4C). No differences were found between the men and women in the mean number of fellowships pursued for neurosurgical spine, orthopedic spine, and combined spine ($P = 0.8571$, $P = 0.8295$, and $P = 0.8268$, respectively; Figure 4B).

DISCUSSION

In 1995, the American Academy of Orthopedic Surgeons (AAOS) commissioned the RAND Corporation (Santa Monica, California, USA) to project the orthopedic workforce needed in 2010.[14] A survey of orthopedic surgeons generated practice data and noted the number of full time equivalent (FTE) orthopedists needed to treat the existing population. Orthopedists in their first 5 postgraduate years were estimated as equivalent to 0.35, 0.5, 0.5, 0.75, and 1.0 FTEs, respectively. Female orthopedists were estimated at 0.85 FTE.[15] Using the then-existing AAOS membership and U.S.

Table 1. Overview of *h*-Index for Spine Surgical Disciplines

	Publicly Available *h*-Index				Verified *h*-Index			
Spine Residency Type	*n*	Min	Max	Mean ± SEM	*n*	Min	Max	Mean ± SEM
Neurosurgical	416	0	62	12.93 ± 0.60	257	0	62	13.69 ± 0.79
Orthopedic	507	0	85	10.87 ± 0.59	244	0	85	12.43 ± 0.98

n, number; Min, minimum; Max, maximum; SEM, standard error of the mean.

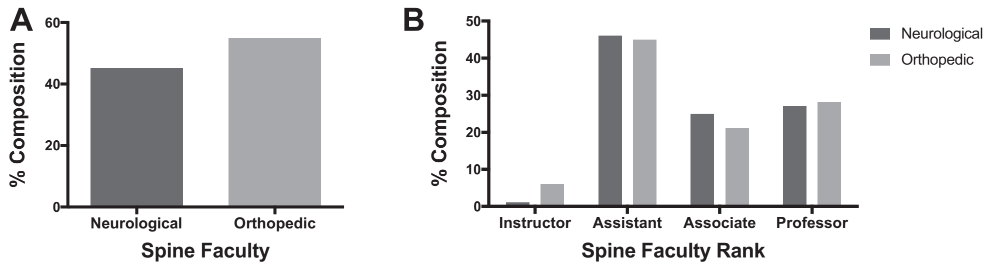

Figure 1. Academic spine surgeons stratified by discipline and academic rank. Bar graphs denote breakdown of academic spine surgeons by (**A**) parent discipline and (**B**) academic rank.

Census Bureau projections for 2010, they projected a demand for 6.0 orthopedic surgeon FTEs and a supply of 7.5 FTEs in 2010 and called for a reduction in residency training spots to alleviate a presumed surgeon surplus. In response to the RAND study, Weinstein et al.[16] used a population-based model to examine the regions with high-quality orthopedic care and no apparent need for additional orthopedists. They believed the RAND calculation of 7 FTEs per 100,000 population to be an overestimation and the then-current need to be 5 per 100,000 population. Subsequent orthopedic data[17] noted the inaccuracy of earlier workforce modeling in the face of data predicting a 24% increase in physician supply, a 26% increase in physician demand, and a 12,000–15,600 orthopedic surgeon shortage by 2020.

In 2009, Schwend and the Pediatric Orthopedic Society of North America[10] reported 6.1 orthopedic surgeons per 100,000 population, with 3.7% of those having completed a pediatric fellowship, 25 pediatric orthopedic fellows being trained annually, and a gap of 7–20 additional pediatric fellows annually necessary to meet the pediatric orthopedic surgeon needs by 2020. In 2008, Iorio et al.[11] examined the projections for adult reconstructive surgeons needed to perform total hip and knee arthroplasties on the Baby Boomer population, which was expected to have arthritis in 50% and obesity in >33%, with a projected 23% increase in orthopedic service demand from 2000 to 2020. Of 620 orthopedic residents graduating in 2005, >90% planned to enter a fellowship, with only 6% designated

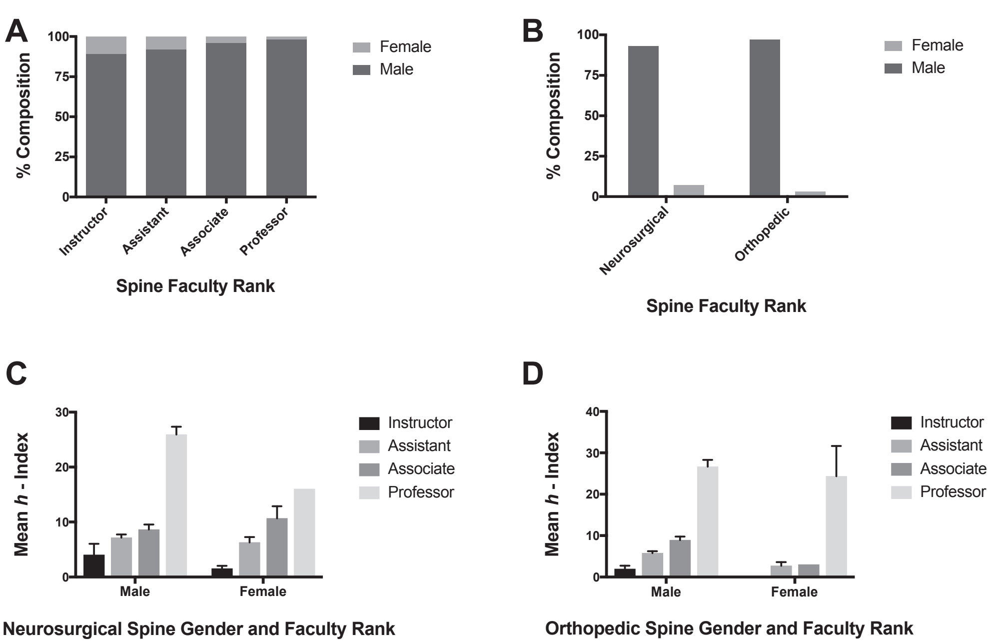

Figure 2. Gender disparity for both neurosurgery and orthopedic spine surgery seen across all academic ranks. *h*-Index correlated with academic rank. (**A, B**) Bar graphs showing gender breakdown of academic spine surgeons across disciplines and academic rank. (**C, D**) Bar graphs showing mean ± standard error of the mean *h*-index with academic rank for neurosurgeons and orthopedic surgeons of both genders.

Table 2. Overview of *h*-Index and Faculty Rank for Spine Surgical Disciplines

	h-Index											
	Neurological Surgery				Orthopedic Surgery				Combined			
Faculty Rank	*n*	Min	Max	Mean ± SEM	*n*	Min	Max	Mean ± SEM	*n*	Min	Max	Mean ± SEM
Publicly available data												
Instructor	4	1	6	2.75 ± 1.11	23	0	17	2.83 ± 1.07	27	0	17	2.82 ± 0.92
Assistant	162	0	29	6.86 ± 0.46	181	0	26	5.62 ± 0.43	343	0	29	6.21 ± 0.32
Associate	89	0	33	12.82 ± 0.92	83	0	31	8.86 ± 0.85	172	0	33	10.91 ± 0.65
Professor	96	0	62	25.80 ± 1.42	114	0	85	26.63 ± 1.58	210	0	85	26.25 ± 1.08
Verified data												
Instructor	3	1	6	3.00 ± 1.53	8	0	17	4.00 ± 2.63	11	0	17	3.73 ± 1.91
Assistant	109	0	29	7.06 ± 0.61	90	0	26	5.16 ± 0.65	199	0	29	6.20 ± 0.45
Associate	56	0	32	12.50 ± 1.16	47	0	31	8.85 ± 1.25	103	0	32	10.84 ± 0.87
Professor	70	0	62	26.76 ± 1.67	70	0	85	28.21 ± 2.19	140	0	85	27.49 ± 1.37

n, number; Min, minimum; Max, maximum; SEM, standard error of the mean.

as adult hip or knee reconstruction, and the 2006—2007 and 2007—2008 fellowship years having 77% and 62% filled positions, respectively. In 2008, Salsberg et al.[18] estimated that ≥90% of all orthopedic residents would take ≥1 years of accredited or unaccredited fellowship, with the most common being sports medicine (25%—30%), hand surgery (<20%), and adult spine surgery (<15%) according to the AAOS 2005—2006 census report.[19]

Neurosurgical workforce decisions have traditionally been based on the 1:100,000 population ratio derived from the 1977 government-sponsored Study on Surgical Services for the United States,[20] with later estimations of 1:55,000 in 2000[21] and 1:61,000 in 2012.[22] In 2005, Gottfried et al.[23] reported a significant 5-year increase in the number of recruitment advertisements in 2 major neurosurgical journals "concomitant with a severe decline in the number of active neurosurgeons and a static supply of

Table 3. Overview of Duration of Practice for Spine Surgical Disciplines

Spine Surgical Discipline	*n*	Min	Max	Mean ± SEM
Neurosurgical	297	1	53	15.94 ± 0.65
Orthopedic	338	1	48	17.91 ± 0.56
Faculty rank				
Neurosurgical practice duration (years)				
Instructor	4	6	28	17.25 ± 5.02
Assistant	122	1	35	9.41 ± 0.66
Associate	66	1	52	17.38 ± 1.28
Professor	75	1	53	25.25 ± 1.16
Orthopedic practice duration (years)				
Instructor	14	1	35	12.00 ± 2.88
Assistant	122	1	48	12.89 ± 0.85
Associate	60	2	41	17.60 ± 1.09
Professor	81	6	46	25.86 ± 0.86

n, number; Min, minimum; Max, maximum; SEM, standard error of the mean.

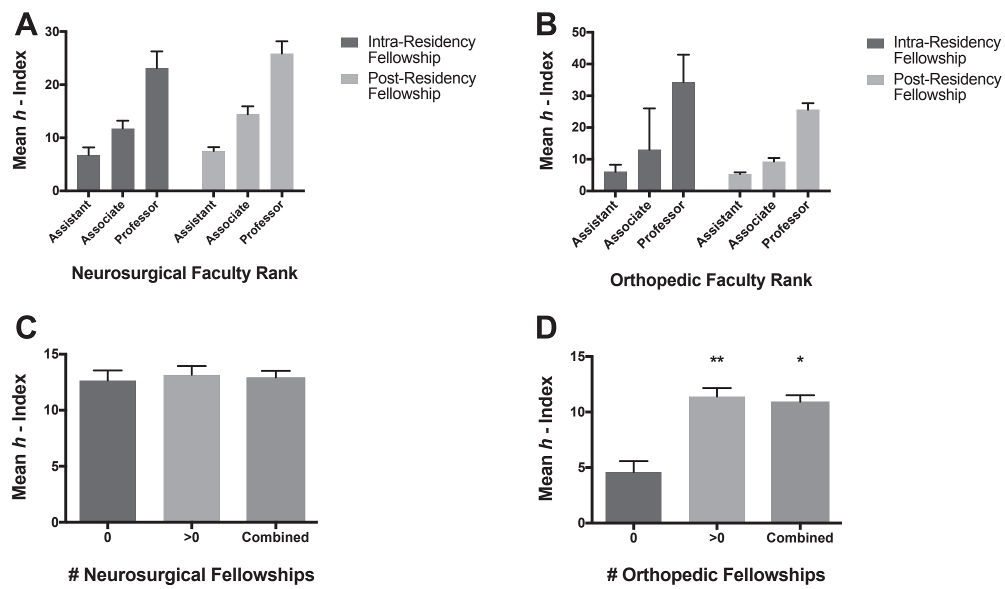

Figure 3. *h*-Index correlated with academic rank but not with fellowship type. Bar graphs showing mean *h*-index ± standard error of the mean (SEM) between spine surgeons with intraresidency or postresidency fellowship training: (**A**) neurosurgical and (**B**) orthopedic surgeons. Bar graphs showing mean *h*-index ± SEM between spine surgeons (**C**) with and (**D**) without fellowships. No differences were found among neurological surgeons. However, a statistically significant difference was seen between orthopedic surgeons with and without fellowships (** $P = 0.0065$; * $P = 0.0174$).

residents." A 2012 position statement from the American Association of Neurological Surgeons (AANS), American Board of Neurological Surgeons (ABNS), Congress of Neurological Surgeons, and Society of Neurological Surgeons (SNS) before the Institute of Medicine[24] made note of these alarming trends and suggested changes in policy, curriculum, and funding that would ensure a neurosurgical workforce capable, in volume and knowledge, to meet these daunting demands. They also noted subspecialty workforce variance stating, "not only are there overall shortages of neurosurgeons in many geographic areas of the country (in part because of the tendency of specialists to cluster around facilities in large urban centers), but certain subspecialties within neurosurgery are also in short supply."

In 2008, Durham and Shipman[8] reviewed 22 accredited pediatric neurosurgery fellowships, their 193 graduates in the previous 15 years, and the subset of 143 graduates then-eligible for pediatric neurosurgery board certification. They noted 18 women (12.6%) and 125 men (87.4%) and a projected pediatric neurosurgeon deficit owing to the capacity to train >20 fellows annually but estimations of training only 6 fellows annually and only 66% eventually completing American Board of Pediatric Neurosurgery certification. A subsequent study of the pediatric neurosurgery workforce identified 158 "pediatric practitioners" (with >75% of patients aged <21 years or ≥125 cases/year of patients aged ≤12 years) and 92 "nonpediatric practitioners" (with <75% pediatric patients).[7] Of the pediatric practitioners, 27 (17%) were female and 131 (83%) were male; the women were more likely to have completed a pediatric fellowship and had performed fewer operative cases than their male counterparts. No other significant differences between the genders, including age, salary, hours, certification rate, practice type, or years in practice, were reported.[7]

Ecker et al.[25] and Zipfel et al.[26] suggested that, as noninvasive tests improved and procedural complications decreased, the demand for vascular neurosurgical care would likely outstrip the relatively small number of interventional neurosurgeons—many of whom practiced in major medical centers. They believed a multidisciplinary workforce from neurosurgery, neurology, cardiology, and radiology would be needed to treat vascular patients, often outside of major medical centers.

Our study examined the landscape of neurological and orthopedic spine surgeons, and we noted similar patterns of breakdown by academic rank and no difference in academic productivity between male and female surgeons within each faculty rank. Fellowship timing did not significantly affect academic productivity for either surgical specialty. However, the addition of ≥1 fellowships produced a statistically significant difference in the h-index for orthopedic surgeons but not for neurological surgeons.

The percentage of neurosurgical spine surgeons completing 0 fellowships and 1 fellowship was 35.4% and 51.9%, respectively. The percentage of orthopedic spine surgeons completing 0 fellowships and 1 fellowship was 14.7% and 70.2%, respectively (**Figure 4C**). The small number of orthopedic surgeons completing 0 fellowships and the large number completing 1 fellowship might indicate a neurosurgeon's relative increase in comfort with spinal procedures immediately completing residency, as suggested by a 2006 survey of senior neurosurgical and orthopedic surgery residents.[27] They noted that "significant differences in time and

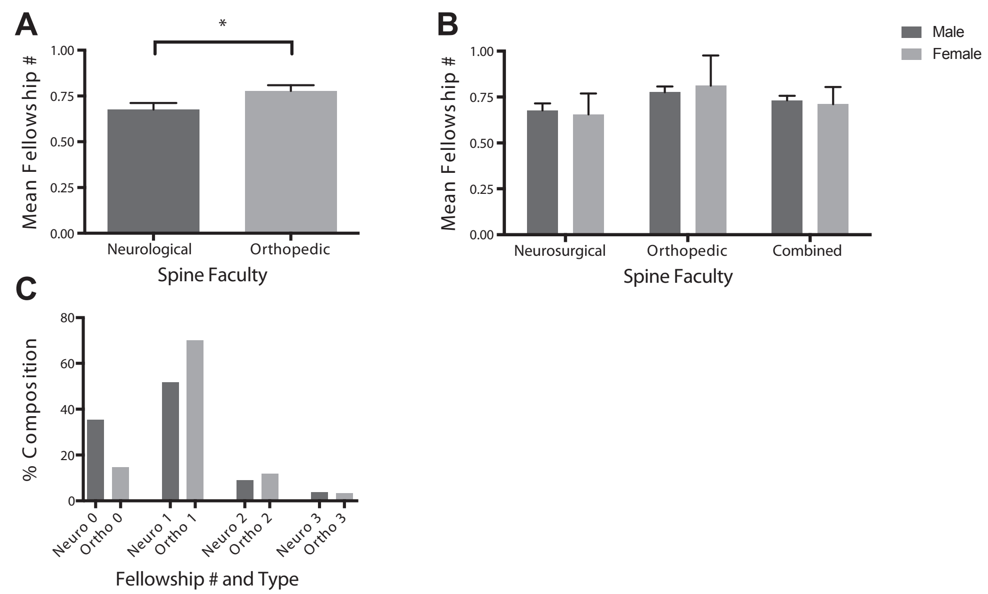

Figure 4. Orthopedic Spine Surgeons Have More Fellowships than Neurological Spine Surgeons. (**A**) Bar graph showing mean number of fellowships ± standard error of the mean (SEM) between neurological and orthopedic spine surgeons (* $P = 0.0355$). (**B**) Bar graph showing breakdown of academic spine surgeons across the number of completed fellowships. (**C**) Bar graph showing mean number of fellowships ± SEM between men and women for neurological spine surgery, orthopedic spine surgery, and combined.

exposure to spine training differentiated the neurosurgical and orthopedic residencies (37% and 16% of total residency time devoted to spine, respectively)" and that "census data from the American Academy of Orthopedic Surgeons and the American Association of Neurological Surgeons reveal that spinal procedures comprise approximately 14% of orthopedic practice and up to 60% of neurosurgical practice." A more recent data analysis of the American College of Surgeons—National Surgical Quality Improvement Program from 2006 to 2013 showed spinal procedures represented an additional increasing percentage of neurosurgical procedures (76.8%, up from 68%).[28] Therefore, orthopedic residents who want to subspecialize in the spine might be more compelled to complete a fellowship to obtain more spine-case exposure.

The percentage of female spine surgeons was staggeringly low in all academic ranks in both surgical disciplines, and female orthopedic spine surgeons were more than twice as rare as female neurological spine surgeons. However, this is not a new phenomenon. In 2008, the Board of Directors of the AANS commissioned a white paper by the Women in Neurological Surgery leadership, which found that women represented ~60% of each graduating medical school class, ~10% of all neurosurgical residents, and ~5.9% of the neurosurgeons practicing at that time.[29] From 1990 to 2003, the rate of female resident applicants choosing neurological surgery remained constant at 0.2%. At that time, they cited a marked difference in the rate of female academic advancement (relative to their male counterparts). "No female neurosurgeon has ever been president of the AANS, Congress of Neurological Surgeons, or SNS or chair of the ABNS. No female neurosurgeon has even been on the ABNS or the Neurological Surgery Residency Review Committee and, until this year [2008], no more than 2 women have simultaneously been members of the SNS."

Day et al.[30] reported a decrease in women transitioning from the 2006—2007 medical school classes into orthopedic residencies and an underrepresentation of full female professors compared with their presence on the faculty at academic orthopedic institutions. Furthermore, they noted that orthopedic surgery had the lowest representation of female residents, behind that of general surgery and other nonsurgical fields. In 2016, orthopedic surgery showed a similar trend of gender disparity, with Rohde et al.[31] noting that women represented 13% of orthopedic surgery residents and 4% of the members of the American Academy of Orthopedic Surgeons. In a survey of the female members of the Ruth Jackson Orthopedic Society, an independent orthopedic specialty society serving as a mentoring network for women, spine surgery was the orthopedic subspecialty least commonly reported (4 of 209 respondents). According to the 2017 AAMC report on U.S. medical school faculty, orthopedic surgery had a male and female breakdown of 189 and 53 for instructors (22%), 970 and 229 for assistant professors (19%), 583 and 88 for associate professors (13%), 628 and 44 for professors (7%), and 2399 and 435 overall (15%), respectively.[32]

Both neurosurgery and orthopedic surgery have previously recognized this gender disparity and have made calls for increased female representation at all levels, including leadership positions.[30,33-35] Our study compared the academic output between spine subspecialties and found that the gender discrepancy persists within the spine subspecialty of each discipline. There is a need for further study and to reduce these disparities and to investigate other metrics of productivity such as surgical output.

The present study was subject to several limitations. The initial identification of appropriate faculty members for inclusion was dependent on the publicly available website data. Faculty members were identified through their online biographies, inclusion in the hospital or departmental spine group or section, and direct contact with the departments. Because only residency training programs active through 2016—2017 were selected for our study, our data included a small subset of the workforce. Wide variability was found among the department and hospital websites regarding the level of specific faculty information available. Some websites did not list academic rank, year of residency completion, or fellowship training. Also, the lack of full information, including the actual spine case number, made it difficult to separate those with spine "ability" or "interest" from those with spine "expertise," as defined by our selection criteria. Additional efforts to obtain this information were pursued by contacting the department or, in select cases, directly contacting the faculty member. We have presumed that most departments' listed information was relatively stable and that changes in personnel and their academic rank were relatively rare. Although verification was not obtained from each department, we believe that both the publicly available and the verified data were valid, and our data (recent work being considered for publication) have shown concordance between the 2.

Every effort was made to ensure that the data used for h-index calculations were correct. In particular, the Scopus database was used because each individual has a unique author profile with respect to the identification of articles they have published. Previously, Scopus had not cited articles before 1996, potentially resulting in absent data unless a labor-intensive manual calculation of pre-1996 citations was performed. This had been performed in other studies, and those investigators postulated that exclusion of pre-1996 citations should become less impactful as older researchers (with pre-1996 citations) retire.[36] Since 2014, Elsevier has been adding pre-1996 references to the Scopus library to enable accurate searches back to 1970.

CONCLUSION

The spread of spine surgeons across academic ranks followed a similar pattern from neurological to orthopedic surgery with similar trends in academic productivity measured by h-index trends and no additional academic effect conferred by the timing of fellowships. A marked gender disparity was found, with fewer female spine surgeons at every rank in neurological and orthopedic surgery. Orthopedic spine surgeons had a greater mean number of fellowships than their neurosurgical counterparts, and orthopedic surgeons without fellowships had a mean h-index that was significantly lower than that of orthopedic spine surgeons with fellowships. This fellowship disparity was not seen among neurological spine surgeons.

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