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The Spine Journal 17 (2017) 1749–1754

THE SPINE JOURNAL

Technical Report

Gender trends in authorship of spine-related academic literature—a 39-year perspective

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Received 23 April 2017; revised 9 June 2017; accepted 27 June 2017

Abstract

BACKGROUND CONTEXT: Despite recent advances in gender equity in medicine, the representation of women in orthopedic and neurosurgery remains particularly low. Furthermore, compared with their male colleagues, female faculty members are less likely to publish research, limiting opportunities in the academic promotion process. Understanding disparities in research productivity provides insight into the "gender gap" in the spine surgeon workforce.

PURPOSE: This study aims to determine the representation and longevity of female physician-investigators among the authors of five spine-related research journals from 1978 to 2016.

STUDY DESIGN: This is a retrospective bibliometric review.

METHODS: The authors of original research articles from five prominent spine-related journals (*European Spine Journal*, *The Spine Journal*, *Spine*, *Journal of Spinal Disorders and Techniques*, and *Journal of Neurosurgery: Spine*) were extracted from PubMed. For authors with a complete first name listed, gender was determined by matching first name using an online database containing 216,286 distinct names across 79 countries and 89 languages.

The proportion of female first and senior authors was determined during the time periods 1978 to 1994, 1995 to 1999, 2000 to 2004, 2005 to 2009, and 2010 to 2016. The authors who had their first paper published between 2000 and 2009 were included in additional analyses for publication count and longevity (whether additional articles were published 5 years after first publication). Student *t* test, chi-square analysis, and Cochran-Armitage trend test were used to determine significance between groups.

RESULTS: From 1978 to 2016, 28,882 original research articles were published in the five spine-related journals. A total of 24,334 abstracts (90.9%) had first names listed, identifying 120,723 authors, in total of which 100,286 were successfully matched to a gender. A total of 33,480 unique authors were identified (female authors: 31.8%).

Female representation increased for first and senior authors from 6.5% and 4.7% (1978–1994) to 18.5% and 13.6% (2010–2016, p<.001). Growth in female senior author representation declined after 2000 (12.3% vs. 12.9% vs. 13.5% between 2000–2004, 2005–2009, and 2010–2016). Compared with male authors, on average, female authors published fewer articles (mean: 2.1 vs. 3.3, p<.001).

Of 15,304 authors who first published during 2000 to 2009, 3,478 authors (22.7%) continued to publish 5 years after their first publication. Female authors were less likely to continue publishing after their first article (15.3% of female authors vs. 24.8%, p<.001).

CONCLUSIONS: Female representation in academic spine research has doubled over the past 4 decades, although the growth of female representation as senior author has plateaued. Female physician-investigators are half as likely to continue participating in spine-related research longer than 5 years and on average publish half as many articles as senior author. In addition to recruiting more women into research, efforts should be made to identify and address barriers in research advancement and promotion for female physician-investigators.

Keywords: Authorship; Diversity; Female; Gender; Large database analysis; Leadership

FDA device/drug status: Not applicable.

Author disclosures: ***DCS:*** Nothing to disclose. ***DJ:*** Nothing to disclose. ***DO:*** Nothing to disclose.

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https://doi.org/10.1016/j.spinee.2017.06.041
1529-9430/

Introduction

In 2015, women made up 52% of all matriculating medical students; however, women constitute only 14.8% and 17.3% of orthopedic and neurosurgery residents [1]. This disparity is even more pronounced in practicing physicians because, although 34% of practicing physicians are women, only 4.6% and 7.4% of practicing orthopedic surgeons and neurosurgeons are women [2,3]. Furthermore, the percentage of women in spine surgery is lower than in any other orthopedic subspecialty [3].

This underrepresentation has been widely acknowledged and thought to be attributable to, among other factors, poor exposure to surgical subspecialties in medical student education, ongoing misperceptions about orthopedic surgery, and unconscious sex biases [4]. Female physician awardees of National Institute of Health career development awards report experiencing gender bias and sexual harassment [5]. In surveys of academic literature, there exists a "gender gap" in the representation of women as authors, especially in surgical literature with women rarely publishing as senior author (4%–6% of articles) [6,7].

Over time, efforts have been made toward promoting gender diversity in regard to promotions and leadership opportunities; however, the progress of female representation within the field of spine-related research has not been previously described. Thus, the goals of this study were to determine how gender trends in authorship of spine-related academic literature have changed over the past 39 years. We hypothesize that although women are still less likely to take leadership roles as first or last author, the gender gap has decreased over time.

Methods

Data source

Citation data from 33,002 articles published between 1978 and 2016 in five peer-reviewed spine research journals (*European Spine Journal* [ESJ], *The Spine Journal* [SpineJ], *Spine*, *Journal of Spinal Disorders and Techniques* [now known as *Clinical Spine Surgery*; JSDT/CSS], and *Journal of Neurosurgery: Spine* [JNS]; Table 1) were extracted and retrieved from PubMed. Data elements included PubMed ID, journal name, article title, type of article, date of publication, and complete author listing. A total of 4,122 articles that were not primary research articles (ie comments, letters, editorials, announcements, etc.) were excluded.

Table 2
Publication characteristics

Original research articles	28,882
Articles listing first name	24,334 (90.9%)
Total number of authors identified	120,723
Authors per article: mean (SD)	5.0 (3.0)
Authors matched to gender	100,286
Female: n (%)	16,881 (16.8%)
Unique authors identified	33,480
Female	8,072 (31.8%)

Author identification

Authors were categorized as first, middle, or senior authors based on author list ordering. For all authors with a complete first name listed, gender was determined by matching first name using an online database containing 216,286 distinct names across 79 countries and 89 languages. (www.genderize.io). Of 120,723 total author names identified, 100,286 were matched to gender (83.0%). In total, gender was identified for 33,480 unique authors, of which 31.8% were women (Table 2).

Gender trend analysis

The top 10 most published male and female authors were identified in the time periods 1978 to 2016 and 2011 to 2016. All authors identified in the top 10 were verified to have correctly assigned gender via online academic profiles. The proportion of female first, middle, and senior authors was determined during the time periods 1978 to 1994, 1995 to 1999, 2000 to 2004, 2005 to 2009, and 2010 to 2016. The number of "leadership roles" was assessed by determining the number of first or senior authorships for each unique author (Table 3).

Table 1
PubMed/MEDLINE indexed spine publications

	First volume			2015 volume				
Journal	Year	No. issues*	Average no. pages	Year	No. issues*	Average no. pages	Year first indexed on PubMed†	Impact factor (2016)
Spine	1976	4	58	2015	24	78.4	1978	2.439
Clinical Spine Surgery (*Journal of Spinal Disorders and Techniques*)	1988	4	67.3	2015	10	63	2002	2.291
European Spine Journal	1992	4	63.8	2015	12	249.9	1992	2.066
Journal of Neurosurgery: Spine	1999	4	128.5	2015	12	123.5	2004	2.126
The Spine Journal	2001	6	75.3	2015	12	203.9	2003	2.66

* Supplemental issues were not included.
† After approval by the Health Literature Selection Technical Review Committee.

Table 3
(A) Most published authors by gender, 1978 to 2016. (B) Most published authors by gender, 2011 to 2016

(A)

Female					Male				
Name	First	Mid	Sr	Total	Name	First	Mid	Sr	Total
Virginie A. Lafage	8	93	26	127	Alexander R. Vaccaro	46	186	107	339
Leah Y. Carreon	26	38	35	99	Lawrence G. Lenke	19	223	50	292
Anne F. Mannion	38	29	30	97	Keith H. Bridwell	26	168	45	239
Nancy E. Epstein	52	1	33	86	Michael G. Fehlings	24	87	76	187
Serena S. Hu	7	42	15	64	Christopher I. Shaffrey	1	136	35	172
Michele C. Battié	12	25	22	59	Todd J. Albert	11	116	45	172
Donna D. Ohnmeiss	10	27	16	53	Jeffrey C. Wang	16	72	76	164
Margareta C. Nordin	4	43	6	53	Christopher P. Ames	13	65	79	157
Tracey P. Bastrom	2	42	7	51	Howard S. An	17	79	57	153
Kathy M. Blanke	0	25	23	48	Ziya L. Gokaslan	1	108	40	149

(B)

Female					Male				
Name	First	Mid	Sr	Total	Name	First	Mid	Sr	Total
Virginie A. Lafage	4	82	25	111	Christopher I. Shaffrey	0	112	16	128
Anne F. Mannion	14	18	17	49	Alexander R. Vaccaro	14	75	37	126
Leah Y. Carreon	11	18	17	46	Christopher P. Ames	5	61	57	123
Tracey P. Bastrom	2	30	2	34	Michael G. Fehlings	12	56	48	116
Miyako Suzuki	2	27	0	29	Justin S. Smith	12	99	4	115
Lindsay A. Tetreault	7	19	0	26	Frank J. Schwab	4	95	4	103
Jing Li	1	19	5	25	Daniel M. Sciubba	5	44	33	82
Wenyan Zhao	0	25	0	25	Lawrence G. Lenke	4	64	13	81
Leyla Karaca	10	11	2	23	Ziya L. Gokaslan	1	70	10	81
Linda A. Koester	0	11	9	20	Charles G. Fisher	15	37	23	75

A secondary analysis to evaluate research longevity was performed using a subset of authors who had their first paper published between 2000 and 2009, allowing all authors to have at least 7-year follow-up from first publication. A Kaplan-Meier survival analysis was then performed to observe the time between initial publication and most recent publication. For example, if an author had only published once, the most recent publication would be the initial publication, and thus, the research longevity would be 0. For an author continuing to publish for 3 years after initial publication who then stopped publishing, the research longevity would be 3 years.

Statistical testing

Student *t* test, chi-square analysis, and Cochran-Armitage trend test were used to determine significance between groups. A p-value <.05 was considered significant. All statistical analysis was performed using R 3.0.2 (R Foundation, Vienna, Austria, www.r-project.org).

Results

Prevalence of female authorship

Overall female representation increased over time from 7.3% (1978–1994) to 18.5% (2010–2016, p<.001; Fig. 1). Female representation increased for both first and senior authorships from 6.5% and 4.7% (1978–1994) to 18.5% and 13.6% (2010–2016, p<.001). Middle authorship experienced growth from 6.4 to 18.3% (p<.001). Growth in female senior author representation declined after 2000 (12.3% vs. 12.9% vs. 13.5% between 2000–2004, 2005–2009, and 2010–2016) relative to overall authorship participation (15.5% vs. 16.0% vs. 18.5%).

Top 10 most published authors by gender

The 10 most frequently publishing male and female authors are shown in Table 2. For the entire study duration of 1978 to 2016, the top 10 female authors published 2.75 times fewer publications compared to the top 10 male authors (737 publications vs. 2,024). This trend also holds true in the top 10 authors in recent years (2011–2016, 2.65 times fewer publications). Among the top 10 authors in 2011 to 2016, females were senior authors in 20% of all publications compared with 24% among male authors. However, women were first author in 13% of publications compared with 7% of men.

Among the top 10 most published authors all-time, 2 of 10 female were clinicians compared with 10 of 10 men. This trend continues to hold true in recent years with 3 of 10 women being clinicians compared with 10 of 10 men.

Leadership roles

Among the 33,480 unique authors (8,072 female authors and 25,408 male authors), 63.7% of female authors were only attributed with middle authorship. Comparatively, 54.1% of

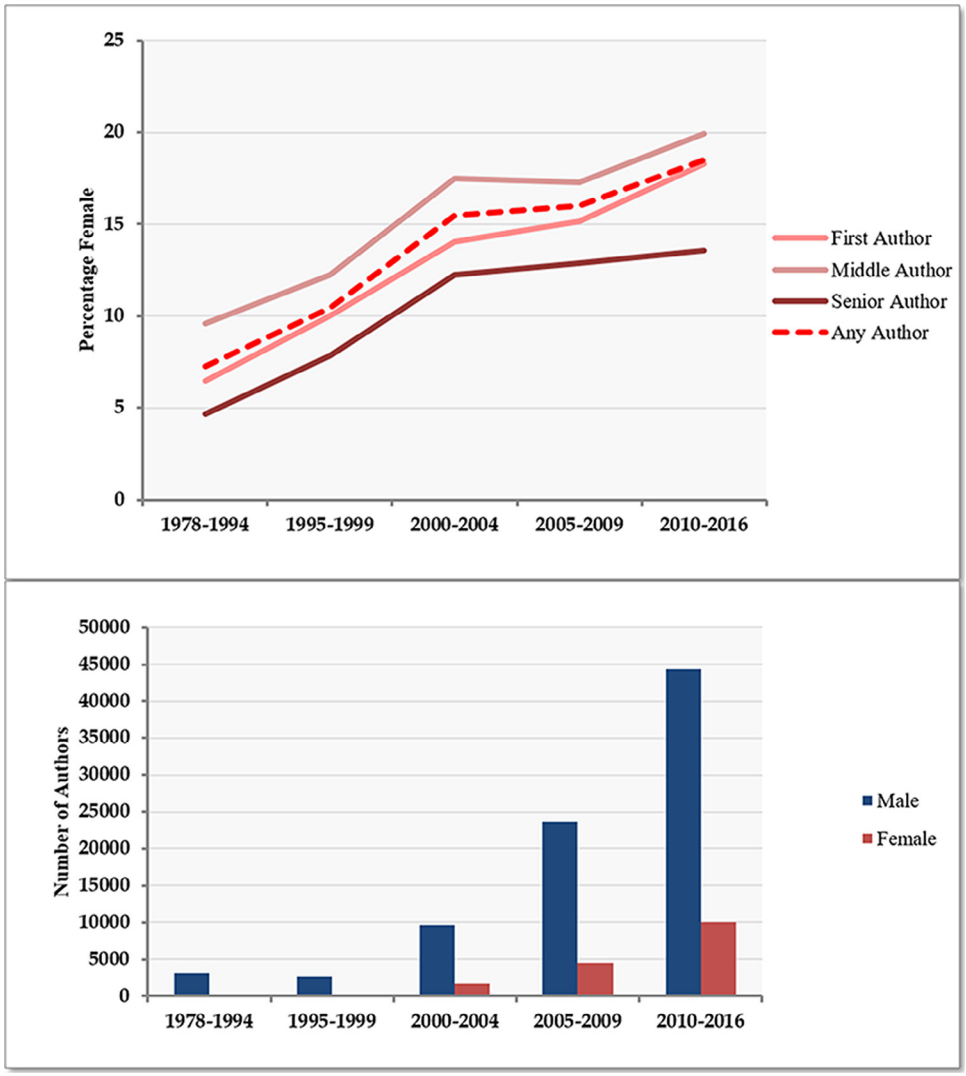

Fig. 1. (Top) Percentage of authors that are female, stratified by first, middle, senior, or any position. (Bottom) Number of female and male authors over time.

male authors took leadership roles (p<.001; Fig. 2). Among authors publishing in leadership roles in three or more articles, 13.3% were female authors. By number of publications, female authors averaged a mean of 0.4 first author publications, 1.4 middle author publications, and 0.3 senior author publications compared with 0.6, 2.0, and 0.7 among male authors (Table 4).

Research longevity

Of 15,304 unique authors who first published during 2000 to 2009, 3,478 authors (22.7%) continued to publish 5 years after their first publication. Women were less likely to continue publishing 5 years after their first article (15.3% of female authors vs. 24.8% of male authors, p<.001; Fig. 3). Among the authors analyzed in this subgroup, 65.4% of female authors only published one time compared with 55.3% of male authors (Table 5, p<.001).

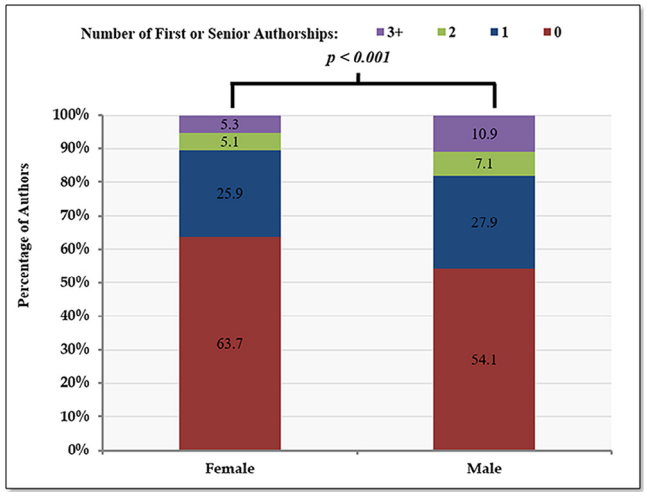

Fig. 2. Percentage of female and male authors publishing as first or senior authors.

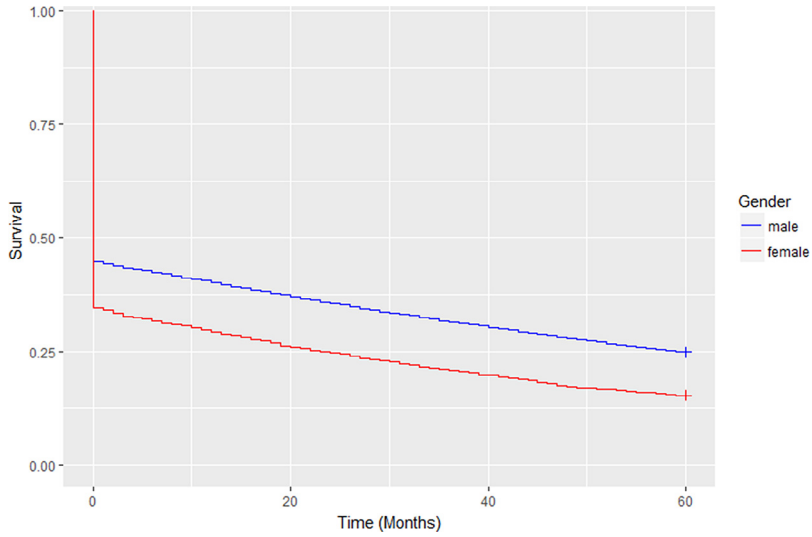

Fig. 3. Survival curve of research longevity, indicating elapsed time between first and most recent publication. Greater than 5 years of research longevity is represented at the 5-year time point. Authors who never published again after their first publication are represented as having a research longevity of 0 month.

Table 4
Publication analysis for unique authors, 1978 to 2016

	Female	Male	p
Total number of unique authors	8,072	25,408	
Number of first or senior authorships: n(%)			<.001
0	5,143 (63.7)	13,758 (54.1)	
1	2,089 (25.9)	7,082 (27.9)	
2	414 (5.1)	1,796 (7.1)	
3 or more	426 (5.3)	2,772 (10.9)	
Average number of authorships: mean (SD)			
First author	0.4 (1.3)	0.6 (1.9)	<.001
Middle author	1.4 (2.8)	2 (5)	<.001
Senior author	0.3 (1.3)	0.7 (2.9)	<.001
Any author	2.1 (4.2)	3.3 (8.4)	<.001

Table 5
Prolificity of authors first publishing during 2000 to 2009*

	Female	Male	p
Total number of unique authors	3,326	1,1978	
Number of authors continuing to publish ≥5 years after first publication: n (%)	508 (15.3)	2,970 (24.8)	<.001
Number of authors only publishing once: n (%)	2,176 (65.4)	6,627 (55.3)	<.001

* All authors had at least 7 years of follow-up data available after first publication.

Discussion

In this study, we show that women continue to be underrepresented in academic spine literature. However, over the last 4 decades, there has been increasing involvement of female authors. Although there continues to be differences in the frequency with which women publish as first or senior author, as well as the sheer number of publications per unique author, these differences trend toward more gender parity. Although women continue to be underrepresented in the literature, these trends point to increased engagement of female trainees over time.

Although women are increasingly involved in spine research, they remain underrepresented, are more likely to be full-time research staff or faculty, are less likely to play leadership roles, and have shorter research careers compared with men. These findings are consistent with recent reports that women produce lower h-indices and shorter careers among academic orthopedic faculty [8], are less likely to be department chairperson or involved in leadership positions in professional societies [9–11], and are proportionally less likely to produce original research in academic medicine [6,7,12].

No previous data have been published regarding the number of women spine surgeons. Our data do not comment on the absolute number of women in spine-related careers, but do suggest that women involved in spine research are much more likely to be full-time research staff or faculty. This may reflect lifestyle concerns or priorities, as 78% of female members of the Ruth Jackson Orthopaedic Society cited inability to have a good work-life balance as the most common reason for why women might not choose careers in orthopedics [3], as well as 65% of female orthopedic residents planning on reducing work hours to part-time status at some time in their career [13]. Family planning may also play a large role in averting women from pursuing orthopedics, as female surgeons face nearly two times the risk of pregnancy complications compared with the general US population [14]. As spine patients tend to require more in-hospital postoperative care than in other subspecialties such as hand, foot/ankle, or sports medicine, this increased demand in work hours may be especially pertinent to women desiring greater work-life balance.

Our findings that women are less likely to continue publishing more than 5 years after their first publication also

support these sentiments, likely reflecting a deprioritization of extracurricular time to pursue research. Although our data do not answer whether or not equally qualified women are less likely to be promoted compared with men, the shorter longevity of research career among women is likely an important disadvantage for pursuing more senior faculty status or greater involvement in academics. Combined with the proportionally smaller number of women taking on leadership roles in spine research, these factors likely directly contribute to perceptions that there is lesser acceptance of women in the field [15].

Despite these current barriers, there is no evidence suggesting that men outperform women in residency training [16], and an increasing number of orthopedic residency programs have at least 10% female trainees [17,18]. In recognizing the importance of female representation, increasing efforts to improve early exposure and recruitment of women have been discussed [19–21]. As the number of female trainees increases, prospective female applicants may be more likely to find an acceptable social support peer network and relate better with peers during residency training. Continuing to pursue greater diversity will benefit the spine surgeon workforce, yielding more perspectives and greater understanding of diverse patient populations.

An important limitation of our study is that the total number of women capable in pursuing spine-related research as an extracurricular or primary career interest is difficult to measure. These data would improve our ability to interpret whether or not women are less interested in participating in research or if gender-related barriers reduce opportunities for research and advancement. Furthermore, spine research is published outside of the five spine-specific journals studied, but identifying a dataset of all spine-related articles published is difficult. The number of publications attributable to an author does not reflect quality or impact of the research presented, and project contributions are limited to analysis of author order. However, this large, complete sample of spine literature over 4 decades has advantages of tracking authors over time, analysis of authorship position, and likely reflects the greater spine research community.

In conclusion, this bibliometric analysis of 40 years of spine literature suggests that although women are increasingly participating in spine research, they represent a relatively small proportion of authors, especially in leadership roles. The progress in closing the gender gap in spine research should be commended, although efforts to encourage women to pursue academic research opportunities remain desirable.

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