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Representation of Women in Academic Orthopaedic Leadership: Where Are We Now?

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Abstract

Background Women have long been underrepresented in orthopaedic surgery; however, there is a lack of quantitative data on the representation of women in orthopaedic academic program leadership.

Questions/purposes (1) What is the proportion of women in leadership roles in orthopaedic surgery departments and residency programs in the United States (specifically, chairs, vice chairs, program directors, assistant program directors, and subspecialty division chiefs)? (2) How do women and men leaders compare in terms of years in position in those roles, years in practice, academic rank, research productivity as represented by publications, and subspecialty breakdown? (3) Is there a difference between men and women in the chair or program director role in terms of whether they are working in that role at institutions where they attended medical school or completed their residency or fellowship?

Methods We identified 161 academic orthopaedic residency programs from the Accreditation Council for Graduate Medical Education (ACGME) website. Data (gender, length of time in position, length of time in practice, professorship appointment, research productivity as indirectly measured via PubMed publications, and subspecialty) were collected for chairs, vice chairs, program directors, assistant program directors, and subspecialty division chiefs in July 2020 to control for changes in leadership. Information not provided by the ACGME and PubMed was found using orthopaedic program websites and the specific leader's curriculum vitae. Complete data were obtained for chairs and program directors, but there were missing data points for vice chairs, assistant program directors, and division chiefs. All statistical analysis was performed using SPSS using independent t-tests for continuous variables and the Pearson chi-square test for categorical variables, with $p < 0.05$ considered significant.

Results Three percent (4 of 153) of chairs, 8% (5 of 61) of vice chairs, 11% (18 of 161) of program directors, 27% (20 of 75) of assistant program directors, and 9% (45 of 514) of division chiefs were women. There were varying degrees of missing data points for vice chairs, assistant program directors, and division chiefs as not all programs reported or have those positions. Women chairs had fewer years in their position than men (2 ± 1 versus 9 ± 7 [95% confidence interval -9.3 to -5.9]; $p < 0.001$). Women vice chairs more commonly specialized in hand or tumor compared with men (40% [2 of 5] and 40% [2 of 5] versus 11% [6 of 56] and 4% [2 of 56],

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Ethical approval was not sought for the present study.
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respectively; $X^2(9) = 16$; p = 0.04). Women program directors more commonly specialized in tumor or hand compared with men (33% [6 of 18] and 17% [3 of 18] versus 6% [9 of 143] and 11% [16 of 143], respectively; $X^2(9) = 20$; p = 0.02). Women assistant program directors had fewer years in practice (9 ± 4 years versus 14 ± 11 years [95% CI -10.5 to 1.6]; p = 0.045) and fewer publications (11 ± 7 versus 30 ± 48 [95% CI -32.9 to -5.8]; p = 0.01) than men. Women division chiefs had fewer years in practice and publications than men and were most prevalent in tumor and pediatrics (21% [10 of 48] and 16% [9 of 55], respectively) and least prevalent in spine and adult reconstruction (2% [1 of 60] and 1% [1 of 70], respectively) ($X^2(9) = 26$; p = 0.001). Women program directors were more likely than men to stay at the same institution they studied at for medical school (39% [7 of 18] versus 14% [20 of 143]; odds ratio 3.9 [95% CI 1.4 to 11.3]; p = 0.02) and trained at for residency (61% [11 of 18] versus 42% [60 of 143]; OR 2.2 [95% CI 0.8 to 5.9]; p = 0.01).

Conclusion The higher percentage of women in junior leadership positions in orthopaedic surgery, with the data available, is a promising finding. Hand, tumor, and pediatrics appear to be orthopaedic subspecialties with a higher percentage of women. However, more improvement is needed to achieve gender parity in orthopaedics overall, and more information is needed in terms of publicly available information on gender representation in orthopaedic leadership.

Clinical Relevance Proportional representation of women in orthopaedics is essential for quality musculoskeletal care, and proportional representation in leadership may help encourage women to apply to the specialty. Our findings suggest movement in an improving direction in this regard, though more progress is needed.

Introduction

Orthopaedic surgery has long been a specialty that is disproportionately practiced by men. The American Academy of Orthopaedic Surgeons (AAOS) 2018 census reported that AAOS membership consisted of only 5.8% women [3], and, with respect to leadership, in 2016, there was only one woman department chair in orthopaedic surgery (at Icahn School of Medicine at Mount Sinai, New York, NY, USA) [8, 24]. According to the Association of American Medical Colleges (AAMC) 2019 Report on Residents, orthopaedic surgery had the smallest proportion of women residents (15.2%) among surgical subspecialties [4]. Additionally, although women have recently surpassed men in medical school matriculation in the United States, women comprised only 14% of orthopaedic residents, 17.8% of full-time orthopaedic surgery faculty at academic centers, and 8.7% of full professors as of the 2016 to 2017 academic year [8].

Having gender balance in orthopaedic leadership positions is essential, not only to avoid missing out on half of all the good ideas and perspectives, but also to provide mentorship for potential future orthopaedic surgeons [14, 18, 19]. Given how slow orthopaedics as a field has progressed with regard to gender parity, increasing women in leadership roles as mentors is of paramount importance [1]. We were interested in how gender parity in leadership positions has progressed at academic orthopaedic institutions in 2020, and what factors are associated with women in leadership roles. To our knowledge, there have been no studies published on this topic, and in particular, whether women leaders are more commonly found at institutions where they previously trained.

We therefore sought to answer three main questions: (1) What is the proportion of women in leadership roles in orthopaedic surgery departments and residency programs in the United States (specifically, chairs, vice chairs, program directors, assistant program directors, and subspecialty division chiefs)? (2) How do women and men leaders compare in terms of years in position in those roles, years in practice, academic rank, research productivity as represented by publications, and subspecialty breakdown? (3) Is there a difference between men and women in the chair or program director role in terms of whether they are working in that role at institutions where they attended medical school or completed their residency or fellowship?

Materials and Methods

Data Collection

To determine which orthopaedic surgery residency programs would be assessed in this study, we cross-referenced all 183 currently ACGME-accredited orthopaedic surgery residency programs with the AAMC program Electronic Residency Application Services, a portal for graduating medical students to apply to residency programs. We chose the ACGME database as it provides the largest centralized database of chairs and program directors with a combination of self-reported and recorded information. We only considered programs that could be applied to the 2018 to 2019 cycle and were accredited by the ACGME, leaving 161 residency programs included in this retrospective study. Eight military orthopaedic residency programs [5] and community orthopaedic surgery departments without associated residencies were excluded from this study, as we wanted the focus of our study to be on the academic orthopaedic surgery residency program leadership demographic.

All data were collected from a single-month period from June 1, 2020 to July 1, 2020 to account for possible changes in leadership roles. Chair and program director name, gender, and years in position were obtained from the ACGME website for each program. Gender, when available within the ACGME website, was self-reported by the chairs and program directors. All other orthopaedic leadership information, including medical school, residency training, fellowship training, years in practice, and professorship, was collected from each orthopaedic surgery residency program's website and recorded when available. When available, an uploaded curriculum vitae on the program's website was also used. Chairs and program directors' training locations (medical school, residency, and fellowship) were recorded. A recent cross-sectional study of orthopaedic leadership used similar methods [6].

Gender for vice chairs, assistant program directors, and division chiefs were recorded based on name and picture when available, which while inaccurate and requires assumption, remained the only method of obtaining this information. In situations in which only a gender-neutral name was available, a Google-based program that has previously been used in medical authorship research was used [12, 25]. If unsuccessful, the leader was left out of analysis. Medical school, residency program, and fellowship training locations were listed. If an individual had multiple fellowships, each fellowship location and subspecialty was recorded. Each individual's years of experience was calculated from July 1, 2020 retrospectively to the date of board certification, and the number of years in the current position was also calculated retrospectively from the same date to the date of hire or promotion. The level of professorship was recorded at four levels: full professor, associate professor, assistant professor, and other. All information was recorded in this standardized method for chairs, vice chairs, program directors, assistant program directors, and division chiefs when reported by the program's website. Division chiefs were defined as chiefs of service of the nine orthopaedic subspecialties, and were recorded when available on that orthopaedic department's public website.

Each leader's research output was recorded using PubMed. Although an imperfect source, PubMed provides the most expansive, standardized source of research citations to best estimate an individual's research productivity via publication in academic journals of the medical field compared with other web databases such as Google Scholar, SCOPUS, and Web of Science [11]. Textbooks, websites, and journal publications that are not cited within PubMed were omitted based on this search methodology. We preferred to use PubMed citations to H-index as H-index is a calculated score based on an individual's research publications and the number of times each of those publications are cited, and we wished to specifically examine publications in medical academic journals. H-indices also vary depending on the web database used [17]. In addition, we did not use ORCID because of concerns regarding author identification accuracy [15]. Each individual was searched using the strategy last name, first name, and middle initial. This individual's list of publications was then compared directly with PubMed-indexed publications linked to the author's name to provide an indirect estimate of the individual's research output.

Among the 161 orthopaedic surgery residency programs, we identified 153 chairs and 161 program directors. Eight programs were within general surgery and did not have an orthopaedic surgeon as a chair. Due to the nature of our data collection and limitations in available information on orthopaedic department websites on more ancillary leadership positions, we were able to identify 61 vice chairs, 75 assistant program directors, and 514 division chiefs from the nine orthopaedic subspecialties. No leaders were excluded due to an inability to determine gender.

Primary and Secondary Study Outcomes

Our primary study goal was to find the current breakdown of women in orthopaedic leadership roles, specifically among chairs, vice chairs, program directors, assistant program directors, and division chiefs. In an attempt to provide a control group for comparison, we looked at the percentage of full and associate professors in our database who were women, as chairs, vice chairs, and division chiefs typically are drawn from a pool of these candidates.

Our secondary study goals were to examine differences between women and men among chairs, vice chairs, program directors, assistant program directors, and division chiefs, as well as to determine whether gender played a role in chairs or program directors remaining in the same institution in which they trained.

Bias

The main sources of bias in our study involve the fact that our data is based on publicly available internet sources, including ACGME, PubMed, orthopaedic surgery program websites, and others. The accuracy of the data collected is dependent on the accuracy of the data reported by these websites. In addition, there is selection bias from missing data points, in particular about vice chairs, assistant program directors, and division chiefs. Complete data points for all recorded information were found for all 153 chairs and 161 program directors, including training locations. Of the 153 programs that reported an orthopaedic chair, we found 61 vice chairs reported and thus were missing a potential 92 data points (as some programs may not have a vice chair). Of the 161 programs that reported an orthopaedic program director, we found 75 assistant program directors reported and thus were missing a potential

86 data points. There is a much larger discrepancy with regard to programs reporting, or even having, subspecialty division chiefs, and thus it is difficult to draw conclusions on how many missing division chiefs there were in addition to the 514 we found. Again, no leaders were excluded due to an inability to determine gender. These biases are further explored in our limitations section.

Ethical Approval

Ethical approval was not sought for the present study.

Statistical Analysis

Statistical analysis was performed using SPSS (IBM SPSS Statistics for windows, Version 25.0). The percentage of women in leadership positions, and in division chief positions by subspecialty, was calculated and reported as descriptive percentages. Within each leadership position, we statistically compared men and women using independent samples t-tests for parametric data on continuous variables (years in position, years in practice, and number of publications) and the Pearson chi-square test of independence for categorical variables (professorship status, subspecialty, and, for chairs and program directors, if same institution as medical school, residency, or fellowship, respectively). Odds ratios were also calculated for all variables, which created a 2x2 table for analysis (professorship status, and for chairs and program directors, if same institution as medical school, residency, or fellowship, respectively). To have a control group to contextually compare the proportion of women in leadership positions, we performed descriptive statistics on the proportion of women with a professorship title, either full or associate, and subsequently a chi-square test of independence was conducted between professorship status and gender (men and women). Odds ratios were also calculated between professorship status and gender (men and women). P values less than 0.05 were considered statistically significant, and 95% confidence intervals were reported where appropriate.

Results

Proportion of Women in Leadership Roles

Among academic programs, 3% (4 of 153) of chairs, 8% (5 of 61) of vice chairs, 9% (45 of 514) of division chiefs, 11% (18 of 161) of program directors, and 27% (20 of 75) of assistant program directors were women (Fig. 1). A chi-square test of independence was conducted between type of leadership role and gender (man and woman). All expected

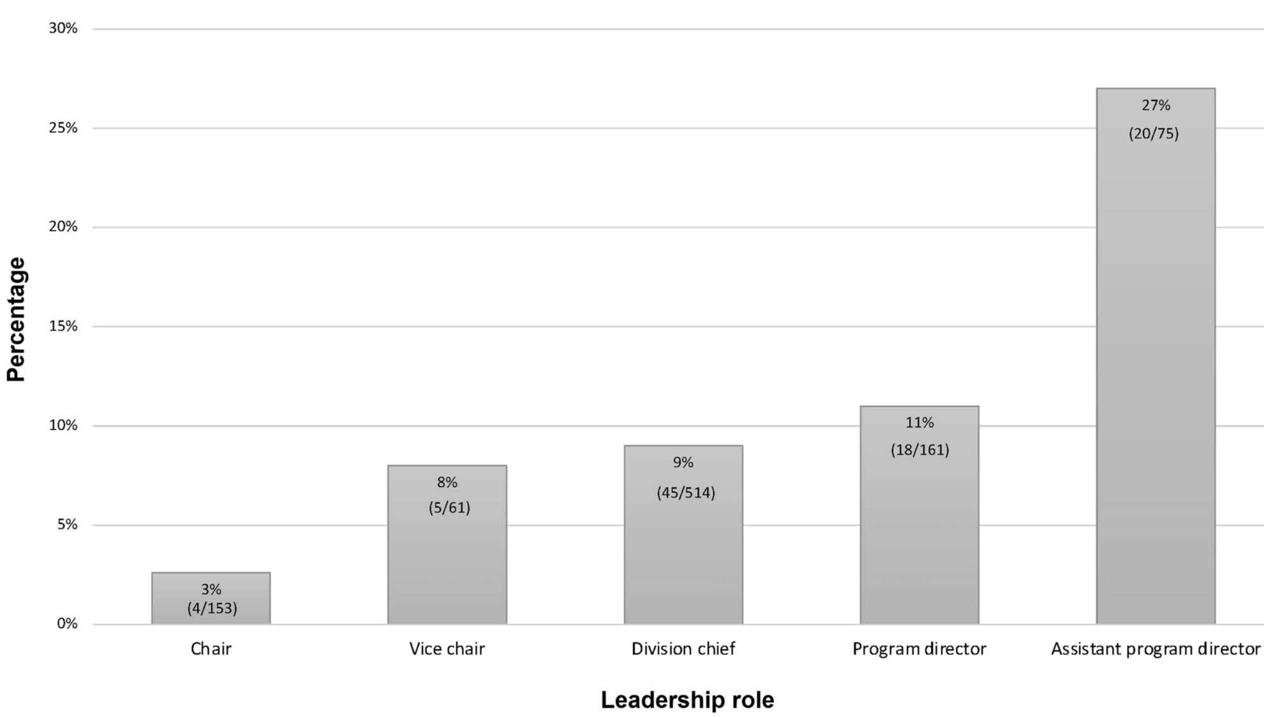

Fig. 1. Proportion of academic orthopaedic leadership positions who are women chairs, vice chairs, division chiefs, program directors, and assistant program directors.

cell frequencies were greater than five. There was an association between leadership role and gender ($\chi^2(5) = 35.4$; $p < 0.001$). The association was small (Cohen, 1988) (Cramer V = 0.192).

There were 813 leaders in our data set who were either full or associate professors, of which 6% (52 of 813) were women. A chi-square test of independence was conducted between professorship status and gender (man and woman). There was an association between professorship status of full or associate and gender ($\chi^2(1) = 9.1$; $p = 0.003$). The association was small (Cohen, 1988) (Cramer V = 0.106). The odds ratio of professorship in men versus women was 2.0 [95% confidence interval 1.3 to 3.3].

Women versus Men in Academic Orthopaedic Leadership Roles

There were several differences between women and men within the chair, vice chair, program director, assistant program director, and division chief leadership positions. Four women chairs had been in their position for a shorter period of years than the 149 chairs who are men (2 ± 1 years versus 9 ± 7 years [95% CI -9.3 to -5.9]; p < 0.001). There were no differences in the mean number of years in practice (21 ± 6 years versus 26 ± 7 years [95% CI -13.0 to 2.8]; p = 0.21), mean number of publications (69 ± 25 versus 73 ± 82 [95% CI -84.8 to 77.7]; p = 0.93), percentage that are full professors (4 of 4 versus 74% [110 of 149]; odds ratio 1.1 [95% CI 1.1 to 1.2]; p = 0.64), or subspecialty breakdown ($X^2(9) = 13.7$; p = 0.13) between women and men, respectively (Table 1).

With regard to vice chairs, there were no differences in the mean number of years in practice (13 ± 4 years versus 21 ± 10 years [95% CI -22.5 to 5.7]; p = 0.24), mean number of publications (49 ± 37 versus 49 ± 77 [95% CI -69.0 to 70.9]; p = 0.98), or professorship status (60% [3 of 5] versus 54% [30 of 56]; OR 1.1 [95% CI 0.2 to 7.2]; p = 0.65) between women and men, respectively. There was a difference in subspecialty breakdown between women and men vice chairs ($X^2(9) = 16.0$; p = 0.04), with the most common subspecialties among women being tumor (2 of 5) and hand (2 of 5) (Table 2).

Women and men in the program director position had no differences in years in their current position (6 ± 4 years versus 7 ± 6 years [95% CI -4.0 to 1.8]; p = 0.46), years in practice (12 ± 7 years versus 18 ± 9 years [95% CI -11.0 to 0.3]; p = 0.06), number of publications (25 ± 26 versus 27 ± 33 [95% CI -18.2 to 13.8]; p = 0.79), or full professorship status (33% [6 of 18] versus 20% [29 of 143]; OR 1.3 [95% CI 0.4 to 3.7]; p = 0.43). There was a difference in subspecialty breakdown between women and men ($X^2(9) = 20.4$; p = 0.02), with the most common subspecialties among women being tumor (6 of 18) and hand (3 of 18) (Table 3).

Table 1. Women versus men in chair positions

	Women chairs (n = 4[a])	Men chairs (n = 149[a])	Statistical test results	p value
Years in position	2 ± 1	9 ± 7	Mean difference: -8 (95% CI -9.3 to -5.9)	< 0.001
Years in practice	21 ± 6	26 ± 7	Mean difference: -5 (95% CI -13.0 to 2.8)	0.21
Number of publications	69 ± 25	73 ± 82	Mean difference: -4 (95% CI -84.8 to 77.7)	0.93
Full professorship	100 (4)	74 (110)	$\chi2(1) = 0.5$ OR = 1.1 (95% CI 1.1 to 1.2)	0.64
Subspecialty			$\chi2(9) = 13.7$	0.13
Adult reconstruction	0 (0)	16 (24)		
Foot and ankle	0 (0)	7 (11)		
Hand/upper extremity	25 (1)	11 (17)		
Pediatrics	25 (1)	4 (6)		
Shoulder/elbow	25 (1)	3 (4)		
Spine	25 (1)	17 (26)		
Sports	0 (0)	19 (28)		
Trauma	0 (0)	18 (27)		
Tumor	0 (0)	10 (15)		

Data presented as mean ± SD or % (n).
[a]No missing data points among orthopaedic chairs. Several chairs had more than one fellowship.

Table 2. Women versus men in vice chair positions

	Women vice chairs (n = 5[a])	Men vice chairs (n = 56[a])	Statistical test results	p value
Years in practice	13 ± 4	21 ± 10	Mean difference: -8 (95% CI -22.5 to 5.7)	0.24
Number of publications	49 ± 37	49 ± 77	Mean difference: 1 (95% CI -69.0 to 70.9)	0.98
Full professorship	60 (3)	54 (30)	$\chi2(1) = 0.01$ OR: 1.1 (95% CI 0.2 to 7.2)	0.65
Subspecialty			$\chi2(9) = 16.0$	0.04
Adult reconstruction	0 (0)	14 (8)		
Foot and ankle	0 (0)	2 (1)		
Hand/upper extremity	40 (2)	11 (6)		
Pediatrics	0 (0)	9 (5)		
Shoulder/elbow	0 (0)	4 (2)		
Spine	0 (0)	29 (16)		
Sports	20 (1)	13 (7)		
Trauma	0 (0)	27 (15)		
Tumor	40 (2)	4 (2)		

Data presented as mean ± SD or % (n).
[a]92 potential missing data points among orthopaedic vice chairs. Several vice chairs had more than one fellowship.

Women assistant program directors had fewer years in practice than men (9 ± 4 years versus 14 ± 11 years [95% CI -10.5 to -1.6]; p = 0.045). Men assistant program directors had more publications than women (30 ± 48 versus 11 ± 7 [95% CI -32.9 to -5.8]; p = 0.01). There was no difference in full professorship status between women and men (5% [1 of 20]

Table 3. Women versus men in program director positions

	Women program directors (n = 18[a])	Men program directors (n = 143[a])	Statistical test results	p value
Years in position	6 ± 4	7 ± 6	Mean difference: -1 (95% CI -4.0 to 1.8)	0.46
Years in practice	12 ± 7	18 ± 9	Mean difference: -5 (95% CI -11.0 to 0.3)	0.06
Number of publications	25 ± 26	27 ± 33	Mean difference: -2 (95% CI -18.2 to 13.8)	0.79
Full professorship	33 (6)	20 (29)	$\chi2(1) = 0.2$ OR: 1.3 (95% CI 0.4 to 3.7)	0.43
Subspecialty			$\chi2(9) = 20.4$	0.02
Adult reconstruction	6 (1)	14 (20)		
Foot and ankle	11 (2)	9 (13)		
Hand/upper extremity	17 (3)	11 (16)		
Pediatrics	6 (1)	9 (13)		
Shoulder/elbow	0 (0)	3 (5)		
Spine	6 (1)	8 (12)		
Sports	11 (2)	16 (23)		
Trauma	11 (2)	23 (33)		
Tumor	33 (6)	6 (9)		

Data presented as mean ± SD or % (n).
[a]No missing data points among orthopaedic program directors.

Table 4. Women versus men in assistant program director positions

	Women assistant program directors (n = 20[a])	Men assistant program directors (n = 55[a])	Statistical test results	p value
Years in practice	9 ± 4	14 ± 11	Mean difference: -5 (95% CI -10.5 to -1.6)	0.045
Number of publications	11 ± 7	30 ± 48	Mean difference: -19 (95% CI -32.9 to -5.8)	0.01
Full professorship	5 (1)	11 (6)	$\chi2(1) = 1$ OR: 0.4 (95% CI 0.1 to 3.5)	0.36
Subspecialty			$\chi2(9) = 9$	0.41
Adult reconstruction	0 (0)	16 (9)		
Foot and ankle	5 (1)	7 (4)		
Hand/upper extremity	25 (5)	18 (10)		
Pediatrics	25 (5)	22 (12)		
Shoulder/elbow	0 (0)	13 (7)		
Spine	5 (1)	9 (5)		
Sports	5 (1)	18 (10)		
Trauma	25 (5)	13 (7)		
Tumor	10 (2)	5 (3)		

Data presented as mean ± SD or % (n).
[a]86 potential missing data points among orthopaedic assistant program directors.

versus 11% [6 of 55]; OR 0.4 [95% CI 0.1 to 3.5]; p = 0.36). The most common subspecialties of women assistant program directors were divided evenly among hand/upper extremity, pediatrics, and trauma (5 of 20 each), with no difference from their counterparts who were men (Table 4).

Division chiefs who were women had been in practice for a shorter amount of time than men (16 ± 7 years versus 21 ± 10 years [95% CI -7.6 to -2.0]; p = 0.001). Women division chiefs also had fewer publications than men (31 ± 34 versus 55 ± 79 [95% CI -38.7 to -12.0]; p < 0.001). However, there was no difference in full professorship status between men and women. The subspecialties with the highest proportion of women division chiefs were tumor (21% [10 of 48]) and pediatrics (16% [9 of 55]), and the subspecialties with the lowest proportion of women were spine (2% [1 of 60]) and adult reconstruction (1% [1 of 70]) (Fig. 2). A chi-square test of independence was conducted between the nine orthopaedic division chief subspecialties and gender (men and women). There was an association between subspecialty and gender ($\chi^2(9) = 25.8$; p = 0.001). The association was small (Cohen, 1988) (Cramer V = 0.224) (Table 5).

Proportion of Chairs and Program Directors Leading Programs at Which They Trained

For orthopaedic surgery chairs, with the numbers available, we found no difference in the proportion of men or women chairs who remained at the same institution where they studied or trained at for medical school, residency, or fellowship (Table 6).

Women were more likely to serve as program directors of programs where they had been a medical student and resident than were men. For medical school, 39% (7 of 18) of women program directors versus 14% (20 of 143) of men stayed at the same institution they studied at (OR 3.9 [95% CI 1.4 to 11.3]; p = 0.02). For residency, 61% (11 of 18) of women program directors versus 42% (60 of 143) of men stayed at the same institution they trained at (OR 2.2 [95% CI 0.8 to 5.9]; p = 0.01). For fellowship, there was no difference in the proportion of women and men program directors (17% [3 of 18] versus 6% [8 of 143]; OR 3.0 [95% CI 0.7 to 12.7]; p = 0.14) who remained at the institution where they did their fellowship in (Table 6).

Discussion

Having women in orthopaedic leadership roles is important because of longstanding gender inequality and the impact that women leaders in orthopaedic surgery have on patient care, mentorship, and new women applicants [16, 18, 19]. In a 2019 AAMC report, orthopaedic surgery was found to have the smallest proportion of women residents in medicine [4], and in 2016, there was only one woman chair and women made up only 8.7% of full professors and 17.8% of full-time orthopaedic surgery faculty at academic centers [8]. We wanted to provide the most comprehensive,

Table 5. Women versus men in subspecialty division chief positions

	Women division chiefs (n = 45)	Men division chiefs (n = 469)	Statistical test results	p value
Years in practice	16 ± 7	21 ± 10	Mean difference: -5 (95% CI -7.6 to -2.0)	0.001
Number of publications	31 ± 34	55 ± 79	Mean difference: -25 (95% CI -38.7 to -12.0)	< 0.001
Full professorship	38 (17)	41 (193)	$\chi2(1) = 0.3$ OR: 0.8 (95% CI 0.4-1.6)	0.34
Subspecialty[a]			$\chi2(9) = 25.8$	0.001
Adult reconstruction (n = 70)	1 (1)	15 (69)		
Foot and ankle (n = 51)	10 (5)	10 (46)		
Hand/upper extremity (n = 59)	14 (8)	11 (51)		
Pediatrics (n = 55)	16 (9)	10 (46)		
Shoulder/elbow (n = 34)	12 (4)	6 (30)		
Spine (n = 60)	2 (1)	13 (59)		
Sports (n = 73)	5 (4)	15 (69)		
Trauma (n = 64)	5 (3)	13 (61)		
Tumor (n = 48)	21 (10)	8 (38)		

Data presented as mean ± SD or % (n).
[a]Percentages for women were calculated based on the n values in the left column; percentages for men were calculated based on n = 469.

objective data set on the current state of women in leadership roles in orthopaedic surgery. We found that although orthopaedics overall continues to be mostly men, there is promise in women representation in leadership roles, particularly in more junior positions, such as assistant program directors.

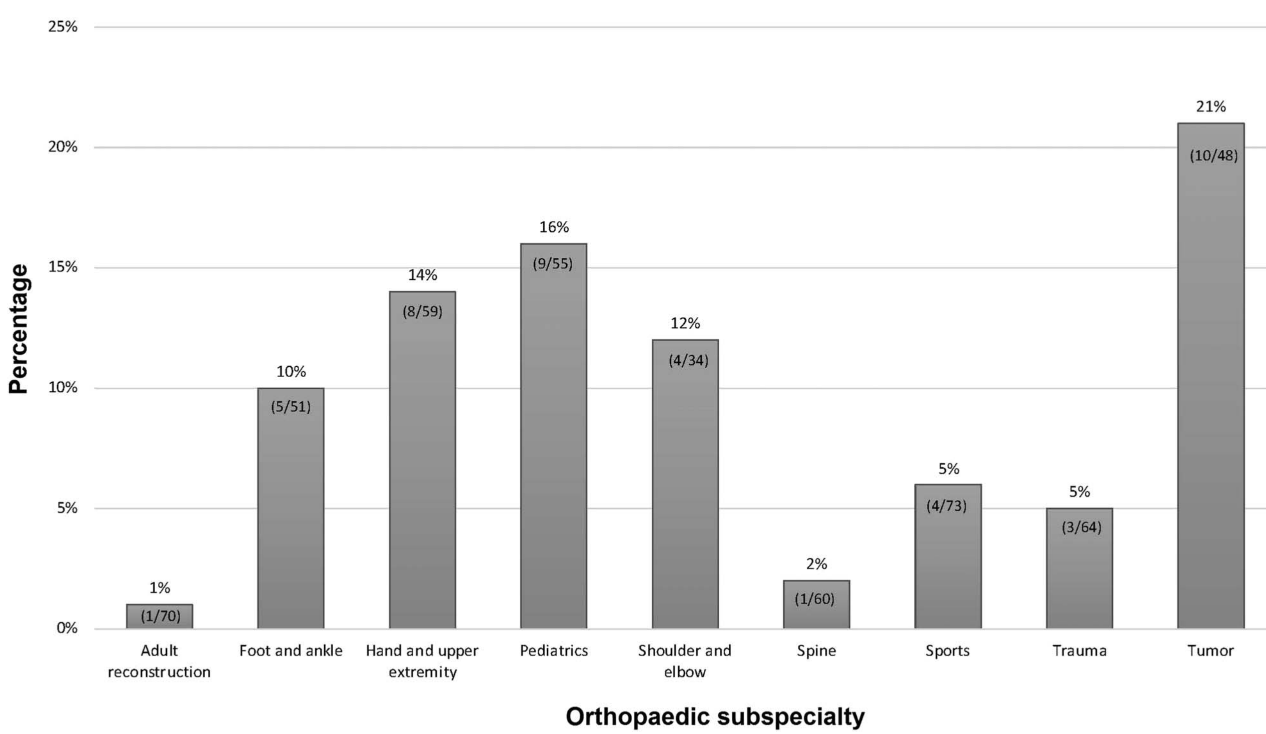

Fig. 2. Proportion of orthopaedic division chiefs who are women by subspecialty.

Table 6. Training location of chairs and program directors

Chairs	Women (n = 4)	Men (n = 149)	Statistical test results	p value
Same institution as medical school	25 (1)	11 (16)	$\chi2(1) = 0.8$ OR: 2.8 (95% CI 0.3-1.2)	0.38
Same institution as residency	25 (1)	22 (33)	$\chi2(1) = 0.02$ OR: 1.2 (95% CI 0.1-11.6)	0.64
Same institution as fellowship	0 (0)	6 (9)	$\chi2(1) = 0.2$ OR: 1.1 (95% CI 1.0-1.1)	0.82
Program directors	**Women (n = 18)**	**Men (n = 143)**	**Statistical test results**	**p value**
Same institution as medical school	39 (7)	14 (20)	$\chi2(1) = 7.1$ OR: 3.9 (95% CI 1.4-11.3)	0.02
Same institution as residency	61 (11)	42 (60)	$\chi2(1) = 2.4$ OR: 2.2 (95% CI 0.8-5.9)	0.01
Same institution as fellowship	17 (3)	6 (8)	$\chi2(1) = 2.5$ OR: 3.0 (95% CI 0.7-12.7)	0.14

Data presented as % (n).

Limitations

There are several limitations to our primarily cross-sectional descriptive study, and our results should be taken with the following in mind. The primary limitation to this study is the lack of standardized, cross-referenced information about leadership among orthopaedic surgery departments in general. A central source such as the ACGME provided comprehensive information about chairs and program directors, but it did not provide information on vice chairs, assistant program directors, or division chiefs. For those leadership positions, we used internet sources primarily involving PubMed and the orthopaedic program website to collect supplemental information regarding chairs and program directors, such as subspecialty and number of publications. We attempted to obtain accurate information, but in cases in which this was not possible, the data were omitted, resulting in nonuniform data. The lack of standardized information about residencies on the internet has been discussed [10, 20]. Hinds et al. [13] published similar findings about the online accessibility of information about orthopaedic trauma fellowships. The reason for missing data points, particularly with regard to vice chairs and assistant program directors, could be multifactorial; for instance, the orthopaedic program does not have a titled vice chair or assistant program director, or the orthopaedic program website did not report that information. Regardless, this makes the interpretation of conclusions about vice chairs and assistant program directors in particular difficult and is akin to transfer bias in a clinical study (the analogy would be loss to follow-up).

Another limitation includes our interpretation of gender definitions throughout the study. When pulling data from the ACGME website, gender is self-reported by chairs and program directors; however, for vice chairs, division chiefs, and assistant program directors who were found on official residency websites, gender was often not reported, and thus gender was assumed by the authors via names stereotypically associated with "men" or "women." In cases in which gender-neutral names existed, we used a gender-determining Google-based program as described in the methods section [12, 25], and no leaders had to be excluded due to failure to determine gender. We acknowledge this limitation, and realize this does not encompass more gender-fluid or transgender leaders; however, we were limited given the lack of self-reported gender on orthopaedic program websites. Similarly, given that no publicly available data provide orthopaedic leaders' ethnicity or race, we elected to defer any attempt at categorizing leaders that way, given the amount of conjecture that would be required based on appearance and/or names.

Another limitation to our study is a lack of a specific and accurate control group, which led to our primarily descriptive study. Ideally, there would be a known amount of midcareer or later academic orthopaedic surgeons who are women, as that is the pool in which orthopaedic chairs, vice chairs, division chiefs, and program directors are often chosen from. As that would be extremely difficult to determine without publicly available data, to determine a comparable control group, we used the percentage of full and associate professors in our dataset that were women. However, that is an imperfect number because our cohort is a group of already selected leaders in chair through assistant program director roles, which is why we did not use that 6.4% proportion to compare statistically but rather used it as an estimated number for comparison. A final limitation of our study is we chose to focus on academic orthopaedic surgery departments associated with a residency programs only, and excluded military and community programs, and thus external validity is limited to academic programs.

Proportion of Women in Leadership Roles

With the data sets available, we found an increasing percentage of women within orthopaedic leadership roles, from chair to vice chair to division chief to program directors to assistant program directors. Although only 3% of chairs were found to be women, when compared with the pool of candidates for a chair position, which we considered to be full or associate professors, our cohort of full and associate professors was found to be 6.4% women, and a prior study by Chambers et al. [8] found that 8.7% of full professors in orthopaedics were women. Women chairs were found to be in the position for a shorter period of time than their men counterparts, and when combined with the growth from one chair in 2016 to four chairs in 2020, this lends credence to theory that as these positions slowly turnover, more women will be considered for the chair position. Vice chair and division chief positions had more than three times the percentage of women than chairs, about comparable with the percentage of full and associate professors who are women. Program directors and assistant program directors often are selected from more junior faculty and can range from full to assistant professors. It is a promising finding that 11% of program directors are women and 27% of assistant program directors are women. Although still far from equal, compared with the 17.8% of women who are full-time faculty at orthopaedic academic centers [8], this growth at junior leadership positions points toward growth in women in leadership roles in the future. This trend is substantiated by the AAOS 2018 census, which demonstrated a higher proportion of younger women in orthopaedic surgery; 15.9% of orthopaedic surgeons younger than 40 years were women, and only 0.2% of those 70 years and older were women [3]. However, improvement must continue at all levels, not just junior leadership roles, as studies have shown that a lack of women mentors is associated with a decreased likelihood that women medical students will apply to orthopaedics [18, 19]. Another study by Shah et al. [23] found that although the overall percentage of women faculty members increased over their study period, the growth was slower than in other medical specialties, and that growth within senior faculty positions, defined as full or associate professors, grew at less than half the number of women in other medical specialties [23]. And a recent study by Acuña et al. [1] demonstrated that at the current rate of change it would take more than 200 years for orthopaedic surgery to achieve gender parity.

Women versus Men in Academic Orthopaedic Leadership Roles

There were few differences between women and men in orthopaedic leadership roles. Chairs, assistant program directors, and division chiefs who were women were found to serve in their leadership role for considerably shorter periods than their men counterparts at the time of our survey; however, there were no differences among men and women vice chairs or program directors. The fact that women chairs were in the position for significantly shorter periods of time than their men counterparts highlights the recent increase in women obtaining the chair position, up from one woman in 2016 to four in 2020. This hopefully suggests that as more chair positions open up, women will continue to be considered and hired. There were no differences in research productivity as defined by PubMed publications among women and men leaders except for among division chiefs and assistant program directors, where men had more publications than women. Brown et al. [7] found that women published at a lower proportion than expected compared with the percentage of practicing orthopaedic surgeons who were women, and that the proportion of growth in the number of publications by women increased more slowly than the proportion of women in orthopaedics. Another study found more promising data after examining three major orthopaedic journals, finding faster growth in the numbers of first and last authors who were women [22]. However, the authors found that none of the nine editors-in-chief were women. No individual leadership positions had a difference in percentage of full professors between genders; however, when taken as a conglomerate, men leaders were more likely to be full professors than women, which corroborates the study by Shah et al. [23]. Vice chairs, program directors, and division chiefs had differences in subspecialty breakdown between women and men. The two most common subspecialties among vice chair and program director women were tumor and hand. The subspecialties with the highest percentage of women among division chiefs were tumor, hand, and pediatrics, and the lowest percentages were in adult reconstruction and spine. Our findings that women in orthopaedics tend to gravitate toward certain subspecialties are corroborated by others; in an analysis of the National Graduate Medical Education Census, a study found that women orthopaedic fellows were more highly represented in pediatrics, hand, and tumor than other subspecialties [21].

Proportion of Chairs and Program Directors Leading Programs at Which They Trained

Women were more likely to serve as program directors of programs where they had been a resident or medical student than were men. This was not found among chairs, although that may have been limited by an extremely small sample size. Several theories may explain this finding. Women in orthopaedics who study and train at an institution for medical school and residency may build a quality reputation and have a positive familiarity, and after returning from fellowship, they may be more likely to be selected to run the program as a program director. There may also be geographic variation to diversity in orthopaedics, as certain residency programs continue to graduate more women orthopaedic surgeons than others. In the most recent AAOS census, only nine orthopaedic programs had more than 20% women enrolled in each of their 5 years of residency, and in 57 residencies at least 1 of the 5 years of the program had more than 20% women. Thirty programs had no women in at least 1 of the 5 years of residency, and eight programs did not have a single trainee who was a woman [3]. A recent study by Chapman et al. [9] found the highest prevalence of women in orthopaedic surgery was in New England and Pacific regions, and the lowest was in the South Atlantic and East South Central regions, and overall, they found a greater level of variation than other medical specialties.

Conclusion

Although orthopaedics overall continues to lag in increasing women in the specialty, there appears to be a promising increase in women in junior leadership positions. The field has increased from a single women chair in 2016 to four in 2020; vice chairs, division chiefs, and program directors are about evenly represented when compared with the percentage of potential candidates who are women, and women assistant program directors may even be represented in slightly larger numbers. Overall, orthopaedics continues to need improvement in the representation of women in the field, and with increasing women in junior leadership positions, and direct mentorship or pipeline programs such as the Ruth Jackson Orthopaedic Society, Nth Dimensions, and The Perry Initiative [16], we as a field must continue to encourage this growth. An area of future research should be directed toward following these data longitudinally to investigate whether this trend of higher percentage of women in junior leadership positions matriculates into increasing the percentage of women in higher levels of leadership, such as chair and vice chair. We propose that future work should be directed at providing higher-quality, more consistent, publicly available information on leadership in orthopaedic surgery. There is currently no publicly available, centralized source of information on vice chairs, assistant program directors, or division chiefs of orthopaedic programs in the United States, and individual program websites vary widely in the quality and availability of information.

References

1. Acuña AJ, Sato EH, Jella TK, et al. How long will it take to reach gender parity in orthopaedic surgery in the United States? An analysis of the National Provider Identifier registry. *Clin Orthop Relat Res*. 2021;479:1179-1189.
2. Adelani MA, Harrington MA, Montgomery CO. The distribution of underrepresented minorities in U.S. orthopaedic surgery residency programs. *J Bone Joint Surg Am*. 2019;101:e96.
3. American Academy of Orthopaedic Surgeons Department of Clinical Quality and Value. Orthopaedic practice in the U.S. 2018. Available at: https://www.aaos.org/globalassets/quality-and-practice-resources/census/2018-census.pdf. Accessed August 1, 2020
4. Association of American Medical Colleges Table B3. Number of active residents, by type of medical school, GME specialty, and sex. Available at: https://www.aamc.org/data-reports/students-residents/interactive-data/report-residents/2019/table-b3-number-active-residents-type-medical-school-gme-specialty-and-sex. Accessed March 30, 2020.
5. Belmont PJ, Hoffmann JD, Tokish JM, Arrington ED, Shawen SB, Orr JD. Overview of the military orthopaedic surgery residency application and selection process. *Mil Med*. 2013;178:1016-1023.
6. Bi AS, Fisher ND, Singh SK, Strauss EJ, Zuckerman JD, Egol KA. The current state of orthopaedic educational leadership. *J Am Acad Orthop Surg*. 2021;29:167-175.
7. Brown MA, Erdman MK, Munger AM, Miller AN. Despite growing number of women surgeons, authorship gender disparity in orthopaedic literature persists over 30 years. *Clin Orthop Relat Res*. 2020;478:1542-1552.
8. Chambers CC, Ihnow SB, Monroe EJ, Suleiman LI. Women in orthopaedic surgery: population trends in trainees and practicing surgeons. *J Bone Joint Surg Am*. 2018;100:e116.
9. Chapman TR, Zmistowski B, Prestowitz S, Purtill JJ, Chen AF. What is the geographic distribution of women orthopaedic surgeons throughout the United States? *Clin Orthop Relat Res*. 2020;478:1529-1537.
10. Davidson AR, Loftis CM, Throckmorton TW, Kelly DM. Accessibility and availability of online information for orthopedic surgery residency programs. *Iowa Orthop J*. 2016;36:31-36.
11. Falagas ME, Pitsouni EI, Malietzis GA, Pappas G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. *FASEB J*. 2008;22:338-342.
12. Gu A, Almeida N, Cohen JS, Peck KM, Merrell GA. Progression of authorship of scientific articles in *The Journal of Hand surgery*, 1985-2015. *J Hand Surg Am*. 2017;42:291.e1-291.e6.
13. Hinds RM, Capo JT, Egol KA. Information on orthopedic trauma fellowships: online accessibility and content. *Am J Orthop*. 2017;46:E320-E325.
14. Leopold SS. Editorial: Fears about #MeToo are no excuse to deny mentorship to women in orthopaedic surgery. *Clin Orthop Relat Res*. 2019;477:473-476.
15. Leopold SS. Editorial: ORCID is a wonderful (but not required) tool for authors. *Clin Orthop Relat Res*. 2016;474:1083-1085.

16. Mason BS, Ross W, Ortega G, Chambers MC, Parks ML. Can a strategic pipeline initiative increase the number of women and underrepresented minorities in orthopaedic surgery? *Clin Orthop Relat Res*. 2016;474:1979-1985.
17. Minasny B, Hartemink AE, McBratney A, Jang H-J. Citations and the h index of soil researchers and journals in the Web of Science, Scopus, and Google Scholar. *PeerJ*. 2013;1:e183.
18. Munger AM, Heckmann N, McKnight B, Dusch MN, Hatch GF, Omid R. Revisiting the gender gap in orthopaedic surgery: investigating the relationship between orthopaedic surgery female faculty and female residency applicants. *J Am Acad Orthop Surg*. 2019;27:295-300.
19. Okike K, Phillips DP, Swart E, O'Connor MI. Orthopaedic faculty and resident sex diversity are associated with the orthopaedic residency application rate of female medical students. *J Bone Joint Surg Am*. 2019;101:e56.
20. Oladeji LO, Yu JC, Oladeji AK, Ponce BA. How useful are orthopedic surgery residency web pages? *J Surg Educ*. 2015;72:1185-1189.
21. Poon S, Nellans K, Rothman A, et al. Underrepresented minority applicants are competitive for orthopaedic surgery residency programs, but enter residency at lower rates. *J Am Acad Orthop Surg*. 2019;27:e957-e968.
22. Rynecki ND, Krell ES, Potter JS, Ranpura A, Beebe KS. How well represented are women orthopaedic surgeons and residents on major orthopaedic editorial boards and publications? *Clin Orthop Relat Res*. 2020;478:1563-1568.
23. Shah KN, Ruddell JH, Scott B, et al. Orthopaedic surgery faculty: an evaluation of gender and racial diversity compared with other specialties. *JB JS Open Access*. 2020;5:e20.00009.
24. Van Heest AE, Fishman F, Agel J. A 5-year update on the uneven distribution of women in orthopaedic surgery residency training programs in the United States. *J Bone Joint Surg Am*. 2016;98:e64.
25. Weiss DA, Kovshilovskaya B, Breyer BN. Gender trends of urology manuscript authors in the United States: a 35-year progression. *J Urol*. 2012;187:253-258.