

ORIGINAL ARTICLE



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Sex Disparities in Authorship Order of Cardiology Scientific Publications Trends Over 40 Years

BACKGROUND: Despite advances in the representation of women in medical training, women continue to be underrepresented in cardiology, academic medicine, and more specifically, in senior positions within academic medicine. Identifying disparities in research productivity and acknowledgment can highlight barriers to female representation in academic cardiology leadership, as well as in academic promotion.

METHODS AND RESULTS: This bibliometric analysis included all authors of original research articles between 1980 and 2017 from 3 high-impact cardiology journals (*Journal of the American College of Cardiology*, *Circulation*, and *European Heart Journal*). We identified 71 345 unique authors of 55 085 primary research articles during our study period. Female authors accounted for 33.1% of all authors; however, they represented only 26.7% of first authors and 19.7% of senior authors. Looking at the most prolific authors within this time period, female authors were not well represented, accounting for only 5% of the top 100 authors. Articles with a female senior author had more female middle authors than articles with a male senior author (mean 1.41 versus 0.97, $P < 0.001$) and were more likely to have a female first author (0.37 versus 0.18, $P < 0.001$). There was an increased representation of female authors as first and senior authors compared with the total number of articles with female authors over time ($P < 0.001$ for trend); however, female senior authorship rates continued to lag first authorship rates.

CONCLUSIONS: Using a large database of published manuscripts, we found that female representation in published cardiology research has increased over the past 4 decades. However, women continue to be not well represented as first authors, senior authors, and in the number of publications. When women were senior authors, they published more articles with female first authors and had more female authors. In addition to recruiting more women into the field of cardiology, additional work is needed to identify and address barriers to academic advancement for female physician-scientists.

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Key Words: authorship ■ female
■ male ■ publications ■ research

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WHAT IS KNOWN

- Women are underrepresented in cardiology, academic cardiology, and leadership roles in academic cardiology.
- Female researchers have to overcome structural barriers and biases to obtain research funding and publication.
- Medical specialties with few women also show lower representation of women in research and research productivity.

WHAT THE STUDY ADDS

- The representation of women researchers in cardiology has steadily increased over 4 decades.
- There is a persistent, but narrowing, gap in female representation in research on all levels, as junior researchers, as first authors, and as senior authors.

Women have historically been underrepresented in the medical field; however, since 2015, women account for >50% of all matriculating medical students in the United States.¹ Despite this growth, there has been a lag of female representation in both training and practice, as women still only represent 13% of the cardiology workforce.^{2–5} Among all American Council for Graduate Medical Education training programs, general cardiology fellowship, at 21.4% female representation, had less female representation than every other specialty with the exceptions of only neuroradiology, neurological surgery, orthopedic surgery, and interventional radiology.^{6,7} Additionally, interventional cardiology has been the most underrepresented by women, with only 8.4% representation.⁷ This issue is paralleled by low female representation in cardiology in the United Kingdom, Italy, and across Europe as well.^{8–10}

In academic medicine, although women make up over 32% of full-time medical faculty members, only 10% of medical school deans, 11% of department chairs, and 14% of full professors in medical schools are women.¹¹ The underrepresentation of women in senior roles has been thought to be multifactorial—attributable in part to fewer research and promotion opportunities.^{12–14} The disparity in leadership positions among women may be partly explained by disparities in research productivity, an important metric in academic advancement and promotion.

For academic physicians, one important measure of research productivity is the number of peer-reviewed publications. In consideration for promotion, the number and impact of publications is explicitly evaluated.^{15–17} In particular, first and senior authorship of publications is seen as a sign of organizing and leading research projects.^{13,18–20} This study seeks to determine trends in authorship of cardiology-related publications

in 3 high-impact general cardiology journals over the past 40 years. We hypothesize that women are less likely to be first or senior author in high-impact published research, but that the sex gap has decreased over time, although not to an equitable distribution.

METHODS

Data Source

PubMed is an online database of over 27 million citations of medical literature developed and maintained by the National Center for Biotechnology Information at the US National Library of Medicine.²¹ For this study, the top 3 impact factor general cardiology journals were identified and articles published from 1980 to 2017 were extracted (Dr Ouyang).^{22–24} Data were extracted on November 28, 2017, from the *Journal of the American College of Cardiology (JACC)*, *Circulation*, and *European Heart Journal (Eur Heart J)*. Citation data such as PubMed ID, article type, article title, date of publication, and authorship list was obtained. After extracting all journal articles, editorials, comments, letters, news, and retractions were excluded from our analysis.

Author Identification

Authors were categorized as first, middle, or senior authors based on author list ordering. The first author, senior author, and up to 15 middle authors were identified. Cofirst and cosenior authorships were not consistently identified across different journals and the author list ordering was used. For all authors with a complete first name listed, sex was determined by matching first name using a previously validated Genderize database containing 216286 distinct names across 79 countries and 89 languages.²⁵

Analysis

The proportion of female first and senior authors was calculated for consecutive 1-year cohorts and in aggregate. The number of articles with female middle authors was used as a proxy for the total number of female researchers in cardiology and was used to compare the relative participation over time of female researchers as first or senior author. Mann-Whitney *U* test and χ^2 test were used to determine significant differences between male and female authors for count data and proportion data, respectively. Generally, statistical tests were comparisons of characteristics of the articles between female and male authors of the same authorship position. Linear regression was used to test the time trend with time as a covariate. Time trends were tested across 4 decades of data, from 1980 to present. Statistical tests were based on 2-sided tests with a significant level of 0.05. Statistical analysis was performed using R 3.4.2 (R Foundation, Vienna, Austria, www.r-project.org). The data, analytic methods, and study materials will be made available to other researchers for purposes of reproducing the results or replicating the procedure.²⁶

RESULTS

We extracted a total of 72362 articles published between 1980 and 2017 (Table). For our analyses, T1

Table. Number of Articles by Author Sex and Journal From 1980 to 2017

Journal	No. of Articles	First Authors	Female First Authors	Male First Authors	Senior Authors	Female Senior Authors	Male Senior Authors
<i>Circulation</i>	25 238	9859	2 620 (26.6)	7 239 (73.4)	6982	1 242 (19.2)	5 640 (80.8)
<i>Journal of the American College of Cardiology</i>	16 806	6507	1 446 (22.2)	5 061 (77.8)	4595	768 (16.7)	3 827 (83.3)
<i>European Heart Journal</i>	13 041	4784	1 169 (24.4)	3 615 (75.6)	3669	602 (16.4)	3 067 (83.6)
Total	55 085	16 613	4 334 (26.7)	12 179 (73.3)	11 160	2 193 (19.7)	8 967 (80.3)

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we excluded editorials, comments, letters, news, and retractions, and identified 55 085 primary/original research articles (Figure 1). Of 261 572 total authorships identified, 257 328 (93.7%) authorships were matched to sex. There were 71 345 unique authors, including 16 613 first authors and 11 160 senior authors.

In total, 23 629 (33.1%) authors were female. Only 4434 (26.7%) of 16 613 first authors were female ($P<0.001$). There was a smaller proportion of female authors in senior authorships, accounting for 2 193 (19.7%) of 11 160 senior authors ($P<0.001$). There was a statistically significantly smaller proportion of female senior authors than female first authors ($P<0.001$). Articles with a female first author had a higher mean number of additional female middle authors than articles with a male first author, (1.49 versus 0.95, $P<0.001$) and articles with a female senior author had a higher mean number of additional female middle authors than articles with a male senior author (1.41 versus 0.97, $P<0.001$). Additionally, articles with a female senior author more frequently had a female first author (0.37 versus 0.18, $P<0.001$).

In the queried journals, authors had a median of 1 article (interquartile range, 1.0–3.0 articles); however,

the top 100 authors published a median of 130 articles each (interquartile range, 114.8–161.2 articles). Female authors accounted for only 5 (5%) of the top 100 most prolific authors (Figure 2). This trend was present at all levels of authorship, as female authors more frequently had few or only 1 publication (Figure 3). Female authors had fewer publications than male authors (mean 4.0 versus 2.3, $P<0.001$).

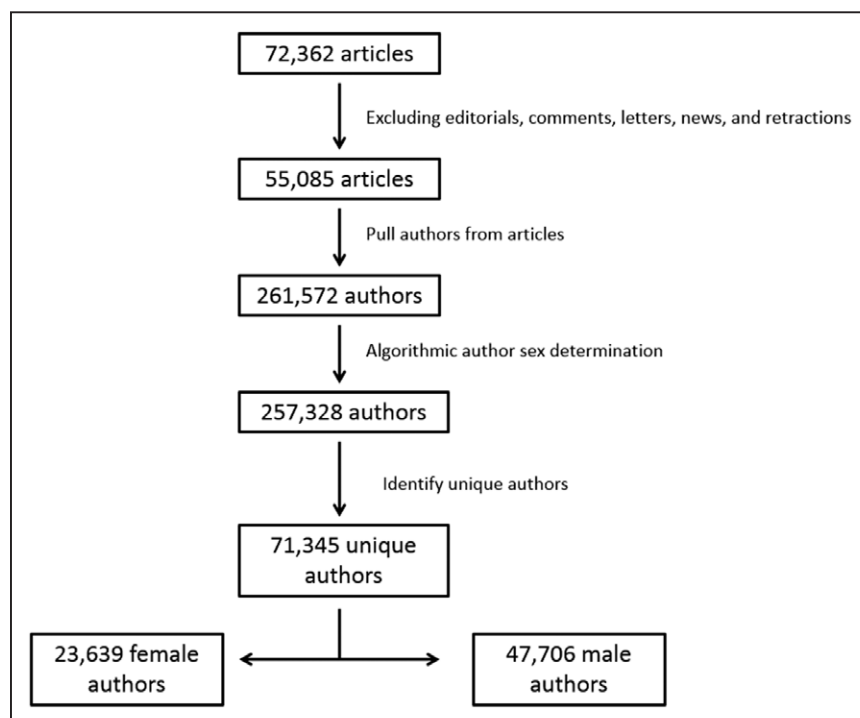
There has been increased representation of female authors over time (Figure 4). Between 1980 and 1989, 9.5% of articles had a female first author, and 5.9% of articles had a female senior author. From 2010 to 2017, 26.2% of articles had a female first author and 17.4% of articles had a female senior author. For each time point, the representation of female authors as senior author lagged the representation of female authors as first author, although there has been a consistent trend toward more representation in the time period studied ($P<0.001$ for trend). To adjust for the possibility that a temporal increase in the number of female researchers explained the increasing prevalence of female first or senior authors, we evaluated whether the ratio of female first and senior author manuscripts

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**Figure 1.** Consort diagram.

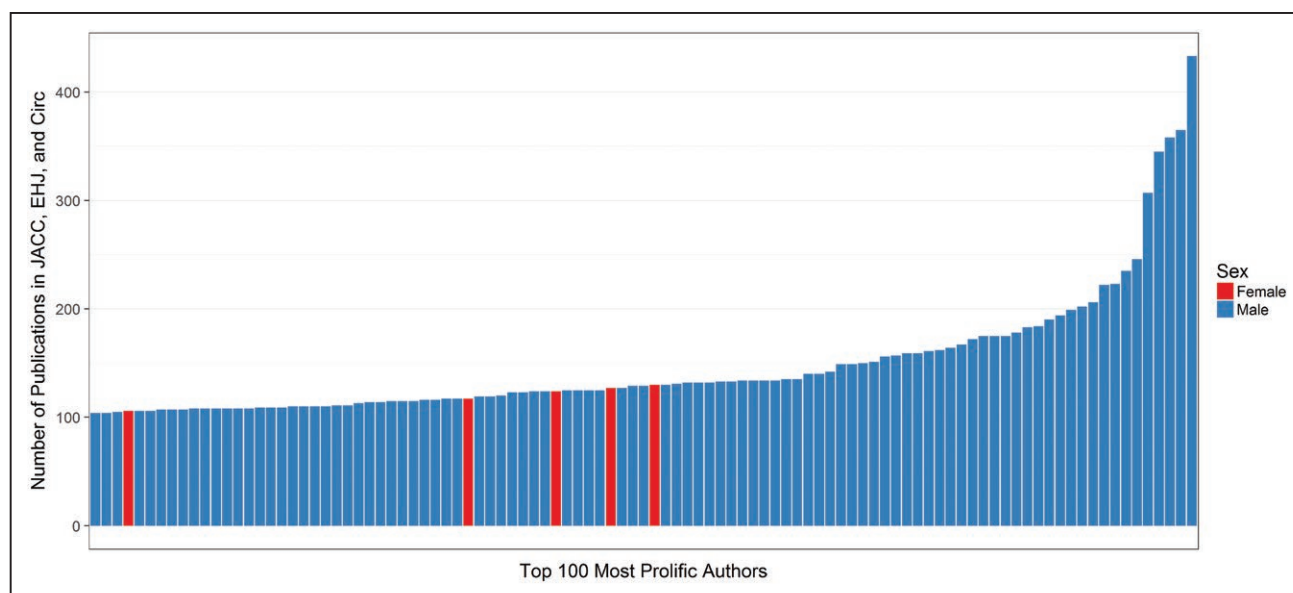


Figure 2. Sex of top 100 most prolific authors in 3 high-impact cardiology journals from 1980 to 2017.

Circ indicates *Circulation*; EHJ, *European Heart Journal*; and JACC, *Journal of the American College of Cardiology*.

F5 to total number of manuscripts changed over time (Figure 5). We hypothesized that this ratio would remain constant over time if increased female representation alone explained the increase in female first and senior authors. Over time, there was a higher proportion of female first and senior author publications compared with total publications with female representation in the author list ($P < 0.001$ for trend for both first and senior authors). The relationship was similar across all 3 journals (Figure I in the [Data Supplement](#)). The proportion of male first and senior author publications compared with total male publications remained steady over time (Figure II in the [Data Supplement](#)).

DISCUSSION

The representation of women in cardiology research as measured by scientific publications and authorships has increased significantly over the past 4 decades. By examining all authors of research articles in 3 top general cardiology journals across 4 decades, our study used a unique, objective measure of research productivity to investigate the sex gap in academic cardiology. Our analysis showed a persistent, though narrowing, gap in female representation in research on all levels, as an author in general, as first author, and as senior author. Our findings are consistent with prior work

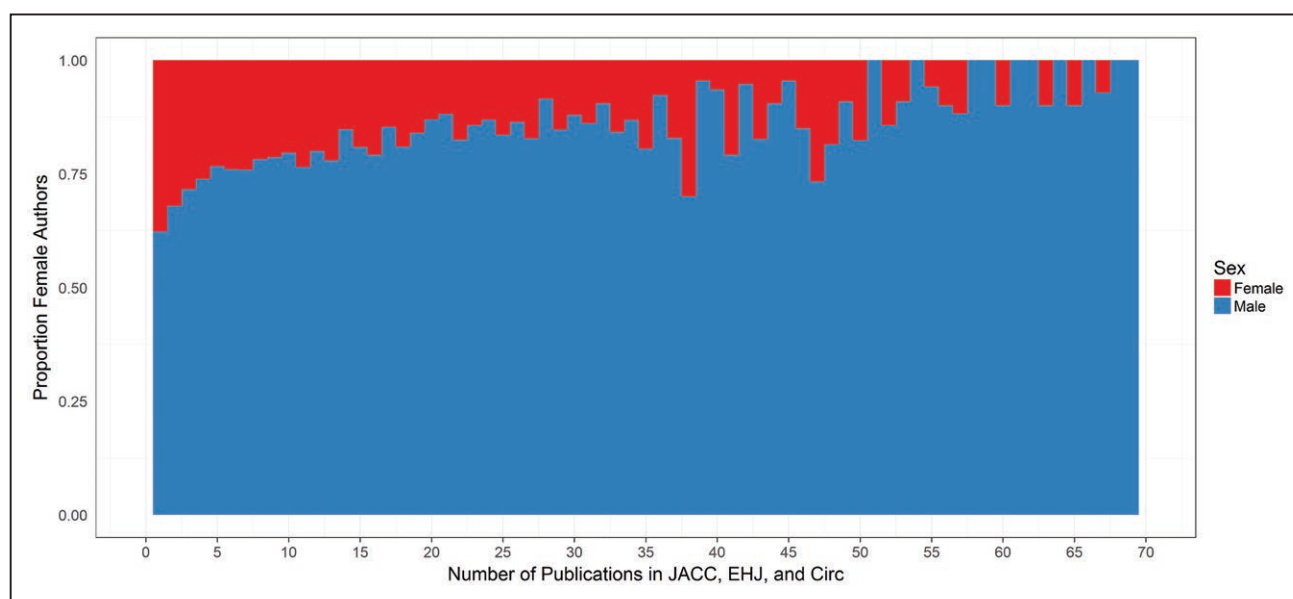


Figure 3. Proportion of male and female authors by the number of publications in 3 high-impact cardiology journals.

Authors were grouped by the number of articles published and the proportion of female and male authors were highlighted per bin. The proportion of female authors decreased at higher numbers of published articles. Circ indicates *Circulation*; EHJ, *European Heart Journal*; and JACC, *Journal of the American College of Cardiology*.

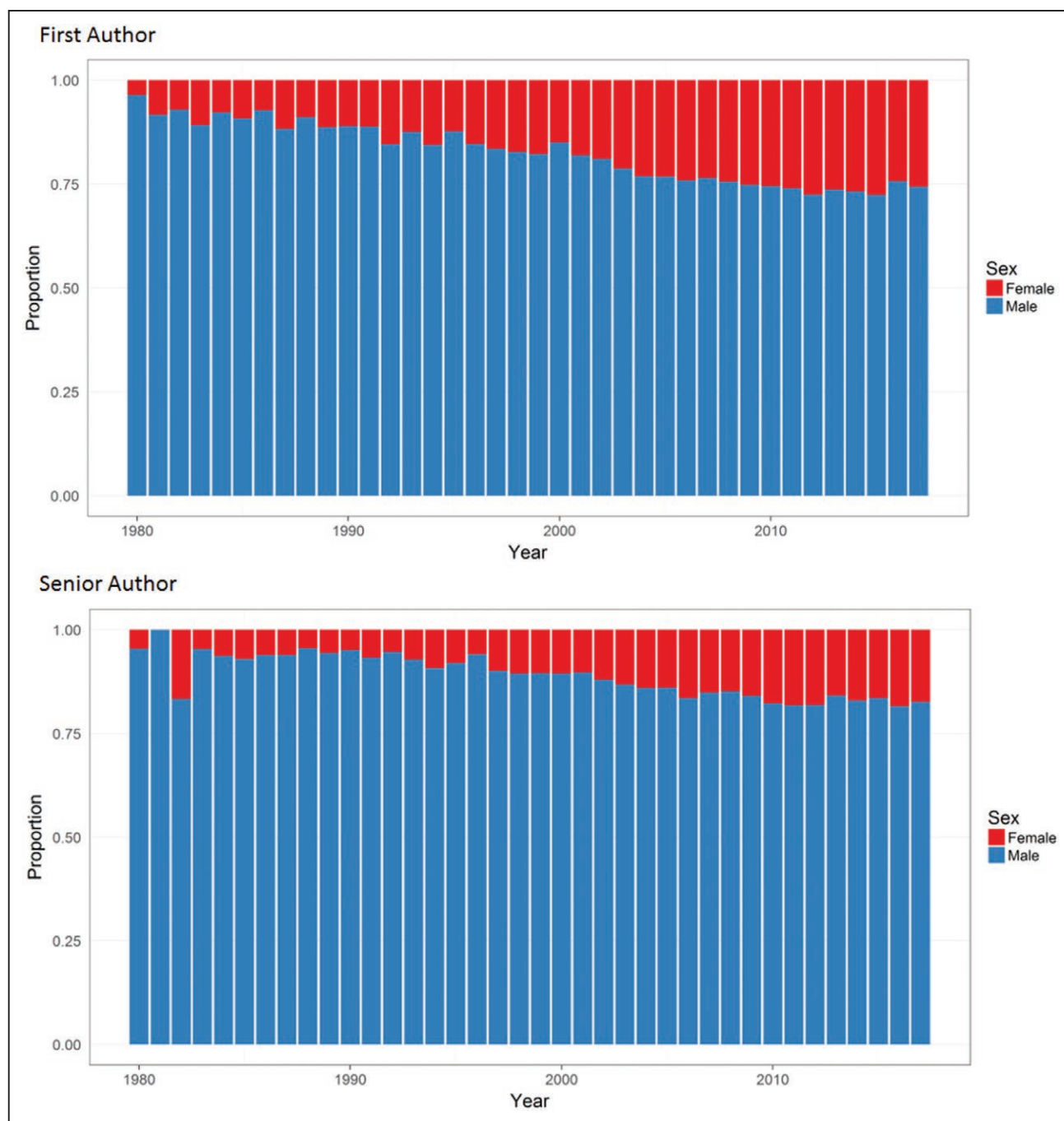


Figure 4. Proportion of female first and senior authors over time.

examining female representation in research across medical specialties and throughout different time eras.^{12–14,27–34} To our knowledge, this study is the first analysis to investigate sex differences in publication in cardiology not limited to R01 funded researchers.³² Our analysis also shows that the presence of female senior authors significantly influenced and increased the number of female senior and middle authors. Previous studies of representation in cardiology have focused on differences in representation in the workforce and in leadership positions, but our study is the first to include

over 10 000 female cardiology researchers, and to use published academic literature as a metric of productivity and inclusion.

Our study supports and extends prior work showing that women, particularly women in underrepresented medical specialties, are less likely to be represented in academic literature. In 2015, 21.4% of cardiology fellows were women, whereas women made up 72.9%, 66.8%, and 61.5% of fellows in endocrinology, allergy and immunology, and rheumatology, respectively.⁷ Previous work has identified similar sex disparities in other

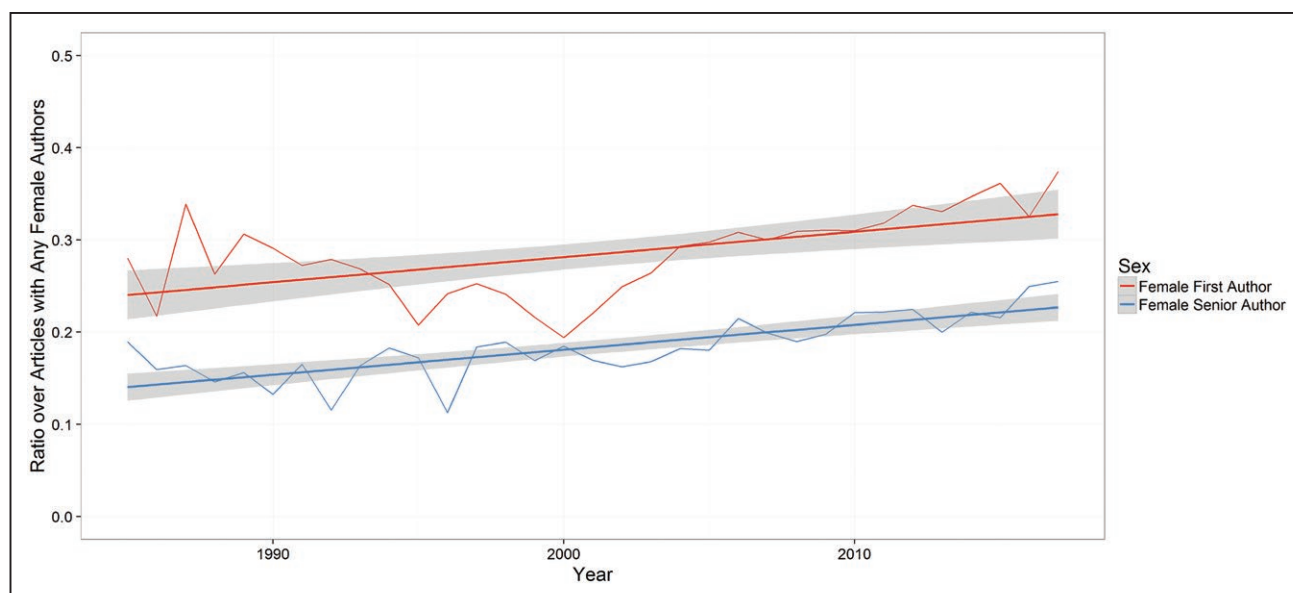


Figure 5. Female first and senior author articles as a proportion of total number of articles published by female authors over time.

Annual point estimates and linear fit of the proportion of female first and senior author articles to total female author articles. The proportion of both female first and senior author articles increased over time.

medical specialties with fewer female clinicians, as well as fields with more female representation.^{27,33,34}

Women also continue to lag behind in academic promotion, including promotion to full professor in academic cardiology.^{11,13,25,29} Authorship of scientific publications is 1 indicator of research productivity, and is an important consideration for faculty promotion. Our study showing sex disparities in high-impact cardiovascular publications is consistent with findings from prior literature. A study on sex differences in physician authorship across all fields found that the proportion of women authors in medical journals in 2004 was 29% of first authors and 19% of senior authors.¹³ Others have reported that women are also less likely to have higher impact publications.¹⁶ A study evaluating sex differences in R01 submissions to the National Institutes of Health found that women tended to have fewer publications and be of lower faculty ranks at the time of their first R01 submissions.¹⁴ Even specifically in cardiovascular research, senior female researchers with R01 funding publish fewer first and senior author manuscripts than similarly funded male researchers.³²

Over time, there has been an increasing proportion of female first authors and female senior authors in cardiology literature. This trend is matched by the trend in female authorship in medical literature in general, in female authorship in other specialties with female underrepresentation, as well as increasing numbers of female cardiologists.^{4,13,27} Over time, there has been an increase in women working at academic medical centers, at higher ranks and in more leadership positions.^{28,30} Our analysis suggests that senior female researchers may serve as role models to junior researchers and also contribute to the increasing proportion of female first authors.

The authorships of manuscripts with female senior authors seem to be different from manuscripts with male senior authors. In our study, we show that papers with female senior authors were more likely to also have female first authors, as well as an increased number of female middle authors. This could be because senior female researchers serve as role models for junior researchers and help recruit junior female researchers into the field of academic cardiology.³⁵ We also found that women were more likely to be represented as middle authors, rather than first, or senior authors. This may reflect higher numbers of women in more junior research roles or that women, when engaging in scientific research, may be more likely to engage in team-based science. Alternatively, women, partly because of lack of mentorship, may have less opportunities to lead original research endeavors. Concrete evidence of sex disparities allows us to investigate possible solutions to achieve sex parity. According to a systematic review of mentorship in medicine, fewer women in junior faculty positions reported having a mentor than men. At the same time, having a mentor was associated with a higher likelihood of promotion to professor.^{36–38} This encouragement and mentorship can be seen in our analysis as female senior authors are more likely to publish articles with female first authors and higher numbers of female middle authors. Current leaders in academic medicine should highlight career opportunities for female junior faculty, and should educate themselves about the unique challenges faced by female faculty in achieving career advancement.

A variety of approaches have been proposed and, in many circumstances, implemented to mitigate sex disparities in research and academic medicine.^{37–40} About

research funding, strategies that include changing the phrasing of funding mechanisms away from terminology that discouraged female applicants, promoting women scientists onto review committees as role models, and actively encouraging female applicants have all been shown to limit selection bias that favors men.^{39,40} Ambiguous grant selection language and criteria with emphasis on subjective assessments of leadership, potential, and risk-taking have been postulated to disadvantage female applicants in the National Institutes of Health Pioneer Research Award and other grant application processes.⁴⁰ The use of sex-based quotas for academic hiring and promotion has been explored in Europe.⁴¹ Editorial boards of medical journals should consider promoting female junior faculty perspectives when they solicit invited commentaries and editorials, and special consideration should be made for blinding authorship lists and balancing reviewers by sex when considering manuscripts for publication. A multifaceted approach including awareness, education, and increased support would best achieve sex equality.

Our analysis has several strengths, including a high-throughput approach that identified all unique authors of research papers in 3 top cardiology journals, systematic cross-matching of authors across journals, and temporal and per-author assessment of author productivity and representation. However, there are also limitations that warrant mention. First, we only evaluated 3 major general cardiology journals to extrapolate trends in academic cardiology research scientific publications. A significant body of literature exists outside of these 3 journals; however, *JACC*, *Circulation*, and *Euro Heart J* are among the longest running cardiology journals and cover a breadth of topics in cardiology. Additionally, publication in these high-impact journals often reflects academic success and productivity. Second, names do not always match perfectly to sex and a small proportion of the names may be misclassified. We manually validated the top 100 authors in our dataset to verify the accuracy of the name database and identified 1 misclassification with the first name of Kim. In the rare instances where we clearly identified sex-name mismatch in our database when compared with online presence, we corrected the change. Conventional East Asian first names were not able to be algorithmically matched to sex. This analysis likely underestimates the representation of both male and female East Asian cardiologists, although we were still able to match 93.7% of all authors. In our analysis, we included first author, senior author, and up to 15 middle authors as a compromise between processing time and thoroughness of analysis. This includes the full authors list for 97.1% of analyzed research articles; however, there is a small minority of articles where the full author list was not pulled. Finally, in a search of the literature, there was no reliable estimate of the number of female academic

cardiology researchers with significant temporal resolution. To assess whether the increasing prevalence of female first and senior authors was not just because of an increasing number of female researchers, the total number of papers published with a female author in any position was used as a proxy for the denominator of the number of women contributing to academic cardiology research.

CONCLUSIONS

Using over 4 decades of publication data from the top 3 high-impact cardiovascular medicine journals, we found persistent disparities in the number of first and senior author publications for women. Although there has been an increase in female representation in research over time, women continue to be not well represented as first authors, senior authors, and in the number of publications. Female senior authors published more articles with female first authors and had more female authors than male senior authors. More work is needed to untangle the reasons behind these disparities and to develop strategies to increase female representation in cardiovascular research.

ARTICLE INFORMATION

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Disclosures

None.

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