Pulmonology 29 (2023) 495—504

PULMONOLOGY

www.journalpulmonology.org

ORIGINAL ARTICLE

Gender equity of authorship in pulmonary medicine over the past decade

F. Geng[a,1], Y. Ren[b,1], H. Hou[a,1], B. Dai[a,1], J.B. Scott[c], S.L. Strickland[d,e], S. Mehta[f], J. Li[c,*]

[a] *Department of Pulmonary and Critical Care Medicine, The First Hospital of China Medical University, Shenyang, China*
[b] *Department of Respiratory and Critical Care Medicine, Peking University People's Hospital, Beijing, China*
[c] *Department of Cardiopulmonary Sciences, Division of Respiratory Care, Rush University, Chicago, Illinois, USA*
[d] *American Epilepsy Society, Programs, Chicago, Illinois, USA*
[e] *Department of Health Sciences, Rush University, Chicago, Illinois, USA*
[f] *Department of Medicine and Interdepartmental Division of Critical Care Medicine, Sinai Health System, University of Toronto, Toronto, ON, Canada*

Received 12 December 2022; accepted 24 March 2023
Available online 18 May 2023

KEYWORDS
Pulmonary medicine;
Gender distribution;
Female first and last authorship

Abstract
Background: Gender disparity in authorship broadly persists in medical literature, little is known about female authorship within pulmonary medicine.
Methods: A bibliometric analysis of publications from 2012 to 2021 in 12 journals with the highest impact in pulmonary medicine was conducted. Only original research and review articles were included. Names of the first and last authors were extracted and their genders were identified using the Gender-API web. Female authorship was described by overall distribution and distribution by country/region/continent and journal. We compared the article citations by gender combinations, evaluated the trend in female authorship, and forecasted when parity for first and last authorship would be reached. We also conducted a systematic review of female authorship in clinical medicine.
Results: 14,875 articles were included, and the overall percentage of female first authors was higher than last authors (37.0% vs 22.2%, $p<0.001$). Asia had the lowest percentage of female first (27.6%) and last (15.2%) authors. The percentages of female first and last authors increased slightly over time, except for a rapid increase in the COVID-19 pandemic periods. Parity was predicted in 2046 for the first authors and 2059 for the last authors. Articles with male authors were cited more than articles with female authors. However, male-male collaborations significantly decreased, whereas female-female collaborations significantly increased.
Conclusions: Despite the slow improvement in female authorship over the past decade, there is still a substantial gender disparity in female first and last authorship in high-impact medical

* Correspondence author at: Department of Cardiopulmonary Sciences, Division of Respiratory Care, Rush University, 600 S Paulina St, Suite 765, 60612 Chicago, IL, USA.
E-mail address: Jie_Li@rush.edu (J. Li).
[1] Contributed equally

https://doi.org/10.1016/j.pulmoe.2023.03.005

journals in pulmonary medicine.

Introduction

In modern-day society, gender disparities broadly persist in many professions. Despite the increasing numbers of women in the medical field, they are under-represented in leadership positions,[1,2] editorial boards,[3-5] and conference speakers.[6,7] As authorship plays a crucial role in faculty promotion, grant application, and academic position,[8-10] understanding gender distribution of prominent author positions helps clarify the roles women hold in an academic environment.

In recent years, gender equity in academic medicine has attracted interest from different medical disciplines.[11-17] Except for nursing,[18] obstetrics and gynecology,[19] and dermatology,[20] most clinical specialties have reported that women have lower representation than men in published articles,[12-17] especially in the last author position.[12,14-17] In articles published between 2008 and 2018 in 40 critical care medicine journals, fewer than one-third of first authors and one-fifth of last authors were women.[14]

Gender disparities in authorship vary between geographic areas and journals. The reported proportions of first and last women authors in countries vary by medical specialties. For example, the percentage of women first authors in radiology was reported to rank high in Asian countries like China and South Korea,[21] in contrast to their representation in surgical medicine,[22] neurosurgical science,[23] and critical care medicine.[14,24,25] Female authorship in high-impact journals is low, especially in the last author position.[26,27] Also, articles with male authors are cited more often than articles with female authors.[28,29] so we sought to explore if there are similar trends in pulmonary medicine journals.

This study aimed to investigate the gender distribution of authorship among high-impact medical journals in pulmonary medicine over the past decade. Additionally, to compare authorship distribution in pulmonary medicine to other medical specialties, we reviewed the publications with the topic of gender distribution in the academic literature on clinical medicine. Because the first authorship typically belongs to the person responsible for most of the work, and the last author is often considered the senior author who supervises the project, we used those positions for this paper.

Material and methods

Data source

We included the top eight journals that were ranked by journal citation reports (JCRs, 2020) in the category of the respiratory system (https://jcr2.clarivate.com), according to the Web of Science database core collection. These journals included Lancet Respiratory Medicine, American Journal of Respiratory and Critical Care Medicine (AJRCCM), European Respiratory Journal (ERJ), Journal of Thoracic Oncology, Journal of Heart and Lung Transplantation, Chest, Thorax, and European Respiratory Review. In addition, we included four general medical journals with the highest impact factors (British Medical Journal [BMJ], Journal of the American Medical Association [JAMA], Lancet, and New England Journal of Medicine [NEJM]). For the four general medical journals, only articles with study content related to pulmonary medicine were included, with article titles and abstracts screened independently by two researchers. Any disagreement regarding if it was pulmonary medicine related article was resolved by discussion with a third researcher.

Articles published in the 12 journals between January 1st, 2012, and December 31st, 2021 were searched on Web of Science core collection. Only original research studies and reviews were included. Articles with a single author were excluded.

Article information extraction

The article information was obtained from Web of Science database and extracted by Python programming software, including publication date, journal, article type, title, abstract, citation, and author information. Detailed information about data extraction is available in the Supplement (page 2). Gender was identified for authors listed in the first and last positions. For the authors who had multiple affiliations, the affiliation listed first was used.

Author's gender identification

The extracted authors' names were entered in Gender-API (https://gender-api.com/), which has been used to identify gender based on name with a reported accuracy of over 98%.[30,31] Gender-API reports gender (male, female, or null) and the predicted accuracy of the determination. If the author's gender was not identified (null) or the predicted accuracy was $<$ 60%, a manual search on Google and/or social media was conducted using the author's name and affiliations listed in the publication. The author's photo and/or biographies by pronouns were used to identify gender. When either or both the first and last authors' genders could not be identified, the articles were excluded.

Evaluation on the publications of female authorship in clinical medicine

We also reviewed the publications on female authorship in clinical medicine. Two investigators independently searched the PubMed database for articles with a focus on female authorship in clinical medicine published in English from January 1st, 2012 to December 31st, 2021. The literature search strategy and eligibility criteria for including studies are available in the Supplement page 3.

To explore the association between the percentages of female faculty/physicians and female authorship in different disciplines of clinical medicine, we extracted the percentages of female physicians and female faculty reported by AAMC.[32] The percentages of female first and last authorship from articles published from January 1st, 2018, to December 31st, 2019, in relevant disciplines were calculated as an average.

Statistical analysis

The distribution of female first and last authors was reported as percentages by overall, article type, countries/regions/continents, and journals. The differences were analyzed using chi-square test. To evaluate female first and last authorship changes over time, linear regression was performed to forecast the year in which parity would be reached between women and men for first and last authorship. Similarly, linear regression was used to analyze the changes over time in female first and last authors by country/region, journal, and gender pairs from 2012 to 2021. To understand the pattern of the pairs of first and last authors, we paired the first and last authors by gender to create four categories, including: (1) female-female, (2) female-male, (3) male-female, and (4) male-male.

The Kolmogorov-Smirnov test was used to test the normality of distribution for article citations, and Mann-Whitney test was used to compare the article citations with different pairs of genders. Multi-factor logistic regression was performed to assess the influential factors with the first and last author's gender. Factors in this model included year (reference: 2012), article type (reference: original research), region of the author (reference: North America), and journal (reference: European Respiratory Review). References were chosen as they were closest to the average overall distribution data.

The first and last authors with the highest number of articles in pulmonary medicine during the study period were included in the top 100 most prolific authors.

Statistical analysis was conducted using SPSS (version 22.0; IBM Corp, Armonk, New York), and visualization of statistics was performed using GraphPad Prism version 8 (GraphPad Software, La Jolla, CA). A two-sided $P< 0.05$ was considered significant.

Results

14,875 articles were included in our study, including 13,297 original research studies and 1,578 reviews (Fig. 1A). Of those included articles, 14,411 had the gender of the first author identified by gender-API, with a probability of 99% (98-100). Likewise, the gender of last authors was identified by gender-API in 14,328 articles, with a probability of 99% (99-100). In the remaining articles, a manual search was performed to determine the gender.

For the evaluation, 1,331 articles were screened and 117 articles were included (Fig. 1B).

Manuscript characteristics and authorship position by gender

Of the 14,875 articles included, 37.0% were first-authored by a woman, which was higher than the percentage

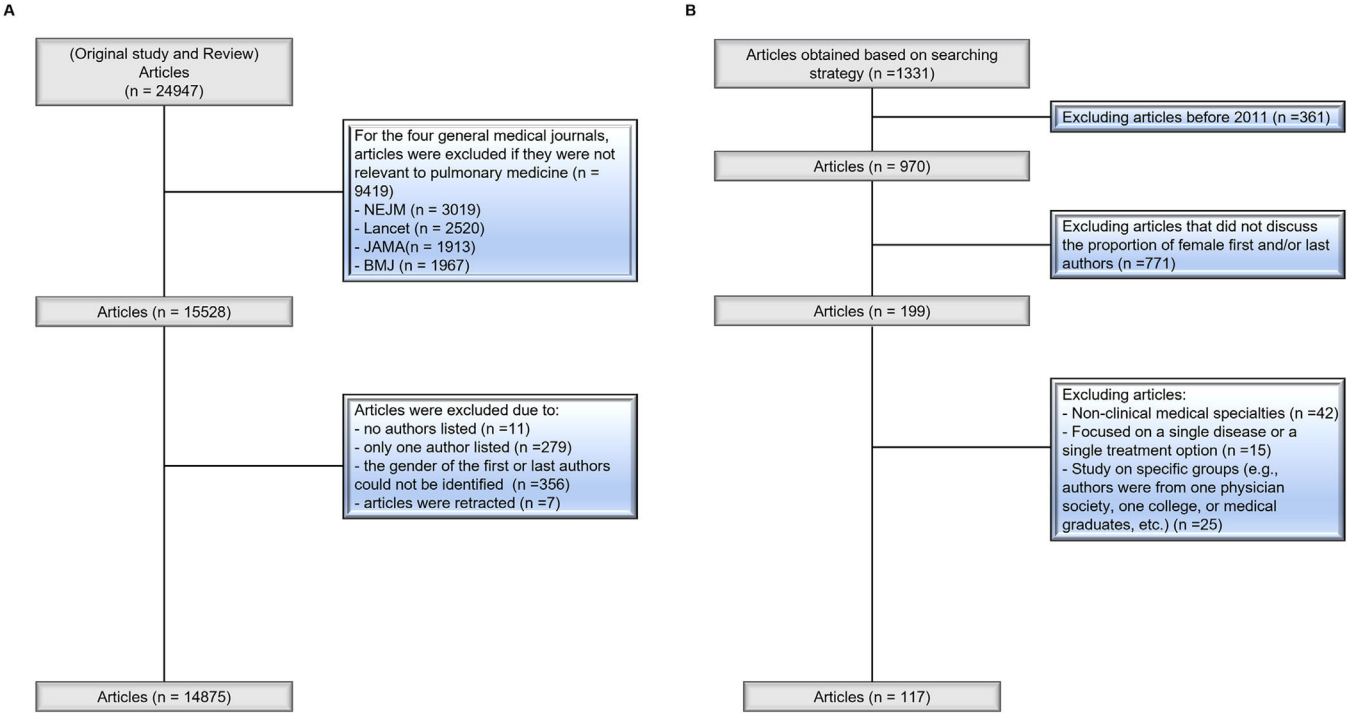

Fig. 1 Flow diagram for selecting articles for **(A)** selection of respiratory system articles published between 2012 and 2021 and **(B)** evaluation on clinical medicine. Abbreviations: BMJ, British medical journal; JAMA, Journal of the American Medical Association; NEJM, New England Journal of Medicine.

Table 1 Manuscript characteristics and authorship position by gender.

	Percentage of female first authors (95% CI)	Percentage of female last authors (95% CI)
Overall	37.0 (36.2–37.8)	22.2 (21.5–22.9)
Article type		
Original research	37.1 (36.3–37.9)	22.2 (21.5–22.9)
Review	35.9 (33.5–38.3)	22.1 (20.1–24.1)
Region		
North America	35.4 (34.3–36.5)	22.9 (21.9–23.9)
Europe	39.8 (38.6–41.0)	22.5 (21.4–23.6)
Asia	27.6 (25.2–30.0)	15.2 (13.2–17.2)
Oceania	46.2 (42.2–50.2)	25.5 (22.0–29.0)
South America	45.5 (37.4–53.6)	20.0 (13.1–26.9)
Africa	34.2 (25.6–42.8)	21.6 (13.9–29.3)
Journal		
European Respiratory Review	37.8 (33.7–41.9)	22.4 (18.9–25.9)
Thorax	44.9 (42.3–47.5)	26.6 (24.2–29.0)
Chest	36.5 (34.8–38.2)	21.2 (19.8–22.6)
Journal of Heart and Lung Transplantation	30.9 (28.5–33.3)	18.1 (16.1–20.1)
Journal of Thoracic Oncology	36.2 (34.1–38.3)	20.9 (19.1–22.7)
ERJ	42.4 (40.4–44.4)	24.6 (22.9–26.3)
AJRCCM	36.5 (34.5–38.5)	21.3 (19.6–23.0)
Lancet Respiratory Medicine	28.0 (24.5–31.5)	20.7 (17.5–23.9)
BMJ	37.0 (33.7–40.3)	26.0 (23.0–29.0)
JAMA	30.1 (24.2–36.0)	18.8 (13.7–23.9)
Lancet	31.7 (26.3–37.1)	23.6 (18.7–28.5)
NEJM	27.3 (22.4–32.2)	27.6 (22.7–32.5)

Abbreviations: CI, confidence interval; ERJ, European Respiratory Journal; AJRCCM, American Journal of Respiratory and Critical Care Medicine; BMJ, British medical journal; JAMA, Journal of the American Medical Association; NEJM, New England Journal of Medicine.

of female last authors (37.0% vs 22.2%, *P< 0.001*) (Table 1). For original research and review articles, female first authors were similar (37.1% vs 35.9% respectively), which was also noted for last authors (22.2% vs 22.1% respectively).

Trends in overall articles gender distribution over time

The percentage of female first authors increased significantly from 2012 to 2021, with an average annual increase of 0.44% (95%CI, 0.13-0.75%, *P= 0.011*) (Fig. 2A), with parity predicted in 2046 (Fig. 2B). Likewise, the percentage of women in the last author position also increased significantly, with an average annual increase of 0.66% (95%CI 0.40–0.91%, *P< 0.001*). At this rate, parity would be reached in 2059.

During the COVID-19 pandemic 2020 and 2021), of 3372 articles published in the 12 journals, 39.0% were first-authored by a female and 25.5% had a female last author (Fig. 2A). While in the two years before COVID-19 (2018 and 2019), of 2581 articles, 36.3% and 23.8% had women first and last authors respectively. More females were first (*P= 0.032*) and last (*P= 0.016*) authors in the COVID-19 pandemic than in non-pandemic periods.

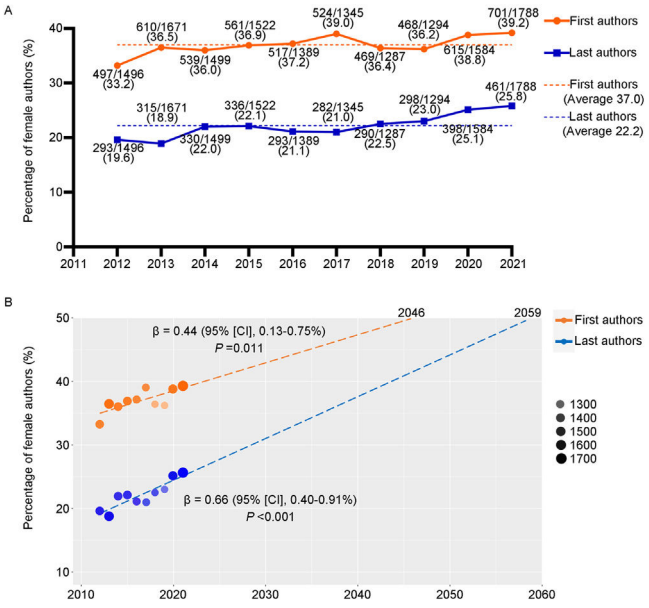

Fig. 2 Trends in overall articles gender distribution over time. **(A)** Trends in female first and last authorship of respiratory system articles published between 2012 and 2021. **(B)** Linear forecast for first and last authors. Abbreviations: CI, confidence interval.

Geographic distribution of female authors

Over 85% of the first and last authors had North American (44.9% and 46.1% respectively) and European affiliations (40.3% and 40.1%, respectively) (eFigure 1A in the Supplement). Regarding authorship on different continents, Oceania had the highest female first (46.2%) and last (25.5%) authors, whereas Asia had the lowest female first (27.6%) and last (15.2%) authors. Over the past decade, female first authors increased significantly in North America (*P= 0.002*) and Asia (*P= 0.028*); and female last authors increased significantly in North America (*P= 0.026*), Europe (*P= 0.004*), and Oceania (*P= 0.045*) (eFigure 2).

When all countries were analyzed together, the United States had the most first and last female author positions (38.1% and 39.5%) in terms of the number of publications, respectively (eFigure 3A). The Netherlands had the highest proportion of female first (52.5%) and last (27.6%) authors by country; and Japan had the lowest proportions (10.1% and 2.6% respectively) (eFigure 3B). Female first authors increased significantly over time in the United States (β=0.66, 95% CI 0.31-1.02%, *P= 0.003*), whereas female last authors increased significantly over time in several countries, including the United States, the Netherlands, Australia, Switzerland, and Denmark (eFigure 4).

Author gender distribution in different journals

In terms of journals, Thorax had the highest female first authors (44.9%), and NEJM had the lowest female first authors (27.3%). In contrast, NEJM had the highest female last authors (27.6%) and Journal of Heart and Lung Transplantation had the lowest female last authors (18.1%) (eFigure 5). Other than NEJM, all journals had a higher percentage of female first authors than female last authors.

Over time, female first authors increased significantly in the European Respiratory Review, Chest, and BMJ; and decreased significantly in Lancet Respiratory Medicine (β=-1.78, 95%CI -3.18 to -0.38%, *P= 0.019*). Female last authors increased significantly over time only in the Journal of Thoracic Oncology (β=1.12, 95%CI 0.71-1.54%, *P= 0.001*) (eFigure 6).

First and last author gender pairs

Of the included articles, 50.9% had males in the first and last author positions (male-male), followed by female-male (26.9%), male-female (12.2%), and female-female (10.0%). Over the past decade, female-female author pairs increased (*P= 0.001*), and between male-male author pairs decreased (*P< 0.001*) (eFigure 7).

High productivity authors

Among the 100 most prolific first and last authors in pulmonary medicine research during the study period, only 10 and 14 were women, respectively (eFigure 8).

Gender disparity in citations

Articles with women as first and last authors were cited less than those with men as first (25 [9-54] vs 29 [11-64] citations, *P< 0.001*) and last authors (24 [9-56] vs 28 [10-61] citations, *P< 0.001*) (eTable 1). In year-by-year data, this pattern was consistent each year from 2018 to 2021 for the articles with female first authors and in 2020 for articles with female last authors. Articles with females as both first and last authors were cited the fewest times (22 [7-49]) (eTable 2), whereas articles with males as first and last authors were cited most (29 [11-65]). Comparisons across the four pairs of first/last author genders were statistically significant (*P< 0.001*).

Multivariable analyses

When using the percentages of female authorship in 2012 as a reference, the odds of female first and last authorship increased overtime (Table 2). Moreover, compared to the female authorship in North America, the odds of being the first author were higher in Europe, Oceania, and South America, but lower for the last author in Europe. In Asia, the odds were lower for the first and last authorship. Furthermore, compared to female authorship in the European Respiratory Review, which had a percentage of female authors equal to the average of the 12 included journals, the odds of female first authorship were higher in Thorax, while Lancet Respiratory Medicine, JAMA, and NEJM had lower odds. For Journal of Heart and Lung Transplantation, the odds were lower for the first and last authorship.

Evaluation of female authorship in biomedical journals

The proportions of female authorship in different disciplines of clinical medicine varied (Table 3). Using the aggregated data published between 2012 and 2021 to generate the overall proportion of female authorship in different disciplines, the top three disciplines ranked by the percentages of female first authorship were nursing (83.0%), obstetrics and gynecology (60.3%), rheumatology (51.5%). Furthermore, the top three disciplines ranked by the female last authorship were nursing (72.0%), obstetrics and gynecology (41.7%), dermatology (35.6%). There were increasing proportions of female first and last authors in most disciplines, such as oncology, pediatric surgery, and anesthesiology (eFigs. 9 and 10).

Discussion

In this study, we found that the percentages of female first and last authors increased slightly between 2012 and 2021, especially a significant increase during the COVID-19 pandemic periods. Parity was foreseen in 2046 for the first authors and 2059 for the last authors. Articles with male-male pairs were cited more than articles with female-female pairs. Male-male pairs decreased significantly from 2012 to 2021, whereas female-female pairs increased significantly.

Our findings are consistent with several recent studies illustrating gender disparities in academic publications.[13,15-17] Our findings were not surprising considering the low number of female physicians in pulmonary medicine (12.3%) and critical care medicine (26.8%) in the United States, according to AAMC.[32] That said, the percentage of

Table 2 Multivariable analyses.

	Odds of female first authorship (95% CI)	*P*	Odds of female last authorship (95% CI)	*P*
Year				
2012	Reference		Reference	
2013	1.161 (1.001–1.346)	*0.048*	0.944 (0.790–1.128)	*0.525*
2014	1.150 (0.987–1.338)	*0.072*	1.145 (0.958–1.367)	*0.136*
2015	1.195 (1.028–1.390)	*0.021*	1.151 (0.964–1.374)	*0.119*
2016	1.212 (1.039–1.415)	*0.014*	1.093 (0.911–1.312)	*0.340*
2017	1.297 (1.110–1.515)	*0.001*	1.070 (0.890–1.287)	*0.474*
2018	1.179 (1.006–1.380)	*0.041*	1.188 (0.989–1.428)	*0.066*
2019	1.149 (0.981–1.346)	*0.086*	1.193 (0.993–1.433)	*0.059*
2020	1.333 (1.147–1.548)	*<0.001*	1.367 (1.150–1.625)	*<0.001*
2021	1.347 (1.165–1.559)	*<0.001*	1.403 (1.186–1.660)	*<0.001*
Article type				
Original research	Reference		Reference	
Review	0.903 (0.800–1.018)	*0.095*	0.927 (0.807–1.064)	*0.280*
Region				
North America	Reference		Reference	
Europe	1.115 (1.030–1.207)	*0.007*	0.891 (0.813–0.977)	*0.014*
Asia	0.650 (0.569–0.743)	*<0.001*	0.563 (0.475–0.667)	*<0.001*
Oceania	1.453 (1.222–1.726)	*<0.001*	1.060 (0.869–1.292)	*0.564*
South America	1.479 (1.060–2.064)	*0.021*	0.803 (0.520–1.242)	*0.325*
Africa	0.975 (0.659–1.442)	*0.897*	0.861 (0.544–1.363)	*0.523*
Journal				
European Respiratory Review	Reference		Reference	
Thorax	1.307 (1.050–1.627)	*0.017*	1.234 (0.959–1.588)	*0.102*
Chest	0.986 (0.801–1.213)	*0.890*	0.890 (0.699–1.133)	*0.346*
Journal of Heart and Lung Transplantation	0.748 (0.595–0.939)	*0.012*	0.716 (0.549–0.935)	*0.014*
Journal of Thoracic Oncology	1.058 (0.852–1.314)	*0.610*	0.973 (0.757–1.252)	*0.834*
ERJ	1.183 (0.961–1.457)	*0.113*	1.131 (0.889–1.439)	*0.318*
AJRCCM	0.969 (0.782–1.200)	*0.771*	0.896 (0.699–1.150)	*0.390*
Lancet Respiratory Medicine	0.629 (0.487–0.813)	*<0.001*	0.870 (0.649–1.164)	*0.348*
BMJ	0.958 (0.652–1.408)	*0.826*	1.145 (0.745–1.759)	*0.536*
JAMA	0.706 (0.501–0.993)	*0.046*	0.744 (0.499–1.109)	*0.146*
Lancet	0.783 (0.571–1.073)	*0.128*	1.061 (0.746–1.510)	*0.741*
NEJM	0.632 (0.461–0.865)	*0.004*	1.217 (0.871–1.701)	*0.249*

Abbreviations: CI, confidence interval; ERJ, European Respiratory Journal; AJRCCM, American Journal of Respiratory and Critical Care Medicine; BMJ, British medical journal; JAMA, Journal of the American Medical Association; NEJM, New England Journal of Medicine.

female first authors (37.0%) in our study is relatively high among all the medical specialties (Table 3).

In many specialties, including emergency medicine, internal medicine, and surgery, the COVID-19 pandemic reduced female researchers' productivity,[33,34] due to family responsibility, childcare needs,[33,35] and the lack of patients or research materials.[36] In contrast, we found a significant increase in publications with females as the first and last authors. This might be explained by the fact that pulmonary medicine was directly impacted by the COVID-19 pandemic. In general, the lack of childcare support and flexible working hours might explain the reduced output of female researchers.

In our study, the percentage of female first authors was nearly double that of female last authors and might be explained by the lack of female senior research mentors.[37] According to the 2021 AAMC report, the percentages of female faculty in the ranks of assistant professors and instructors is similar to that of male faculty (29% vs 29%),[32] while the percentages of female faculty in higher ranks (Associate and full Professors) is lower than that of male faculty (13% vs 26%).[32] Our study suggests that this disparity might eventually be resolved, but this will take 20-30 years at the current rate of change. However, efforts to promote female authorship, grant awards, and academic leadership positions might accelerate the process.[29] We also found a growth in female-female pairs and a decline in male-male pairs, which might be explained by the feminization of the workforce[38] and the increasing numbers of female senior researchers in the field.[39]

Table 3 Percentages of female first and last authors in publications from 2012 to 2021 and percentages of female physicians and faculty reported by AAMC.

Specialties	Percentage of Female First Authors From 2012 to 2021	Percentage of Female First Authors in 2019	Percentage of Female Last Authors From 2012 to 2021	Percentage of Female Last Authors in 2019	Percentage of Female Physicians in 2019 Reported by AAMC	Percentage of Female Faculty in 2021 Reported by AAMC
Nursing	83.0%	83.5%	72.0%	NR	NR	NR
Obstetrics and Gynecology	60.3%	NR	41.7%	NR	58.9%	67.3%
Rheumatology	51.5%	NR	35.3%	NR	46.3%	NR
Dermatology	50.6%	NR	35.6%	NR	51.0%	52.5%
Psychiatry	49.6%	49.5%	35.9%	35.7%	40.2%	55.6%
Family Medicine	49.3%	NR	42.3%	NR	41.3%	54.1%
Pediatrics	44.7%	54.4%	34.8%	37.7%	64.3%	60.3%
Stomatology	41.9%	44.7%	25.7%	NR	NR	NR
Ophthalmology	37.5%	41.3%	25.0%	28.6%	26.7%	41.7%
Pulmonary Disease[a]	**37.0%**	**36.2%**	**22.2%**	**23.0%**	**12.3%**	**NR**
Oncology	36.0%	34.7%	27.6%	30.1%	34.3%	NR
Gastroenterology	33.7%	31.7%	18.7%	19.3%	18.9%	NR
Internal Medicine	32.9%	34.3%	19.1%	16.2%	38.7%	41.9%
Otolaryngology	32.5%	36.4%	22.1%	24.6%	18.3%	36.5%
Critical Care Medicine	31.5%	32.6%	18.5%	21.4%	26.8%	NR
Radiology	30.6%	NR	19.8%	NR	NR	29.9%
Emergency Medicine	30.3%	30.2%	20.4%	22.7%	28.3%	38.5%
Anesthesiology	30.3%	40.6%	16.3%	17.6%	25.9%	37.0%
Cardiovascular Disease	28.0%	38.6%	15.8%	7.9%	14.9%	NR
Surgery Medicine	22.1%	26.9%	13.7%	15.4%	22.0%	27.7%
Neurology	20.3%	20.6%	12.2%	11.6%	30.9%	42.7%
Sports Medicine	17.5%	NR	NR	NR	27.2%	NR

Abbreviations: AAMC, Association of American Medical Colleges; NR, Not Reported; **a**, Data from Our Research Results.

Regarding citations of articles authored by females and males, we found articles with female first authors were cited fewer times than articles with male first authors within four years of publication. These findings agree with results from research by Chatterjee and Werner, who found that articles by women as primary authors had fewer citations within four years of publication.[29] Interestingly, we found that the difference in citations between female and male first authors was not significantly different after four years of publication. Compared to females, males tend to have more opportunities to present at conferences, participate in clinical practice guideline development, serve as content experts, and share their research findings,[40-43] which may result in more citations shortly after study publication.[27] In the long term, citations might be more dependent on the content and relevance of the publication, thus the citations become similar.

Finally, we found lower percentages of female first and last authors in Asian countries, in contrast to high percentages of female authors in European countries. In particular, we found that among the developed countries, the Netherlands has the highest percentages of female authorship in contrast to the lowest proportions in Japan, this finding agrees with research in critical care medicine[44] and transplantation research.[45] The discrepancy between Asian and European countries might be explained by differences in cultural expectations and roles/responsibilities of women in society and family,[45] the overall lack of research training/opportunities, and the lack of female mentors and academic leaders in educational institutions.[14,44,46] Likewise, the only two journals that exceeded the average percentage of overall female first authorship among the 12 journals were Thorax and ERJ, which both belonged to European scientific/medical societies, and both societies made rules or policies on female representations and participation,[47,48] with an endeavor to achieve gender equality. To what extent these rules or policies contribute to female authorship remains unclear. Recently, Chest journal starts to collect authors' gender during manuscript submission and whether these data help improve gender equality requires more investigation.

Our findings suggest that female researchers should have the same opportunities to disseminate the findings of their research as their male counterparts. Solutions may include increasing mentorship and sponsorship opportunities, encouraging and inviting women to pursue formal research training, and for senior investigators to invite early-career women onto their teams. Further studies are needed to identify factors that influenced our findings.

Strengths of our study include the large sample size and comprehensive analyses of gender distribution in different geographic areas, journals, trends over time, collaborations between first and last author genders, and article citations in high-impact journals of pulmonary medicine. Notably, the journal impact factor is just one measure of scientific output as highlighted and advocated by the Declaration on Research Assessment (DORA), thus high-impact journals included in this study might not represent their true academic reputation and scientific influence. Additionally, we conducted a thorough literature search and performed an evaluation of female authorship. This study also has limitations. First, we only included original research and review articles published by pulmonary medicine journals with the highest impact factors, thus our findings may not be generalizable to all journals in academic medicine. Second, gender was determined by an online web tool, which may have resulted in misclassification, even though genders that were assigned with a low probability of accuracy were manually evaluated. Third, there was a risk of misclassifying publication types. Fourth, single-author articles were excluded. Lastly, the exact number of female researchers (the denominator) in academic pulmonary medicine worldwide is unknown.

Conclusion

In conclusion, this study demonstrates a significant difference between female and male authorship in medical journals pertaining to pulmonary medicine. These findings appear to differ between countries and continents, suggesting that some regions and academic environments might be more supportive of female researchers. We suggest that efforts be made by academic institutions globally to ensure equal opportunities for any individual pursuing research.

Author contributions

JL and BD designed this project. YR and FG conducted the screening and data extraction for the study of academic literature in pulmonary medicine, while YR and HJH performed literature search, screening, and data extraction for the evaluation. FG performed the data analysis. BD participated in the resolution of discrepancies on data extraction. FG and YR had full access to the data and verified the data. JBS, SLS, and SM interpreted the data and provided critical edits and comments on the manuscript. JL, BD, YR, FG, and HJH attended bi-monthly web meetings. JL drafted the manuscript, all authors reviewed the manuscript for important intellectual content, and approved the final manuscript. FG, YR, HJH, and BD equally contributed to the overall project described in this article. JL was responsible for the decision to submit the manuscript.

Funding/support

This study did not receive any funding support.

Data Sharing Statement

Data will be available immediately after article publication to researchers who provide a proposal for any purpose of analysis.

Conflict of Interest

JL discloses research funding from Fisher & Paykel Healthcare Ltd, Aerogen Ltd, and Rice Foundation, and speaker fees from American Association for Respiratory Care, Aerogen Ltd, Heyer Ltd, and Fisher & Paykel Healthcare Ltd. JL also serves as section editor for *Respiratory Care*. JBS

discloses research funding from Teleflex and speaker fees from Aerogen and Medline Industries, LP.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.pulmoe.2023.03.005.

References

1. Hauw-Berlemont C, Aubron C, Aissaoui N, et al. Perceived inequity, professional and personal fulfillment by women intensivists in France. Ann Intensive Care. 2021;11(1):72 https://doi.org/10.1186/s13613-021-00860-2.
2. Merman E, Pincus D, Bell C, et al. Differences in clinical practice guideline authorship by gender. Lancet. 2018;392 (10158):1626—8. https://doi.org/10.1016/S0140-6736(18)32268-2.
3. Amrein K, Langmann A, Fahrleitner-Pammer A, Pieber TR. Zollner-Schwetz I. Women underrepresented on editorial boards of 60 major medical journals. Gend Med. 2011;8(6):378—87. https://doi.org/10.1016/j.genm.2011.10.007.
4. Ehrlich H, Nguyen J, Sutherland M, et al. Gender distribution among surgical journals' editorial boards: Empowering women surgeon scientists. Surgery. 2021;169(6):1346—51. https://doi.org/10.1016/j.surg.2020.12.026.
5. Subramaniam M, Azad N, Wasan SK, Long MT. Equal opportunity: women representation on editorial boards and authorship of editorials in gastroenterology and hepatology journals. Am J Gastroenterol. 2021;116(3):613—6. https://doi.org/10.14309/ajg.0000000000001183.
6. Mehta S, Burns KEA, Machado FR, et al. Gender parity in critical care medicine. Am J Respir Crit Care Med. 2017;196(4):425—9. https://doi.org/10.1164/rccm.201701-0076CP.
7. Dijksterhuis WPM, Stroes CI, Tan WL, et al. From presentation to paper: gender disparities in oncological research. Int J Cancer. 2020;146(11):3011—21. https://doi.org/10.1002/ijc.32660.
8. van den Besselaar P, Sandström U. Vicious circles of gender bias, lower positions, and lower performance: gender differences in scholarly productivity and impact. PLoS One. 2017;12(8): e0183301. https://doi.org/10.1371/journal.pone.0183301. Published 2017 Aug 25.
9. Bagga E, Stewart S, Gamble GD, Hill J, Grey A, Dalbeth N. Representation of women as authors of rheumatology research articles. Arthritis Rheumatol. 2021;73(1):162—7. https://doi.org/10.1002/art.41490.
10. Geagea A, Mehta S. Advancing women in academic medicine: ten strategies to use every day. Can J Anaesth. 2020;67 (1):9—12. https://doi.org/10.1007/s12630-019-01447-z.
11. Luc JGY, Vervoort D, Percy E, et al. Trends in female authorship: a bibliometric analysis of the annals of thoracic surgery. Ann Thorac Surg. 2021;111(4):1387—93. https://doi.org/10.1016/j.athoracsur.2020.06.031.
12. Asghar M, Usman MS, Aibani R, et al. Sex differences in authorship of academic cardiology literature over the last 2 decades. J Am Coll Cardiol. 2018;72(6):681—5. https://doi.org/10.1016/j.jacc.2018.05.047.
13. Leung KK, Jawaid N, Bollegala N. Gender differences in gastroenterology and hepatology authorship and editorial boards. Gastrointest Endosc. 2021;94(4):713—23. https://doi.org/10.1016/j.gie.2021.05.019.
14. Vranas KC, Ouyang D, Lin AL, et al. Gender differences in authorship of critical care literature. Am J Respir Crit Care Med. 2020;201(7):840—7. https://doi.org/10.1164/rccm.201910-1957OC.
15. Jacobs SA, Van Loveren K, Gottlieb D, et al. Examining the gender gap in emergency medicine research publications. Ann Emerg Med. 2022;79(2):187—95. https://doi.org/10.1016/j.annemergmed.2021.08.008.
16. Prunty M, Rhodes S, Sun H, et al. Redefining the gender gap in urology authorship: an 18-year publication analysis. Eur Urol Focus. 2022;8(5):1512—9. https://doi.org/10.1016/j.euf.2021.12.001.
17. Lasnon C, Girault G, Lebtahi R, Ansquer C, Lequesne J, Quak E. Female authors in nuclear medicine journals: a survey from 2014 to 2020. J Nucl Med. 2022;63(7):995—1000. https://doi.org/10.2967/jnumed.121.262773.
18. Feral-Pierssens AL, Avondo A, Stefano C, Deltour S, Lapostolle F. Gender equity in medical publications: nurses have smashed the glass ceiling. Eur J Cardiovasc Nurs. 2021;20(7):657—9. https://doi.org/10.1093/eurjcn/zvab025.
19. Metheny WP, Jagadish M, Heidel RE. A 15-year study of trends in authorship by gender in two U.S. obstetrics and gynecology journals. Obstet Gynecol. 2018;131(4):696—9. https://doi.org/10.1097/AOG.0000000000002539.
20. Laughter MR, Yemc MG, Presley CL, et al. Gender representation in the authorship of dermatology publications. J Am Acad Dermatol. 2022;86(3):698—700. https://doi.org/10.1016/j.jaad.2021.03.019.
21. Bernard C, Pommier R, Vilgrain V, Ronot M. Gender gap in articles published in European radiology and cardiovascular and interventional radiology: evolution between 2002 and 2016. Eur Radiol. 2020;30(2):1011—9. https://doi.org/10.1007/s00330-019-06390-7.
22. Farooq A, Sahara K, Muneeb A, et al. Analysis of authorship in hepatopancreaticobiliary surgery: women remain underrepresented. J Gastrointest Surg. 2020;24(9):2070—6. https://doi.org/10.1007/s11605-019-04340-8.
23. Pastor-Cabeza M, Torné R, García-Armengol R, et al. Women's role in neurosurgical research: is the gender gap improving? Neurosurg Focus. 2021;50(3):E6. https://doi.org/10.3171/2020.12.FOCUS20911.
24. Mehta S, Ahluwalia N, Heybati K, et al. Diversity of authors of publications from the canadian critical care trials group. Crit Care Med. 2022;50(4):535—42. https://doi.org/10.1097/CCM.0000000000005284.
25. Han JE, Burns KEA, Dodek PM, Mehta S. Improving diversity in activities of critical care societies: missed opportunities due to missing data. Chest. 2021;159(4):1334—7. https://doi.org/10.1016/j.chest.2020.12.006.
26. Molwitz I, Yamamura J, Ozga AK, et al. Gender trends in authorships and publication impact in Academic Radiology-a 10-year perspective. Eur Radiol. 2021;31(12):8887—96. https://doi.org/10.1007/s00330-021-07928-4.
27. Karri J, Navarro SM, Duong A, Tang T, Abd-Elsayed A. Exploration of gender-specific authorship disparities in the pain medicine literature [published online ahead of print, 2019 Nov 2]. Reg Anesth Pain Med. 2019. https://doi.org/10.1136/rapm-2019-100806. rapm-2019-100806.
28. Bendels MHK, Dietz MC, Brüggmann D, Oremek GM, Schöffel N, Groneberg DA. Gender disparities in high-quality dermatology research: a descriptive bibliometric study on scientific authorships. BMJ Open. 2018;8(4):e020089. https://doi.org/10.1136/bmjopen-2017-020089.
29. Chatterjee P, Werner RM. Gender disparity in citations in high-impact journal articles [published correction appears in JAMA Netw Open. 2021 Aug 2;4(8):e2127739]. JAMA Netw Open. 2021;4(7):e2114509. https://doi.org/10.1001/jamanetworkopen.2021.14509.

30. Yalamanchali A, Zhang ES, Jagsi R. Trends in female authorship in major journals of 3 oncology disciplines, 2002-2018. JAMA Netw Open. 2021;4(4):e212252. https://doi.org/10.1001/jamanetworkopen.2021.2252.
31. Sebo P. Performance of gender detection tools: a comparative study of name-to-gender inference services [published correction appears in J Med Libr Assoc. 2022 Apr 1;110(2):E32]. J Med Libr Assoc. 2021;109(3):414—21. https://doi.org/10.5195/jmla.2021.1185.
32. 2021 U.S. Medical School Faculty. AAMC. Accessed June 9, 2022. https://www.aamc.org/data-reports/faculty-institutions/interactive-data/data-reports/faculty-institutions/interactive-data/2021-us-medical-school-faculty.
33. Kibbe MR. Consequences of the COVID-19 pandemic on manuscript submissions by women. JAMA Surg. 2020;155(9):803—4. https://doi.org/10.1001/jamasurg.2020.3917.
34. Andersen JP, Nielsen MW, Simone NL, Lewiss RE, Jagsi R. COVID-19 medical papers have fewer women first authors than expected. Elife. 2020;9:e58807 https://doi.org/10.7554/eLife.58807.
35. Zamarro G, Prados MJ. Gender differences in couples' division of childcare, work and mental health during COVID-19. Rev Econ Househ. 2021;19(1):11—40. https://doi.org/10.1007/s11150-020-09534-7.
36. Rajan D, Koch K, Rohrer K, et al. Governance of the Covid-19 response: a call for more inclusive and transparent decision-making. BMJ Glob Health. 2020;5(5):e002655. https://doi.org/10.1136/bmjgh-2020-002655.
37. Gelardi F, Gozzi N. Women on board: mind the (gender) gap. Eur J Nucl Med Mol Imaging. 2021;48(10):3029—32. https://doi.org/10.1007/s00259-021-05465-2.
38. Frank E, Zhao Z, Sen S, Guille C. Gender disparities in work and parental status among early career physicians. JAMA Netw Open. 2019;2(8):e198340. https://doi.org/10.1001/jamanetworkopen.2019.8340.
39. Weigel KS, Kubik-Huch RA, Gebhard C. Women in radiology: why is the pipeline still leaking and how can we plug it? Acta Radiol. 2020;61(6):743—8. https://doi.org/10.1177/0284185119881723.
40. Files JA, Mayer AP, Ko MG, et al. Speaker introductions at internal medicine grand rounds: forms of address reveal gender bias. J Womens Health (Larchmt). 2017;26(5):413—9. https://doi.org/10.1089/jwh.2016.6044.
41. Fournier LE, Hopping GC, Zhu L, et al. Females are less likely invited speakers to the international stroke conference: time's up to address sex disparity. Stroke. 2020;51(2):674—8. https://doi.org/10.1161/STROKEAHA.119.027016.
42. Silver JK, Slocum CS, Bank AM, et al. Where are the women? The underrepresentation of women physicians among recognition award recipients from medical specialty societies. PM R. 2017;9(8):804—15. https://doi.org/10.1016/j.pmrj.2017.06.001.
43. Raviskanthan M, Rees M, Douglass J, Sleeman K, Higginson I, Smallwood N. Equal or not? Women hold less prestigious roles at respiratory medicine conferences than men. Eur Respir J. 2020;55(1):1900701. https://doi.org/10.1183/13993003.00701-2019.
44. Thomson CC, Riekert KA, Bates CK, et al. Addressing Gender Inequality in Our Disciplines: Report from the Association of Pulmonary, Critical Care, and Sleep Division Chiefs. Ann Am Thorac Soc. 2018;15(12):1382—90. https://doi.org/10.1513/AnnalsATS.201804-252AR\.
45. Benjamens S, Banning LBD, van den Berg TAJ, Pol RA. Gender disparities in authorships and citations in transplantation research. Transplant Direct. 2020;6(11):e614 https://doi.org/10.1097/TXD.0000000000001072.
46. Venkatesh B, Mehta S, Angus DC, et al. Women in Intensive Care study: a preliminary assessment of international data on female representation in the ICU physician workforce, leadership and academic positions. Crit Care. 2018;22(1):211 https://doi.org/10.1186/s13054-018-2139-1.
47. Gaga M, Stolz D, Chorostowska-Wynimko J, Welte T, Simonds A. Respiratory medicine is not gender blind. Eur Respir J. 2020;55(1):1901847. https://doi.org/10.1183/13993003.01847-2019.
48. BTS Policy on Inclusion, Diversity and Equality. British Thoracic Society. Accessed Mar 1, 2023. https://www.brit-thoracic.org.uk/about-us/bts-policy-on-inclusion-diversity-and-equality/.