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Women Authors in Nuclear Medicine Journals: a Survey from 2014 to 2020

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Abstract (350 < 350 words)

Despite the feminization of the medical workforce, women do not have the same career perspectives as men. In nuclear medicine, little information is available on the gender gap regarding prominent author positions of scientific articles. Therefore, the purpose of this study was to evaluate recent trends in the gender distribution of first and last authorship of articles published in nuclear medicine journals.

Methods

We conducted a bibliometric analysis of first and last author gender of articles published from 2014 to 2020 in 15 nuclear medicine journals. Manuscript title, article type, journal impact factor, date of publication, first and last name and country of provenance of first and last authors were noted. The Gender-API software was used to determine author gender. All statistics were descriptive.

Results

Women represented 32.8% of first authors and 19.6% of last ones. Female authorship increased from 28.2% (428 of 1518 articles) in 2014 to 35.5% (735 of 2069 articles, relative increase 72%) in 2020 ($p<0.001$) for first authors and from 15.6% (237 of 1518 articles) in 2014 to 20.5% (424 of 2069 articles, relative increase 79%) in 2020 ($p<0.001$) for last ones. Parity was forecasted in 2035 for first authors and in 2052 for last ones. Female authorship increased in Europe for first ($p=0.014$) and last authors ($p<0.001$), in high-ranking journals for first ($p=0.004$) and last authors ($p<0.001$) and in other journal ranks for last authors ($p=0.01$). Female first and last authorship rose for original articles ($p=0.02$ and $p=0.01$ respectively) and case reports ($p<0.001$ and $p=0.002$ respectively). Regarding collaborations, the proportion of articles produced by male first and last authors decreased from 62.2% in 2014 to 52.9% in 2020 in favor of female first and last authors (OR=1.07, $p<0.001$), male first and female last authors (OR =1.05, $p<0.001$) and female first and male last authors (OR=1.03, $p<0.001$).

Conclusion

Female first and last authorship in nuclear medicine journals increased substantially from 2014 to 2020, in particular in high-ranking journals, in Europe and for original articles and case reports. Male/male collaborations decreased by 10% in favor of all other collaborations. Parity can be foreseen in a few decades.

Introduction

Despite efforts to offset the tendency, gender gaps and prejudices broadly persist in modern-day society. Despite the feminization of the workforce in medicine, women do not have the same career perspectives or pay as men (*1*–*4*). In the field of medical imaging, the 'pipeline' to the top positions has been described as leaky for female talent, and leadership positions are predominantly held by men (*5*–*10*).

Regarding nuclear medicine, the literature on the gender gap and gender-related career challenges is scarce. A recent study reported the underrepresentation of women in academic and leadership positions compared to men in North America and Canada, despite equal academic performances (*11*). In Europe, a 2007 membership survey of the European Association of Nuclear Medicine showed that one-third of physicians were women, with an increasing percentage of women physicians over time and at a younger age (*12*). However, the gender distribution varied widely between countries, and the evolution of the gender gap in nuclear medicine over time and higher up the career ladder has received little attention.

As scientific publishing is a key factor for career advancement, trends in the gender distribution of prominent author positions may reflect future evolutions of women towards leadership positions. Therefore, the main objective of the current study was to evaluate recent trends in the gender distribution of the most prestigious author positions, i.e. first and last authorship, in articles published in Anglophone nuclear medicine journals from 2014 to 2020 by means of a descriptive bibliometric analysis.

Materials and Methods

This study was exempt from local institutional review board approval.

We performed a PubMed search for the years 2014 to 2020 to retrieve all articles published in the 15 purely Anglophone nuclear medicine journals in the Radiology, Nuclear Medicine & Medical Imaging

category of the Journal of Citation Reports (JCR) 2019: *Journal of Nuclear Medicine, European Journal of Nuclear Medicine and Molecular Imaging, Clinical Nuclear Medicine, Seminars in Nuclear Medicine, Journal of Nuclear Cardiology, Molecular Imaging and Biology, Molecular Imaging, EJNMMI Research, Annals of Nuclear Medicine, EJNMMI Physics, Nuclear Medicine and Biology, Contrast Media & Molecular Imaging, Quarterly Journal of Nuclear Medicine and Molecular Imaging, Nuclear Medicine Communications, and Hellenic Journal of Nuclear Medicine.* The bibliographic references of all articles were imported into the bibliographical data management software Endnote. An import filter was created to add the following PubMed bibliographic data to the usual bibliographic fields: publication date, first and last name of all authors, affiliation addresses, article type. This dataset was exported to Excel, and the following variables were recorded for each entry: manuscript title, publication year, first and last name of the first and last authors, article type, journal impact factor (IF) according to the JCR 2019, and country of provenance of first and last authors. The Gender-API software (Gender-API.com) was used to determine the gender of the first and last authors. Performance metrics of this software can be found elsewhere (*13*). Date of censoring for the year 2020 was February 24, 2021. Preprints of the year 2020 were excluded. In the event of missing data, entries were excluded, as were entries with a single author. The following article types were excluded: Published Erratum, Retracted Publication, News, Lecture, Historical Article, Biography, Portrait, Introductory Journal Article, and English Abstract.

The main aim of the study was to analyze the evolution of the percentages of female first and last authorship over the study period. Secondary aims were as follows: a) to forecast the year parity will be attained for first and last authors, b) to evaluate gender distributions according to continent, journal rank and article type, and c) to evaluate collaborations between genders. For the analysis of author gender according to provenance, countries were classified according to continent. For the analysis of author gender according to journal rank, references were classed as High Ranking (IF [7.887 – 6.622]) or Others (IF [3.544 – 0.982]). For the analysis of author gender according to article type, references were

categorized as original article, review, case report, and editorial/letter. References tagged solely as Journal Article by PubMed were categorized as original article.

Collaboration between first and last author gender was explored by classifying articles in the four following categories: male first and last authors, female first and male last authors, male first and female last authors, and female first and last authors.

All statistics were descriptive. Fisher's exact tests were used to analyze the distribution of female authorship from 2014 to 2020. Linear regression was used to forecast the year in which parity for first and last authorship will be reached. A multinomial logistic regression model was constructed to measure the evolution of the distribution of collaborations over time, in which male first and male last authorship was considered as the reference. Graphic and statistical analyses were performed on XLSTAT Software (XLSTAT 2007: Data Analysis and Statistical Solutions for Microsoft Excel, Addinsoft (2017)) and R Software (version 4.0.2). For all statistical tests, a two-tailed p value of less than 0.05 was considered as statistically significant.

Results

Data characteristics

A total of 15720 references were imported, of which 12450 (79.2%) fulfilled the article type criteria and presented complete data regarding first and last author gender and provenance. Data characteristics are presented in Table 1.

First authors

Overall, 4082 of 12450 (32.8%) first authors were female (Table 1). Female first authorship increased over time from 428 of 1518 (28.2%) in 2014 to 735 of 2069 (35.5%) in 2020 ($p < 0.001$) (Figure 1), representing a relative increase of 72% in 7 years (+307 articles). At this rate, parity was forecasted for the year 2035 (Figure 1). Conversely, male first authorship increased by 22% between 2014 and 2020 (+244 articles). Detailed absolute numbers of articles for each year between 2014 and 2020 for female and male first authors are depicted in Figure 2.

Regarding the geographical provenance of first authors, 12054 of 12450 (96.8%) articles came from three continents: Asia (3370 of 12450 (27.1%)), Europe (5699 of 12450 (45.8%)) and North America (2985 of 12450 (24.0%)). Data from Africa, Oceania and South America were insufficient to be included in the analysis and can be found in supplemental Figure 1. In Europe, female first authorship increased from 232 of 700 articles (33.1%) in 2014 to 385 of 910 articles (42.3%) in 2020 ($p = 0.014$). In Asia and North America, percentages of female first authorship per year did not significantly differ from 2014 to 2020 ($p = 0.06$ and $p = 0.15$ respectively) (Figure 3A).

Regarding journal rank, percentages of female first authorship in high-ranking journals increased from 240 of 847 articles (28.3%) in 2014 to 371 of 1015 articles (36.6%) in 2020 ($p = 0.004$). No changes were observed for the other journal ranks ($p = 0.11$) (Figure 3C).

Regarding article type, female first authorship increased for original articles, from 338 of 1116 articles (30.3%) in 2014 to 516 of 1428 articles (36.1%) in 2020 ($p = 0.03$), and for case reports, from 64 of 288 articles (22.2%) in 2014 to 153 of 389 articles (39.3%) in 2020 ($p < 0.001$). No change was observed for reviews and editorials/letters over time ($p = 0.08$ and 0.48 respectively). Female first authors were underrepresented in the category editorial/letters (Figure 3E).

Last authors

Overall, 2445 of 12450 (19.6%) last authors were female (Table 1). Female last authorship increased over time from 237 of 1518 (15.6%) in 2014 to 424 of 2069 (20.5%) in 2020, representing a relative increase of 79% (+187 articles), with a peak of 21.8% in 2017 ($p < 0.001$) (Figure 1). Parity was forecasted for the year 2052 (Figure 1). Conversely, male first authorship increased by 28% between 2014 and 2020 (+364 articles). Detailed absolute numbers of articles for each year between 2014 and 2020 for female and male last authors are depicted in Figure 2.

Regarding the geographical provenance of last authors, 12063 of 12450 (96.9%) articles again came from three continents: Asia (3290 of 12450 (26.4%)), Europe (5638 of 12450 (45.3%)) and North America (3135 of 12450 (25.2%)). Data from Africa, Oceania and South America can be found in supplemental Figure 1. In Europe, female last authorship increased from 126 of 693 articles (18.2%) in 2014 to 208 of 906 articles (23.0%) in 2020, with a peak of 25.5% in 2017 ($p <0.001$). In Asia and North America, percentages of female last authorship per year did not significantly differ from 2014 to 2020 ($p = 0.06$ and $p = 0.46$ respectively) (Figure 3B).

Regarding journal rank, female last authorship in high-ranking journals increased from 135 of 847 articles (15.9%) in 2014 to 211 of 1015 articles (20.8%) in 2020, with a peak of 24.6% in 2018 ($p < 0.001$), and in other-ranking journals from 102 of 671 articles (15.2%) in 2014 to 213 of 1054 (20.2%) ($p = 0.013$) (Figure 3D).

Regarding article type, female last authorship increased from 170 of 1116 articles (15.2%) in 2014 to 262 of 1428 articles (18.3%) in 2020 ($p = 0.01$) for original articles, and from 51 of 288 articles (17.7%) in 2014 to 104 of 389 articles (26.7%) in 2020 for case reports, with a peak of 29.7% in 2018 ($p = 0.002$). No change was observed for reviews and editorials/letters ($p = 0.10$ and 0.49 respectively) (Figure 3F).

Collaborations

Assuming a linear evolution of outcomes over the study period and the year as a continuous factor, we observed a decrease in the proportion of articles produced by male first and last authors in favor of female first and last authors (OR = 1.07, $p < 0.001$), male first and female last authors (OR = 1.05, $p < 0.001$) and female first and male last authors (OR = 1.03, $p < 0.001$). Indeed, 944 of 1518 articles (62.2%) were produced by male first and last authors in 2014, and 1094 of 2069 (52.9%) in 2020. On the other hand, there was an increase in the proportion of articles produced by female first and male last authors from 337 of 1518 articles (22.2%) in 2014 to 551 of 2069 (26.6%) in 2020, by female first and last authors from 91 of 1518 articles (6%) in 2014 to 184 of 2069 (8%) in 2020, and by male first and female last authors from 146 of 1518 articles (9.6%) in 2014 to 240 of 2069 (11.6%) in 2020 (Figure 4).

Discussion

There was a marked gender gap in first and particularly last authorship of articles published in nuclear medicine journals from 2014 to 2020. Women's representation increased over time from 28.2% to 35.5% ($p < 0.001$) for first authors and from 15.6% to 20.5% for last ones, with a peak of 21.8% in 2017 ($p < 0.001$). Relative increases of 72% and 79% for female first and last authorship respectively were observed between 2014 and 2020. Parity was predicted in the year 2035 for first authors and in 2052 for last ones. A significant increase in female first and last authorship was observed in Europe and for publications in high-ranking journals. Female participation increased in original articles and case reports but not in reviews or editorials/letters. The proportion of articles produced by male first and last authors decreased by 10% in favor of all other collaborations.

To our knowledge, this is the first exhaustive bibliometric analysis of author gender in a wide spectrum of

Anglophone nuclear medicine journals over several years. Similar gender gaps in authorship have been reported in other domains of medicine and the STEM (Science, Technology, Engineering, Mathematics) sciences (*4*,*14*,*15*). For example, Bendels et al recently reported 33.1% female first and 18.1% female last authorship in high-quality research in 54 journals listed in the Nature Index in the categories Life Science, Multidisciplinary, Earth & Environmental and Chemistry (*4*).

The lower percentage and rate of increase in female last authorship, a senior position, compared to female first authorship found in our study seem to confirm the presence of an invisible barrier for women to attain leadership positions: the so-called glass ceiling. Moreover, female last authorship increased from 2014 to 2017 but plateaued from 2017 to 2020. These findings could fuel the discussion recently launched by three European women nuclear medicine physicians about the challenges women currently face in this field dominated by men (*16*) and the steps that should be taken to allow female talent to achieve its full potential. Scientific societies, journal editors and publishing companies, scientific institutions, industry, funding agencies and governments all have their role to play in the promotion of female scientific careers and the creation of a diverse and inclusive research environment. As an example, Gelardi et al. and Evangelista et al. have recently highlighted the underrepresentation of women on editorial boards of nuclear medicine journals, regardless of the rank within the board or the geographical provenance of the journal (*17*,*18*). Female participation varied from 14% to maximum 32%. As our study shows that one in three first authors in nuclear medicine is female, female participation in all ranks of editorial boards should at least mirror this proportion.

Strategies could be put in place in all the aforementioned bodies to promote parity, such as providing transparency on women's representation metrics, training on the benefits of diversity in healthcare and even proposing gender quota just as in politics. Obviously, those propositions are not miracle solutions for equality, but they are tools with potentially strong symbolic effects. It is worth to mention here some successes. The Athena SWAN Charter and Horizon Europe within the European Research Area are

examples of initiatives aiming to overcome persisting gender gaps (*19*,*20*). Also, within nuclear medicine societies, several initiatives now exist such as the EANM Women's Empowerment or the SNMMI Women in Nuclear Medicine aiming to promote female networks and careers (*21*,*22*).

Female authors were equally represented among the journal ranks, and their participation increased for both high-ranking and other-ranking journals, suggesting that a possible gender bias during peer-review did not result in an unbalanced representation of women across the journal ranks. However, although female participation increased for original articles and case reports, it did not change for reviews and editorials/letters. Furthermore, female first authors were underrepresented for editorials/letters. The productivity puzzle is composed of many intricate pieces and explanations for our findings are probably multifactorial. Gendered differences in time management and publication patterns, thereby taking into account the "cost-benefit ratio" of different article types, maybe partly explain the unchanged female participation in reviews in favor of an increased female participation in original articles. Reviews are time-consuming to write but have less academic value than original articles in the same journal type. The potential gain in visibility by publishing a review might thus not be worth the investment when time is limited. When it comes to case reports female participation was large and increased, although the academic value of this article type is low. Should we consider this as a symptom of lower consideration by team leaders rather than a scientific achievement? Another explanation for our findings might be the invitation that can be required to write certain article types (*8*,*19*). A case-control study of gender disparities in invited commentaries showed that women had a 21% lower odds of receiving such an invitation than men despite having similar experience, and that this disparity was greater for senior researchers (*22*).

An almost 10% decrease in the proportion of articles with a male first and last author was observed, in favor of all other collaborations. This might be due to the feminization of the workforce and/or an

increased will of senior male team members to collaborate with female team members. Overall, the increasing tendency for collaboration with female first and last authors is encouraging.

This study has some principal limitations: the use of a software application to assign gender, the relatively short study period from 2014 to 2020 due to the absence of last author provenance on PubMed before 2014, insufficient data for three of the six continents, the absence of nuclear medicine publications outside the 15 journals analyzed, and the absence of professional or demographic data on the workforce worldwide, which prevented subgroup analyses or comparisons. Furthermore, there are no available data thus far on factors that impact career choices and evolutions in nuclear medicine. Nor are there any data on gender inequity in the nuclear medicine workforce, such as measures of unconscious bias, sexual/racial harassment, and the gendered division of domestic labor impacting scientific productivity. National and international nuclear medicine associations could follow in the footsteps of the European Society for Medical Oncology by conducting a survey in male and female workers on gender-related challenges (*21*). Lastly, the year 2020 was marked by lockdowns due to the COVID-19 pandemic. However, a preliminary analysis showed no alterations in the quantity of publications in medical imaging by women authors during this period (*26*).

In conclusion, although the scientific production in nuclear medicine is no exception to gender inequity, the absolute numbers and proportions of female-authored publications substantially increased from 2014 to 2020, thereby narrowing the gender gap. Parity can be foreseen in a few decades.

Key points

Question

What are recent trends in gender distribution of first and last authorship of articles published in nuclear medicine journals?

Pertinent findings

Although the scientific production in nuclear medicine is no exception to gender inequity, our bibliometric study showed a substantial increase in female first and last authorship of articles published in nuclear medicine journals. We observed a wider gender gap for last than for first authorship. While the gender gap in the authorship of original articles and case reports has narrowed over time, particularly in Europe, parity is still a few decades away.

Implications for patient care

Diversity, equity and inclusion can drive innovation and improve the quality of care for our diverse patient population.

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Declarations

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Conflicts of interest: None related to the submitted work. Conflicts of interest outside the submitted work: RL Advanced Accelerator Applications, Ipsen, Sirtex, Boston Scientific. CA Advanced Accelerator Applications, Novartis, Ipsen, Eisai. EQ Advanced Accelerator Applications.

Availability of data and material: The dataset analyzed in the current report was the result of a free PubMed search and the use of the Gender-API software. The dataset is available from the corresponding author on reasonable request and after signature of a data access agreement.

Code Availability: Not applicable

Authors' contributions: Study concept and design, CL, JL, EQ; Data acquisition and data analysis/interpretation, all authors; Manuscript drafting or revision for important intellectual content, all authors; Statistical analysis, CL, JL, EQ; Guarantors of integrity of the entire study, all authors; Approval of final version of submitted manuscript, all authors.

Ethics approval: Not applicable

Consent to participate: Not applicable

Consent for publication: Not applicable

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Variable	
Number of publications, n	12450
Year, n (%)	
2014	1518 (12.2)
2015	1594 (12.8)
2016	1783 (14.3)
2017	1869 (15)
2018	1660 (13.3)
2019	1957 (15.7)
2020	2069 (16.6)
First-author gender, n (%)	
Female	4082 (32.8)
Male	8368 (67.2)
First-author continent, n (%)	
Africa	64 (0.5)
Asia	3370 (27.1)
Europe	5699 (45.8)
North America	2985 (24.0)
Oceania	211 (1.7)
South America	121 (1.0)
Last-author gender, n (%)	
Female	2445 (19.6)
Male	10005 (80.4)
Last-author continent, n (%)	
Africa	62 (0.5)
Asia	3290 (26.4)
Europe	5638 (45.3)
North America	3135 (25.2)
Oceania	217 (1.7)
South America	108 (0.9)
Journal rank, n (%)	
High-ranking	6205 (49.8)
Others	6245 (50.2)
Article type, n (%)	
Original article	8612 (69.2)
Review	1017 (8.2)
Case report	2394 (19.2)
Editorials / Letters	427 (3.4)

Table 1. Data characteristics. Journals ranked according to impact factor: High-Ranking (IF [7.887 – 6.622]) or Others (IF [3.544 – 0.982]).

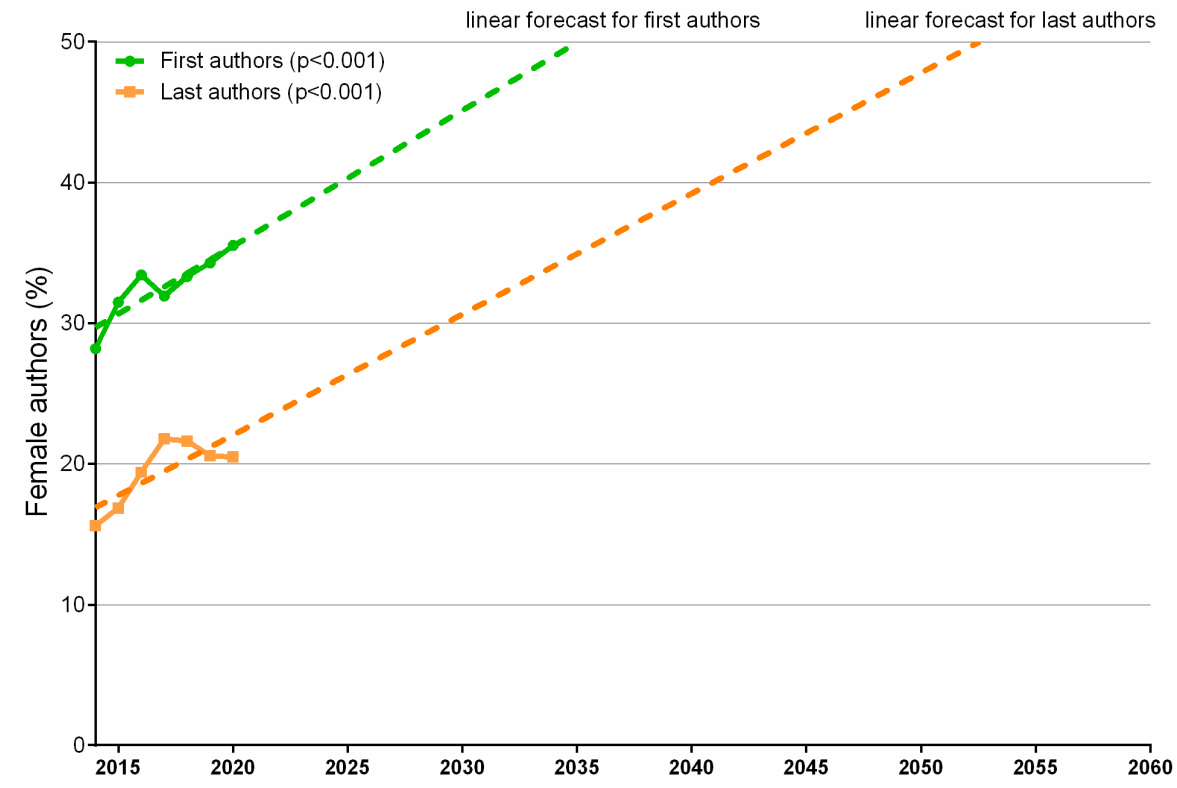


Figure 1. Female authorship increased from 28.2% in 2014 to 35.5% in 2020 (p<0.001) for first authors and from 15.6% in 2014 to 20.5% in 2020 (p<0.001) for last ones. For female last authors, a peak of 21.8% was observed in 2017. Linear forecasts show that at the current rate, parity for first authors is predicted in 2035 and for last authors in 2052.

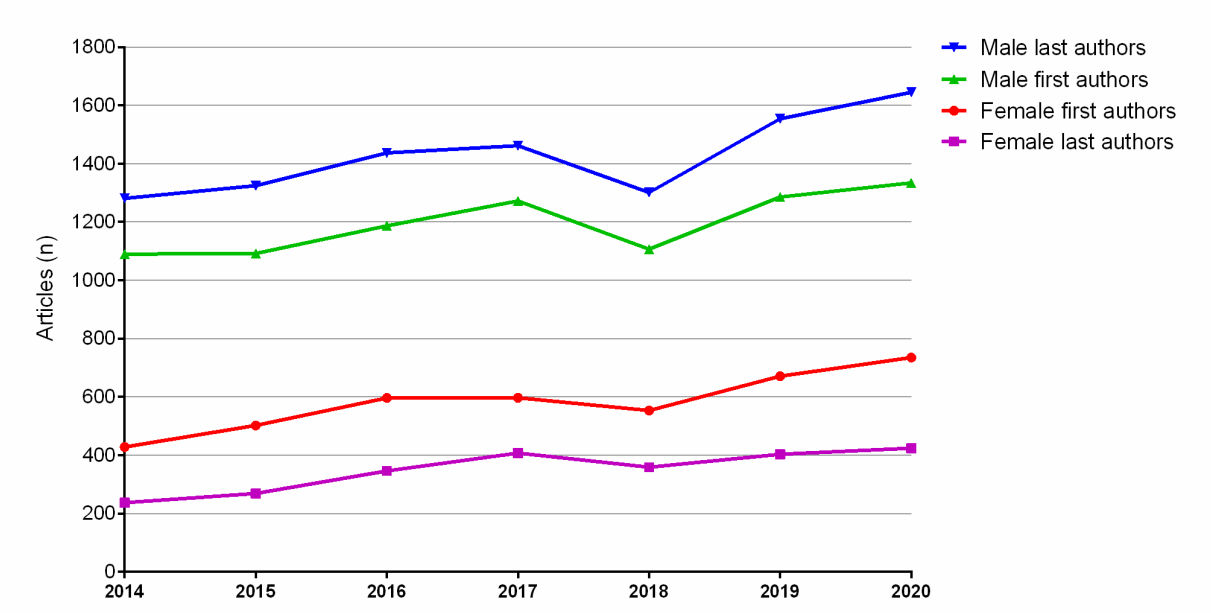


Figure 2. Absolute numbers of articles for female and male first and last authors from 2014 to 2020. Articles by female first authors increased from 428 of 1518 in 2014 to 735 of 2069 in 2020, while articles by male first authors increased from 1090 of 1518 in 2014 to 1334 of 2069 in 2020. Articles by female last authors increased from 237 of 1518 in 2014 to 424 of 2069 in 2020, while articles by male last authors increased from 1281 of 1518 in 2014 to 1645 of 2069 in 2020.

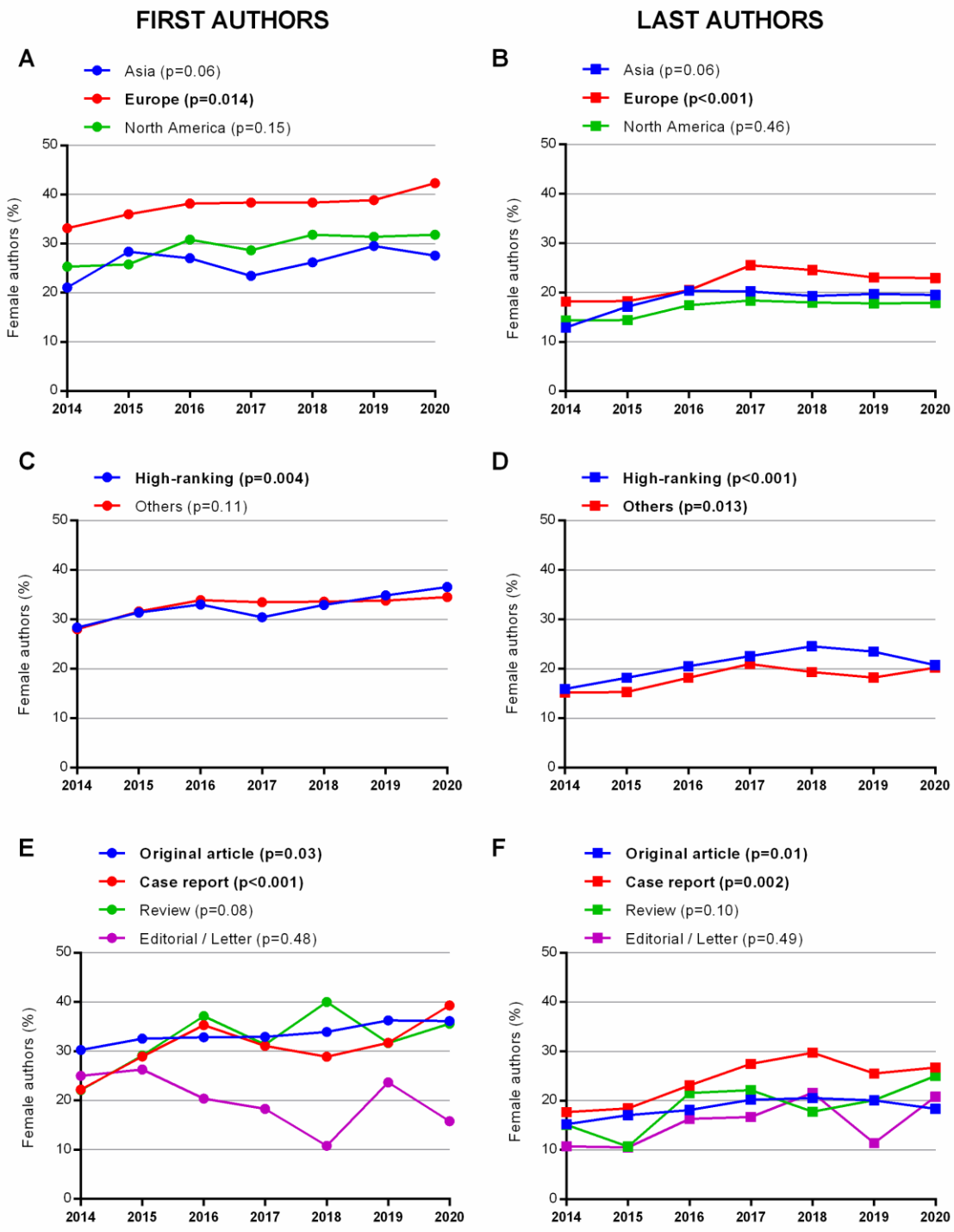

FIRST AUTHORS
LAST AUTHORS
A
Asia (p=0.06)
Europe (p=0.014)
North America (p=0.15)
B
Asia (p=0.06)
Europe (p<0.001)
North America (p=0.46)
C
High-ranking (p=0.004)
Others (p=0.11)
D
High-ranking (p<0.001)
Others (p=0.013)
E
Original article (p=0.03)
Case report (p<0.001)
Review (p=0.08)
Editorial / Letter (p=0.48)
F
Original article (p=0.01)
Case report (p=0.002)
Review (p=0.10)
Editorial / Letter (p=0.49)
Female authors (%)
0
10
20
30
40
50
2014
2015
2016
2017
2018
2019
2020

Figure 3. Graphs on left show percentage of female first authorship from 2014 to 2020 according to continent of provenance (A), journal rank (C) and article type (E). Graphs on right show percentage of female last authorship from 2014 to 2020 according to continent of provenance (B), journal rank (D) and article type (F). Bold values are statistically significant. Journals were ranked according to impact factor: High-Ranking (IF [7.887 – 6.622]) or Others (IF [3.544 – 0.982]).

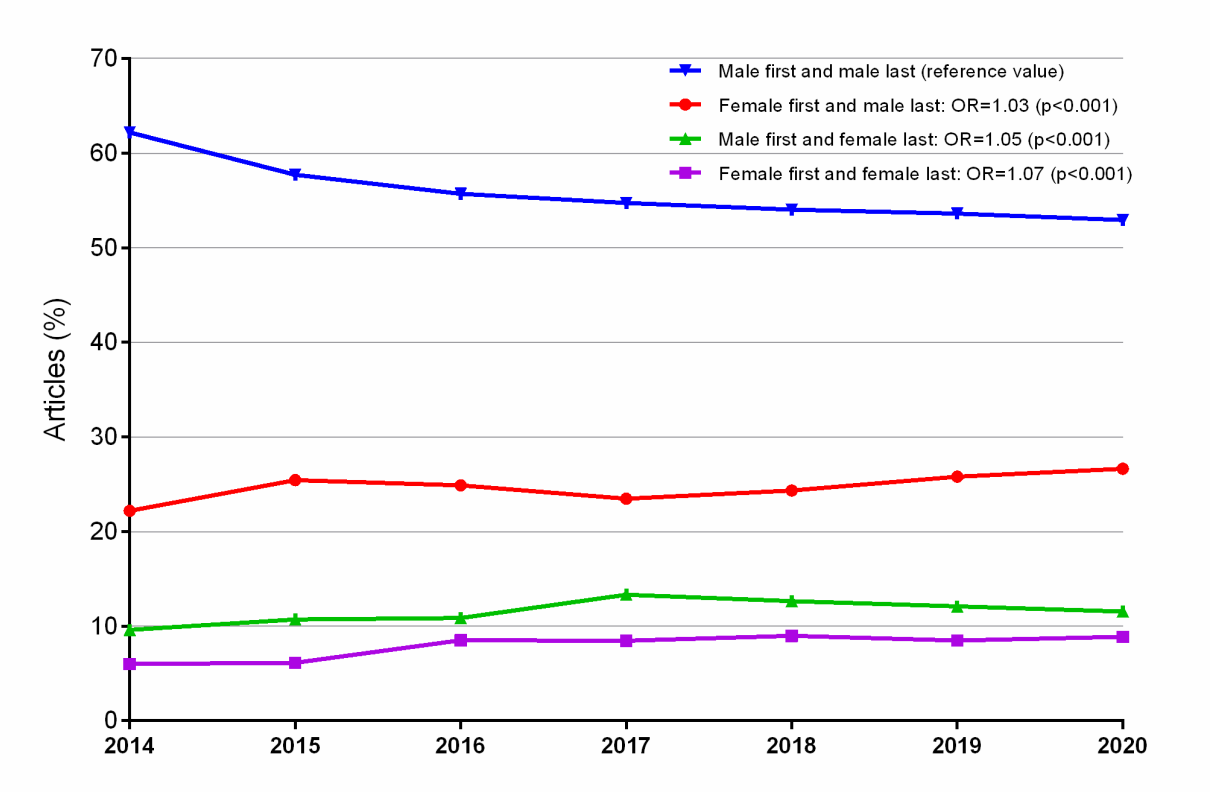
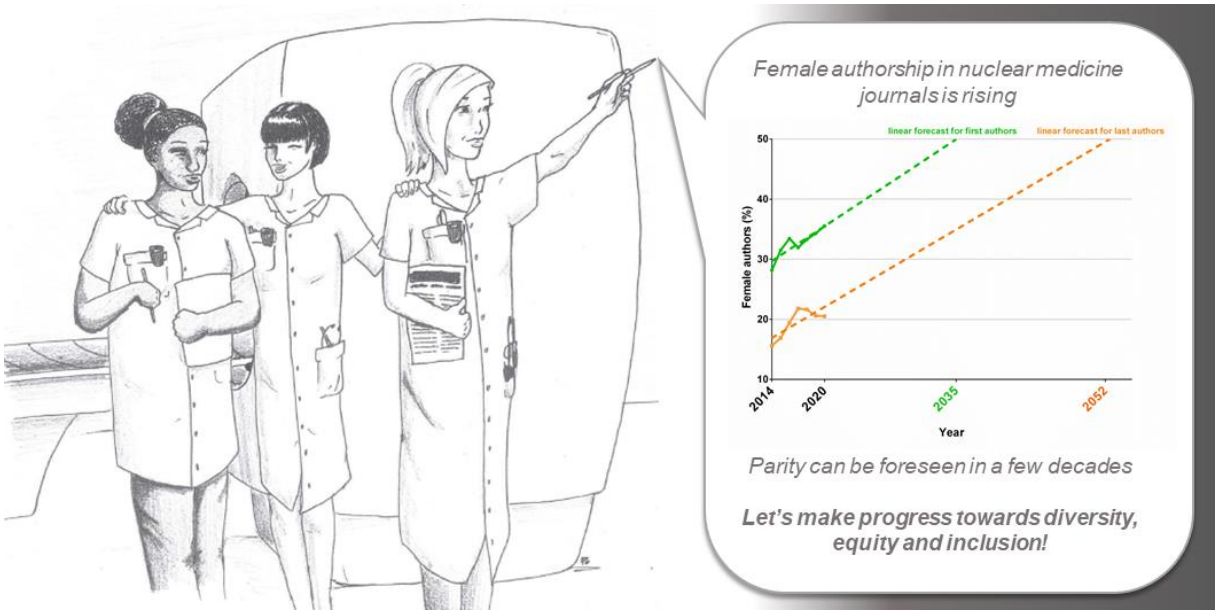
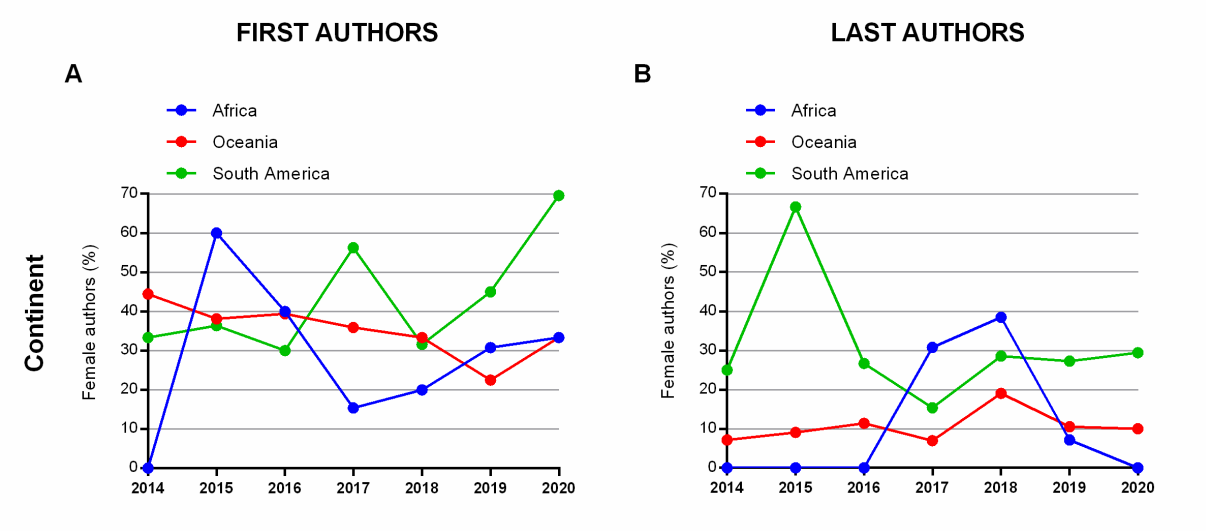


Figure 4. Percentage of collaboration between male and female first and last authors for articles published from 2014 to 2020. Male/male collaboration declined over time from 62.2% in 2014 to 52.9% in 2020 in favor of all other collaboration types.



Graphical Abstract



Supplemental Figure 1. Percentage of female first (A) and last (B) authorship from 2014 to 2020 for Africa, Oceania and South America.