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Gender authorship trends in spine research publications - Research across different countries from 1976 to 2020

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1. Introduction

During the last five decades, women's participation in medicine has increased dramatically. In 2020, women accounted for 53.6% of all matriculating medical students (Association of American Medical Colleges, 2020) compared to 9.3% in 1965 in the United States (U.S.) (Jolliff et al., 2011). Similar numbers were also noted in Europe; for example, in the UK, women made up 57.1% of all medical students in 2018 (General Medical Council, 2020). However, the percentage of female residents in the spine-related fields of orthopedics and neurosurgery remains particularly low, with 16% and 19.5%, respectively (AAMC. ACGME, 2019). This disparity is even more evident in practicing physicians; while 36.3% of practicing physicians are women, the proportion of practicing female orthopedic- and neurosurgeons is only 5.8% and 9.3%, respectively (Association of American Medical Colleges, 2019).

The gender disparity has also been confirmed in the authorship of academic articles; however, women continue to comprise a small minority of physicians who publish in medical journals, particularly in surgical fields (Kim et al., 2019; Wininger et al., 2017; Nkenke et al., 2015; Silvestre et al., 2016). Publications in medical journals are an important way to assess academic productivity. It is also imperative to gain promotions in the educational field and an important method through which the academic medical community communicates. Studies have shown that high research productivity is an important factor in securing a residency position in the U.S. (Schrock et al., 2016). As a result, there is an increased pressure for both practicing and trainee physicians to publish. In addition, the increased focus on publication participation has led to a growing interest in the investigation of authorship-trends in the specialty-specific medical literature.

This study aims to provide an up-to-date overview of these current developments. Therefore, we analyzed authorship trends in four prominent spine-related journals over the past five decades and examined the apparent differences between countries and regions.

2. Materials and methods

2.1. Data collection

We performed a bibliometric analysis of four peer-reviewed spine research journals (*European Spine Journal [Impact factor: 3.3], Journal of Neurosurgery: Spine [Impact factor: 3.5], Spine [Impact factor: 4.3], The Spine Journal [Impact factor: 4.3]*) from 1976 to 2020. Ten-year increments were chosen since this method has been used by most previous studies evaluating authorship trends in different specialties (Brinker et al., 2018; Jagsi et al., 2006). As our research was completed in 2021, data from 2020 was added and analyzed to present the most up-to-date data.

All primary research articles (original research articles, clinical trials, systematic and non-systematic reviews, case reports) from selected years were included for data collection. Other articles, such as letters, editorials, announcements, memorandums, authors' comments, and other short reports (such as "Images of Spine Care" in *The Spine Journal*) were excluded from the analysis. The author's first name, the author's position, and affiliation - including the country and region – of both the first and senior author were noted from the selected articles. For the authors based in the U.S., the state was recorded as well. For the data in 2020, the author's academic title was also noted.

The author's gender was detected by inspecting his or her first name. If a first name review could not determine an author's gender, the gender was identified using a "Baby Name Guesser" website (www.gpeters.com/names/baby-names.php). This approach has been used previously (Wininger et al., 2017; Gu et al., 2017; Lehman et al., 2017). The program indicates a gender ratio whereby a ratio of 3.0 or higher was

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Abbreviations:

GGGI	Global Gender Gap Index
MD/DO	Doctor of Medicine/Doctor of Osteopathic Medicine
Ph.D.	Doctor of Philosophy
U.S.	United States

considered a correct identification of gender. If a ratio of <3.0 was found, the entry was excluded from gender analyses. However, regarding the most up-to-date data in 2020, we performed extensive research using Google search and 'researchers' networks like researchgate.com, consulting the author's affiliated institution and contacting them directly via email. The author's academic titles, if listed, were classified into three categories: Doctor of Medicine/Doctor of Osteopathic Medicine (MD/DO), others (such as Doctor of Philosophy [Ph.D.]), and none.

Moreover, we have also included data from the Global Gender Gap Index (GGGI), which measures gender gaps in access to resources and opportunities. The GGGI is an annual analysis published by the World Economic Forum (Global Gender Gap Report, 2020, 20202020). We also added data for female physicians (data.oecd.org, 2020; Xiong, Chen, Zhao, et al.), neurosurgeons (Steklacova et al., 2017; Fujimaki et al., 2016; Jung et al., 2019; Olson et al., 2021; Drummond et al., 2021; Dossani et al., 2020), and orthopedic surgeons (Diversity in orthopaedics and traumatology, 2020) as a percentage for each country analyzed.

For further analyses, contributing countries and states were grouped into regions: All states from the U.S. and Canada were designated as North America. Mexico, along with Central and South America, was set as Latin America. Asia was defined as all Asian countries east of Turkey, including the Middle East and Israel. The European continent, including Russia and Turkey, was designated as Europe. Finally, the other regions were described as Africa and Australia/New Zealand, which we defined as Oceania for this study. This classification of countries and states has been used previously by others (Wininger et al., 2017; Brinker et al., 2018).

2.2. Statistical analyses

All data are reported as total numbers and percentages. Analyses between groups of continuous data were performed. To determine a significant difference of changes over time, the two-tailed z-test was used due to the assumption that the data follows a normal distribution given the sufficiently large sample size of at least 30. A p-value of <0.05 was considered significant. Statistical analyses were performed using Python programming language (Python Software Foundation, Version 3.7.4, www.python.org).

The z-tests were conducted using the package statsmodels.stats.proportion.proportions_ztest from SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python (Virtanen et al., 2020).

3. Results

A total of 4436 articles and 8776 authors were included for analysis. Of those authors, 7238 were matched to a gender (82.5%), 17.5% (1538 authors) of all entries were excluded due to an unidentifiable gender. There were 1034 female authors (14.3%) and 6204 male authors (85.7%) (Table 1).

For the first authors, female authorship increased from 0% to 19.8% between 1976 and 2020. However, regarding senior authorship, the increase in senior authorship from 4.3% to 14.4% within the same period was found not to be statistically significant. (Fig. 1, Table 2).

Overall, in including both first and senior authors, female representation increased significantly over time from 2.2% (n = 1) in 1976 to 17.1% (n = 383) in 2020 (Fig. 1, Table 2). In addition, there was an upward trend in female authorship between 1976 and 1986 (2.2% [n = 1] to 10.1% [n = 28]) and 2016 to 2020 (14.9% [n = 300] to 17.1% [n = 383]), but these were not statistically significant.

3.1. Gender analyses across regions and countries

Due to the small number of authors with identifiable gender from Oceania (n = 193), Latin America (n = 81), and Africa (n = 35), these regions were excluded from further gender trend analyses. The authors originating from the other included areas were distributed as follows: 3272 authors from North America, 2091 from Europe, and 1566 from Asia.

There was an increase in female authorship over time in all included regions. The largest increase was noted in Europe (0% in 1976 to 23.7%, n = 125 in 2020), followed by North America (2.8%, n = 1 in 1976 to 16.2%, n = 153 in 2020), and Asia (0% in 1976 to 8.6%, n = 58 in 2020) (Fig. 2, Table 2).

A detailed analysis was performed to compare the female representation of authorship among countries in 2020 (Fig. 3). Countries that contributed only a small number of authors (less than 50) with identifiable gender were excluded from this comparison to minimize the risk of

Table 1
Female authorship trends over time, stratified by journals. Total numbers are shown in square brackets.

Journal	1976	1986	1996	2006	2016	2020
Spine	53	402	810	1221	919	876
Women (%)	2.2 [1/45]	10.1 [28/276]	9.1 [65/717]	16.9 [173/1026]	14.2 [94/662]	16.6 [131/787]
Men (%)	97.8 [44/45]	89.9 [248/276]	90.9 [652/717]	83.1 [853/1026]	85.8 [568/662]	83.4 [656/787]
Gender not identifiable	8	126	93	195	257	89
European Spine Journal	–	–	145	401	943	628
Women (%)	–	–	6.7 [5/80]	12.8 [44/343]	14.7 [99/673]	20.0 [119/595]
Men (%)	–	–	93.8 [75/80]	87.2 [299/343]	85.3 [574/673]	80.0 [476/595]
Gender not identifiable	–	–	65	58	270	33
The Spine Journal	–	–	–	225	419	436
Women (%)	–	–	–	7.1 [14/197]	18.4 [56/304]	16.6 [70/421]
Men (%)	–	–	–	92.9 [183/197]	81.6 [248/304]	83.4 [351/421]
Gender not identifiable	–	–	–	28	115	15
Journal of Neurosurgery: Spine	–	–	–	364	466	468
Women (%)	–	–	–	7.2 [21/291]	13.5 [51/379]	14.3 [63/442]
Men (%)	–	–	–	92.8 [270/291]	86.5 [328/379]	85.7 [379/442]
Gender not identifiable	–	–	–	73	87	26
Total authors	**53**	**402**	**955**	**2211**	**2747**	**2408**
with identifiable gender	45	276	797	1857	2018	2245
women	1	28	70	252	300	383

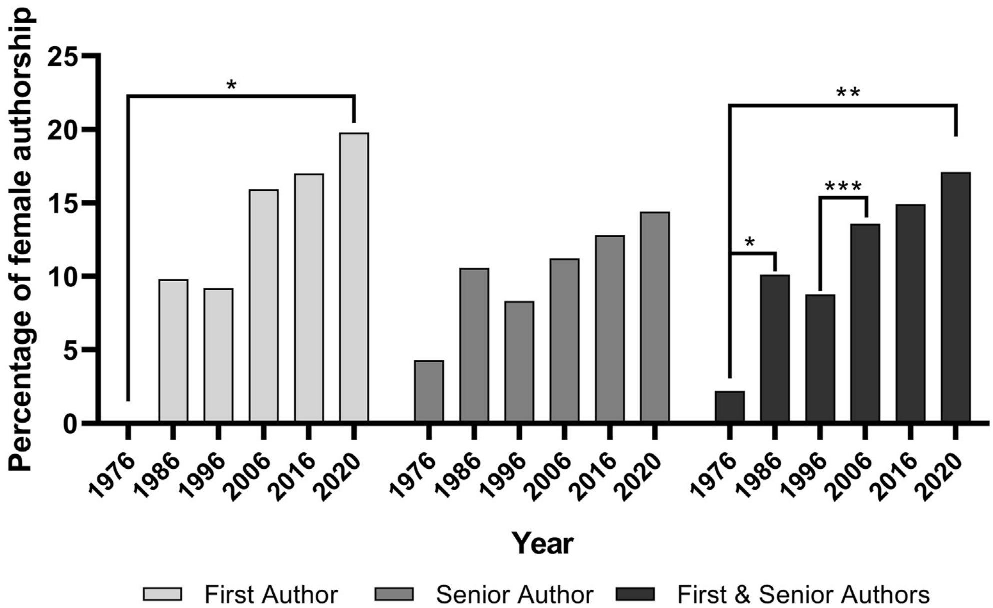

Fig. 1. Female authorship trends over time, segmented by First, Senior and First & Senior positions. *$p < 0.05$, **$p < 0.01$; ***$p < 0.001$.

Table 2
Female authorship trends over time, segmented by region and author position. Oceania, Latin America, and Africa are excluded due to small sample size over the time in consideration. Total numbers are shown square brackets.

	Publication Year					
Variable	**1976**	**1986**	**1996**	**2006**	**2016**	**2020**
First & Senior Author						
Women (%)	2.2 [1/45]	10.1 [28/276]	8.8 [70/797]	13.6 [252/1857]	14.9 [300/2018]	17.1 [383/2245]
North America	2.8 [1/36]	12.2 [23/188]	9.3 [37/397]	13.2 [107/808]	12.9 [116/900]	16.2 [153/943]
Europe	0 [0/7]	9.1 [5/55]	10.0 [25/249]	15.9 [108/679]	20.6 [118/573]	23.7 [125/528]
Asia	0 [0/2]	0 [0/29]	2.4 [3/124]	6.2 [19/307]	10.5 [45/429]	8.6 [58/675]
Others	- [0/0]	0 [0/4]	18.5 [5/27]	28.6 [18/63]	18.1 [21/116]	27.3 [27/99]
Men (%)	97.8 [44/45]	89.9 [248/276]	91.2 [727/797]	86.4 [1605/1857]	85.1 [1718/2018]	82.9 [1862/2245]
North America	97.2 [35/36]	87.8 [165/188]	90.7 [360/397]	86.8 [701/808]	87.1 [784/900]	83.8 [790/943]
Europe	100 [7/7]	90.9 [50/55]	90.0 [224/249]	84.1 [571/679]	79.4 [455/573]	76.3 [403/528]
Asia	100 [2/2]	100 [29/29]	97.6 [121/124]	93.8[288/307]	89.5 [384/429]	91.4 [617/675]
Others	- [0/0]	100 [4/4]	81.5 [22/27]	71.4 [45/63]	81.9 [95/116]	72.7 [72/99]
First Author						
Women (%)	0 [0/22]	9.8 [15/153]	9.2 [38/413]	15.9 [148/929]	17.0 [168/989]	19.8 [220/1111]
Men (%)	100 [22/22]	90.2 [138/153]	90.8 [375/413]	84.1 [781/929]	83.0 [821/989]	80.2 [891/1111]
Senior Author						
Women (%)	4.3 [1/23]	10.6 [13/123]	8.3 [32/384]	11.2 [104/928]	12.8 [132/1029]	14.4 [163/1134]
Men (%)	95.7 [22/23]	89.4 [110/123]	91.7 [352/384]	88.8 [824/928]	87.2 [897/1029]	85.6 [971/1134]

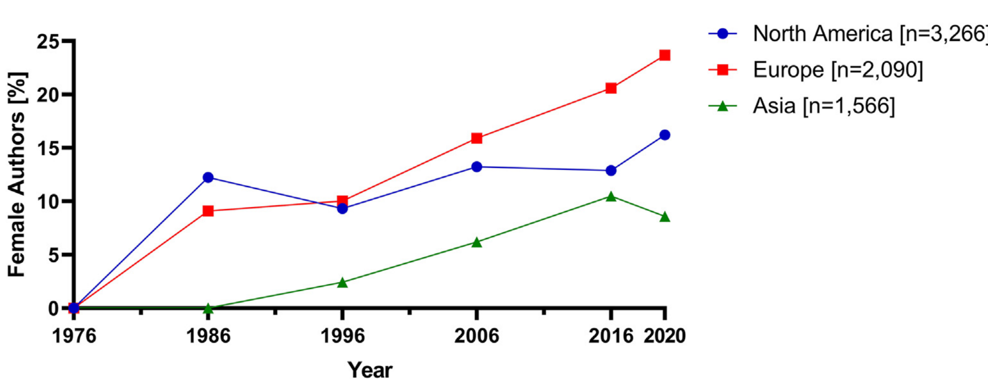

Fig. 2. Female first and senior authorship trends by region (North America n = 3272; Europe = 2091; Asia n = 1566; Others n = 309) over time Oceania, Latin America, and Africa are excluded due to small sample size.

skewed representation. In total, 11 out of 60 (18.3%) countries met the inclusion criteria. The Netherlands showed the highest female representation of 33.8%, whereas Japan had a low female proportion of 3.2% (Fig. 3, Table 3).

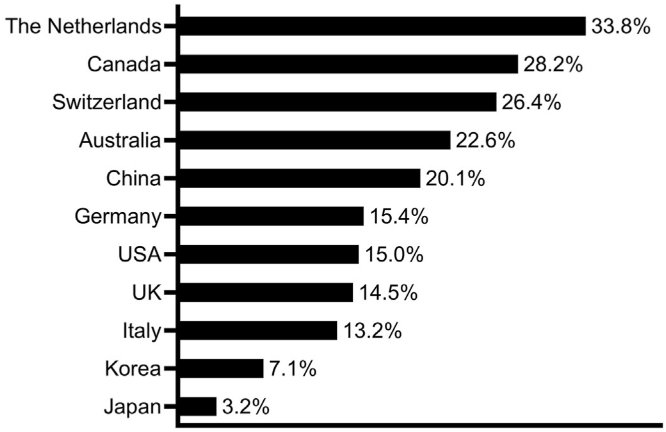

Fig. 3. Percentage of female authors (first and senior authorship) by country in 2020. Countries with <50 gender-identifiable authors are excluded.

Furthermore, these data correlate with the proportion of female physicians. Countries with a lower percentage of female authors (Fig. 3), such as Japan and Korea, also show a low rate of female physicians (20.3% and 22.3%, respectively), as well as female neurosurgeons (5.6% and 1.7%, respectively) and female orthopedic surgeons (4.9% and 0.8%, respectively) (Table 3). Countries with a high percentage of female authors, such as the Netherlands and Canada, also have a high number of female physicians (51.7% and 41.2%, respectively), neurosurgeons (16.0% and 11.0%, respectively), and orthopedic surgeons (14% and 12%, respectively) (Table 3). Also, the GGGI for Japan and Korea showed, that they ranked 121th and 108th, respectively, out of 153 countries, indicating an overall high gender gap in this country (Table 3).

To further analyze the gender gap differences between author subgroups, an analysis of the author's academic title was performed. The main objective was to determine how many authors involved in authorship were practicing physicians vs. others such as full-time researchers. Authors holding a medical doctor degree (MD/DO) were counted as practicing physicians, whereas authors without any or with different degrees, such as PhDs., were defined as researchers. For this purpose, data from all authors located in the U.S. with identifiable gender were included. The U.S. was selected because the MD/DO from these authors was consistently specified as such, whereas in most other countries, different terminology was used.

A total of 858 authors with identifiable gender from the U.S. were included; 67 authors (7.8%) without specified academic titles were excluded. The remaining 791 authors with identifiable gender and specified academic titles were included for analysis. Two hundred four authors (25.8%) did not hold a medical degree, while the rest held at least an MD/DO. The female representation within non-medical degree holders was significantly higher (34.8% vs. 8.7%; Table 4).

4. Discussion

The purpose of this study was to describe changes in gender disparity from 1976 to 2020 regarding the authorship in four prominent spine-related journals by differentiating between regions and countries. Our findings show an overall significant increase in female contribution from 1976 to 2020. The increase in women authors was highest in the first period of the analysis. This could be due to a political change in medicine. For example, an increased number of women in the U.S. entered medical school since the 1970s. In 1972, two laws were repealed in the U.S., thus prohibiting restrictions on women in the medical field and discrimination based on gender (Paludi et al., 1990).

However, when looking at the increases among first and senior authorship separately, there is a significant increase only among first authors and no significant changes among senior authors. Despite the overall increasing involvement of women in authorship, data from recent years suggest that these trends vary significantly by region: While the proportion of female authors is continuing to increase in Europe and to some extent in North America, it seems that a plateau has been reached in Asia - compared to the dramatic increase in earlier decades.

To the best of our knowledge, there are no data on gender distribution in spine research until 2020. Regarding earlier time intervals, our results are consistent with three studies on female authorship in the spine-related literature through 2016, which showed a significant increase in female participation (Brinker et al., 2018; Sing et al., 2017; Haws et al., 2018). Sing et al. (2017) included five journals from 1978 to 2016 and reported 18.5% of women representing first authors and 13.6% of women representing senior authors between 2010 and 2016, showing a slightly higher percentage than our numbers from 2016 (17% in first authors vs. 12.8% in senior authors). The difference in the results could be explained by the different methods used: Sing et al. included one additional journal in their analysis and determined the female proportion from multiple years combined (e.g., 2010–2016). The other two studies by Haws et al. (2018) and Brinker et al. (2018) focused only on one journal (*Spine*). They analyzed published articles from 1985 to 2015 (Brinker et al., 2018) and 2000 to 2015 (Haws et al., 2018), respectively. Surprisingly, they found different percentages of female first authors in 2015: 15% (Haws et al., 2018) and 18.4% (Brinker et al., 2018). A

Table 4
Authorship subgroup analysis of female representation differentiating between medical degree holders and others in the United States in 2020. MD/DO = Doctor of Medicine/Doctor of Osteopathic Medicine.

Authors with an identifiable gender	**858**
Women (%)	15.0 [129/858]
Authors with identifiable gender and specified title	791
Authors with MD/DO degree (%)	74.2 [587/791]
Women (%)	8.7 [51/587]
Authors without MD/DO degree (%)	25.8 [204/791]
Women (%)	34.8 [71/204]

Table 3
Overview of female doctors, female neurosurgeons, and female orthopedic surgeons per country, and the Global Gender Gap Index (GGGI) provided yearly by the World Economic Forum (rank of all analyzed 153 countries given in parenthesis). The latest available data were used.

Country	Female authors (%)	Female Physicians (%)	Female Neurosurgeons (%)	Female Orthopaedic surgeons (%)	GGGI (Rank)
Japan	3.2	20.3	5.6	4.9	0,652 (121/153)
Korea	7.1	22.3	1.7	0.8	0,672 (108/153)
Italy	13.2	40.3	9.0	11 .0	0,707 (76/153)
UK	14.5	45.8	12.0	4.8	0,767 (21/153)
USA	15	34.1	6.5	6.1	0,724 (53/153)
Germany	15.4	45.2	18.0	27.0	0,787 (10/153)
China	20.1	51.9	2.0	n.a.	0,676 (106/153)
Australia	22.6	39.4	14.0	4.3	0,731 (44/153)
Switzerland	26.4	39.7	22.0	9.0	0,779 (18/153)
Canada	28.2	41.2	11.0	12.0	0,772 (19/153)
The Netherlands	33.8	51.7	16.0	14.0	0,736 (38/153)

difference identified was the method used to determine the gender of an author. Haws et al. conducted an extensive internet search, whereas Brinker et al. used the same "Baby Name Guesser" method that we used. A strength of our study is that we used a combination of methods to identify the gender of an author ("Baby Name Guesser" and extensive internet search). Sing et al. (2017) used a different online database (www.genderize.io) and did not communicate any requirements to the reliability of the method as we did (gender ratio ≥3.0 in "Baby Name Guesser"). Besides this, our study provides the most up-to-date data on authorship trends, including a detailed analysis of these numbers regarding regional differences, which seems to vary significantly.

In contrast to the studies mentioned above, we analyzed the regional distribution of female first and senior authors in detail by country. Other studies looked roughly at regional differences, showing that Europe had the highest proportion of female authors in 2015, followed by North America and Asia (Brinker et al., 2018; Haws et al., 2018). These findings are consistent with our results. Additionally, we observed differences in gender distribution on the country level. The Netherlands had the largest share of female authors, accounting for a percentage of more than ten times higher than Japan, which has the lowest proportion of female representation in authorship. Similar trends are seen in other fields. A recent study about gender disparities in Transplantation research showed as well a clear difference between The Netherlands (55.1% female authors) and Japan (13.1% female authors) (Benjamens et al., 2020). The authors stated that one reason could be leveling lifestyle demands of parents. For example, male partners in The Netherlands receive 5 weeks of paid parental leave. Moreover, several general measures to promote equality in research have been taken in the Netherlands over the past 20 years. One of these is the recently government-supported "National Action Plan for More Diversity and Inclusion in Higher Education and Research" (Netherlands | European Institute for, 2022). Whereas Japan's gender equality bureau has shown that a considerable gender gap exists with only 16.6% female researchers across all fields, with even lower female involvement in engineering and science fields in 2020 (Gender Equality Bureau Cabinet Office, 2020). The lack of female participation in research might be due to Japanese women's obstacles to establishing an academic career (Osumi, 2018).

Additionally, we analyzed all authors from the USA in 2020 with a detailed overview of the relationship between female authors and academic degrees. The USA was selected because there is a clear distinction between MD/DO (professional title for physicians) and other academic titles such as Ph.D. Our data showed that most researchers in the spine-related field had an MD/DO. This finding is consistent with three other studies. Haws et al. and Wei et al. looked at spine publications ranging from 2000 to 2015 and from 2004 to 2013, respectively, of which both demonstrated that the majority of first and senior authors had MD/DO degrees (Haws et al., 2018; Wei et al., 2016). Similar trends have been shown in other surgical disciplines, such as plastic surgery and anesthetics (Rong et al., 2021; Andry et al., 2019). Another finding of our analyses pointed out that among all authors with MD/DO degrees, only 8.7% were women, whereas the proportion of women among non-MD/DO-holders was significantly higher (34.8%). This could explain why the general female involvement in authorship is higher than among practicing spine-related surgeons, as seen in the Table "Global Gender Gap Index" across all countries listed. Another possible explanation could be, that between 1969 and 2016, the percentage of doctorates awarded to women in the life sciences increased from 15% to 52% (Sheltzer and Smith, 2014; Doctorates, 2017) This equal gender distribution could lead to more female authors in (basic) spine research as well, in contrast, we showed that the proportion of female neurosurgeons and orthopedic surgeons was only 6.5% and 6.1%, respectively.

Nevertheless, our study has limitations. First, if an author's gender could not be determined after attempting the methods described above, they were excluded from gender-specific analyses. As such, our results may not be fully representative of this population. Furthermore, using an online database such as "Baby Name Guesser" keeps the risk of a wrong gender output, even when setting high requirements to correct gender identification (gender ratio ≥3.0). However, these potentially incorrect assignments should happen randomly to both gender groups; thus, this bias is assessed as relatively small. To have the most accurate gender data, the research community should consider including full names with specified gender in every publication. Including this information in research publications could also account for gender equality and introduce the possibility to develop neutral or non-binary gender information in science more conveniently. Second, the gender and country of origin were evaluated only for the first and senior authors, meaning that the trends among middle authors remain unknown. Third, data were only collected at 10-year intervals (except for 2020) and may not fully represent trends for the years in between. We believe that this possibility is rather unlikely since the data published before, which also included periods in between the 10-year interval, showed similar results (Sing et al., 2017). Fourth, spine research is also published outside of the four spine-specific journals studied but identifying a dataset of all spine-related articles published is complex and may be impossible. By selecting four of the most cited spine-related journals with more than 4000 articles included, we have tried to reduce this selection bias as much as possible by requiring a reasonable amount of time and expense.

5. Conclusion

Overall, women have become significantly more involved in spine-related research over the last five decades. Europe has the highest proportion of female authors in 2020, followed by North America and Asia. Despite the increasing numbers of female authors, the results from this study indicate that there is still a significant gender disparity in authorship and that the growth has plateaued in Asia. In addition, the research community, especially journal editors, could participate towards this goal by including both full name and gender in each publication.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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