Gender disparities in pediatric research: a descriptive bibliometric study on scientific authorships

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BACKGROUND: The proportion of women in medicine, especially in pediatrics, is noticeably increasing. Yet, leadership positions are predominantly occupied by men.

METHODS: Academic authorships of 156,642 pediatric original research articles were analyzed with regard to gender disparities. The evaluation included the proportion of female authorships (FAP), distributions over first-, co- and last-authorships, gender-related citation rates, a productivity analysis and investigations on journals, countries and pediatric sub-disciplines.

RESULTS: In all, 46.6% of all authorships in pediatric research were held by female authors. Women held relatively more first-authorships (FAP = 52%) and had higher odds for first- (OR = 1.3) and co- (OR = 1.11) authorships, compared to men. The Prestige Index of −0.13 indicated an underrepresentation of female authors at prestigious first- and last-authorships. Citation rates were not affected by the gender of the key authors. At the country-level pronounced gender-related differences were detected. The time trend showed increasing female prospects forecasting a female-dominated Prestige Index of 0.05 in 2023.

CONCLUSION: The integration of women in pediatric research has advanced. Opportunities for female authors differ at the country-level, but overall women are lacking in leadership positions. Improving career opportunities for women in pediatric research can be expected in the coming years.

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INTRODUCTION
Pediatrics is dominated by women.1 The feminization of medicine is widely apparent, but particularly noticeable in pediatrics. Historically, the sociological assignment of childcare to the role of women made it easier for female doctors to enter pediatrics.2 Over the past decades, the proportion of women in pediatrics has steadily increased.5 Today, >70% of the pediatric residents in the US are female.1 However, gender inequity is evident when considering leadership positions, such as pediatric department chairs, with a female proportion of 26.3% in 2020.3

In this study, we examine the integration of female scientists in pediatric research based on scientific authorships. We anticipate that early-career researchers primarily publish as first- or co-authors in original articles, while senior researchers preferably publish as last-authors.1-6 First- and last-authorships are associated with a certain prestige and are considered a type of currency in academic medicine.4,7

Gender disparities have recently drawn a lot of interest and were evaluated for several medical subjects.5,8-20 Overall, female authors are numerically under-represented in academic medicine and reach lower citation rates than their male colleagues.12,15,22

Previous research on selected pediatric journals has shown an increasing proportion of female authors.5,20 Fishman et al.5 examined three pediatric high-impact journals. They detected an overrepresentation of women at first-authorships with 57.7% and an underrepresentation of women at last-authorships with 38.1% in 2016, in the selected journals.7 Regarding perspective-type articles in four pediatric high-impact journals, Silver et al.23 documented a female underrepresentation at first-, co- and last-authorships.23 The analysis of three Latin American pediatric Journals by Otero et al.20 on the other hand revealed relatively high proportions of female authors.20 In their data set 59.9% of all authors, 54.4% of first-authors, and 48% of last-authors were women in 2015.20

To obtain representative results for the entire field of pediatric science, we analyzed original research data from a total of 400 journals with >690,000 authorships. We evaluated the temporal development and gender-specific citation numbers, and compared...
gender distributions of countries, journals and pediatric sub-disciplines. Finally, we provide a forecast for the near future.

MATERIALS AND METHODS

Data acquisition and integration

Pediatric English-language original research articles published between January 1, 2008 and December 31, 2018 form the basis of this study. The data were acquired from the category ‘Pediatrics’ of the Web of Science Core Collection. The integration and bibliometric analysis was performed by Gendermetrics.Net, a SQL server-based software. The process included the unification of authors by grouping them by their first and last name. In total, 156,642 articles published in 400 journals written by 363,518 authors from 182 countries were acquired (bibliometric overview in Supp. Fig. 1).

Gender determination

The gender determination was algorithmically conducted through Gendermetrics.Net by evaluation of the authors’ first names. We found 146,453 (=40.3%) female authors and 129,729 (=35.7%) male authors. 16,673 (=4.6%) authors had unisex first names and 70,663 (=19.4%) first names could not be identified. Authors with unisex or non-identified forenames and their corresponding authorships (in total 162,400 authorships) were excluded from the gender analysis. The remaining 690,436 male and female authorships formed the data basis of the gender analysis.

For sub-analyses, data were grouped by different criteria (publication year, country of authorship, journal, number of authors per article, subject areas). In order to ensure the statistical validity, only groups with at least 750 male/female authorships and a gender detection output of at least 60% male and female authorships were included. 

The application of the stated criteria led to the exclusion of 287 journals from the journal-specific analysis because of too low numbers of detected female/male authorships. From the country-specific analysis China and South Korea were excluded owing to too high rates of unisex names.

Furthermore, subject areas were defined by tags of Web of Science and formed the basis for the corresponding sub-analysis.

Proportion of female authorships and female authorship odds ratio

The subjects of the analysis were first-, co- and last-authorships. Single authorships were rated as first-authorships, authorships of articles with two authors were counted as first- and last-authorship. Co-authorships described all authorships between one first- and one last-authorship.

The female authorship proportion (FAP) is the percentage of female authorships out of all female and male authorships (FAP = Authorshipsfemale/Authorshipsfemale + Authorshipsmale). In contrast, the female authorship odds ratio (FAOR) describes the relative distribution of female authors over first-, co- and last-authorships compared to men. In order to determine the FAOR for first-authorships for instance, the female odds for first-authorships are divided by the male odds for first-authorships (FAORfirst = Female Oddsfirst/Male Oddsfirst). FAORs for co- and last-authorships were calculated in the equivalent way. A FAOR > 1 represents higher female than male odds for the corresponding authorship. FAORs are determined with a confidence level of 95%.

To provide a good overview, a FAOR triplet is used to present the relative chance distributions. A triplet of (+, +, −) for example, indicates significantly higher (+) female odds to secure first-authorships, equal (=) odds for co-authorships and significantly lower (−) female odds for last-authorships, compared to men.

Summarized, the FAP measures the proportion of female authorships, whereas the FAOR gives information about distribution odds over first-, co- and last-authorships.

Prestige Index

The Prestige Index (PI) is a measure of the distribution of prestigious authorships between male and female authors. Bendels et al. introduced and defined the Prestige Index “as the prestige-weighted average of the FAOR excess εt that is calculated over all authorship types t [...] with the weighting factor wτ. It was computed by εt = wτ FAOR−1 if FAOR ≥ 1 and εt = wτ (1 − 1/FAOR) if FAOR < 1.2” Since first- and last-authorships are associated with a high reputation they are weighted positively with wτ = 1, while co-authorships are weighted with wτ = −1.11,12 Thereby the Prestige Index increases with a higher female odds ratio (OR) for first- or last-authorships and with a lower female OR for co-authorships.13 A gender-neutral prestige distribution is indicated by a Prestige Index of 0, while a positive (negative) Prestige Index states that female authors hold relatively more (less) prestigious authorships than men.13

Analysis of data

Average annual growth rates (AAGR) were determined by computing the mean values of n annual growth rates. The calculations also served the temporal linear predictions of the article count, the FAP, the FAOR and PI.12 In the respective sub-analyses (countries, journals, subject areas) we computed linear correlations of parameters by applying the Pearson correlation. We excluded 10 of 113 considered journals from the journal-specific sub-analysis due to a missing 5-year-impact-factor. Moreover, we applied a Kruskal–Wallis and a post hoc multi-comparison test to test the null hypothesis, whether the not normally distributed citation rates were drawn from the same distribution. Significance thresholds were set at 0.05.

RESULTS

Status quo and temporal development

Female authors are under-represented in pediatric research with a FAP of 46.6% at the global level (Fig. 1a). Female authors hold 52.0% first-, 47.6% co- and 37.5% last-authorships. FAORs are 1.30 for first-authorships (CI = 1.28–1.32), 1.11 for co-authorships (CI = 1.1–1.12) and 0.63 for last-authorships (CI = 0.62–0.64). The corresponding FAOR-pattern is accordingly characterized by the triplet (+, +, −). Proportionally, women secure less prestigious authorships than men as indicated by a global Prestige Index of −0.13. The FAP steadily increased over the last decade from 42.5% in 2008 to 49.9% in 2018 with an AAGR of 1.6%. The highest growth rates are found for last- and first-authorships with 2.2% and 2.0%, respectively (Fig. 1b). The AAGR of female co-authorships is 1.3%.

Female odds to hold first- and last-authorships have increased, while female odds for co-authorships have decreased since 2008. As a result of this drift, the Prestige Index has risen from its minimum of −0.26 in 2009 and has almost approached gender-neutrality at −0.05 in 2018.

Differences across countries

At the country-level, we find a FAP ranging from 21.8% in Japan, 22.7% in Saudi Arabia and 33.3% in Pakistan to 62.8% in Poland, 63.4% in Serbia, and 69.9% in Portugal (Table 1). The Prestige Index varies between a minimum of −0.90 in Italy, −0.80 in Colombia, and −0.77 in Japan, to higher indices of 0.39 in Sweden, 0.42 in Denmark, and then climaxes at a maximum of 0.54 in the Netherlands. Regarding the distribution of authorships, most countries show higher or equal odds ratios for women to be first- or co-authors while men have higher odds to be last-authors. Five countries (Singapore, Kenya, Portugal, Croatia and Tunisia) are characterized by gender-neutrality regarding authorship odds (FAOR triplet (=, =, =)). Remarkably, Ireland is the only country characterized by higher female odds to secure last-authorships compared to men.

A country’s FAP and its Prestige Index are not linearly correlating (r = 0.18, P > 0.05).

Differences across journals

The FAP range on the journal-level starts at 19.4% in Journal of Pediatric Orthopedic-Part B, 24.5% in Journal of Neurosurgery—Pediatrics, and 25.3% in Journal of Pediatric Orthopedics and ascends up to 83.2% in Journal of Pediatric Nursing—Nursing Care of Children & Families, 84.2% in Journal of Perinatal & Neonatal Nursing, to a maximum of 84.8% in Journal of Pediatric Health Care (Table 2).

The lowest representation of female authors in prestigious authorships are found in the Italian Journal of Pediatrics (PI =
The female authorship odds ratio (FAOR, top) with associated FAOR triplets, the proportion of female authorships (FAP, bottom) and the Prestige Index (PI, bottom) are depicted averaged over time and by year from 2008 to 2018. The average FAP is 46.6% and has been increasing over time from 42.5% in 2008 up to 49.9% in 2018. The negative PI (minimum in 2009) approaches a gender-neutral distribution of renowned authorships. Owing to increasing female odds for first- and last-authorships and decreasing female odds for co-authorships the PI rises up to a maximum of −0.05 in 2018. The FAOR-pattern is almost exclusively characterized by the triplet (+, +, −), indicating significantly higher odds ratios (++) for female first- and co-authorships and significantly lower odds ratios (−) for female last-authorships.

FAOR patterns are highly uniform at the level of subject areas (+, +/−−−) with significantly higher female odds to secure first-authorships in almost all subject areas and higher or equal FAORs regarding co-authorships. Men have higher odds to hold last-authorships in all 38 subject areas. Orthopedics displays the most unfavorable FAOR triplet (−, +, −), has the lowest FAP of 23.3% and Prestige Index of −0.54 of this sub-analysis.

A strong correlation between the FAOR and the Prestige Index of a subject area is revealed ($r_{36} = 0.81$, $P < 0.01$, Fig. 2).

Female authorships by the number of authors per article

The number of authors per article has a little impact on the proportion of female authors. Indeed, the FAP remains essentially stable between 45.7% for articles with 1–3 authors and 47.0% for articles with >12 authors (Fig. 3). However, we find a tendency of increasing female odds for co-authorships and overall slightly decreasing odds for women to hold last-authorships as the number of authors increases. As a result of this subtle drift, the Prestige Index decreases from −0.1 for articles with 1–3 authors to −0.22 for articles with >12 authors. The decline of the Prestige Index displays a female underrepresentation regarding prestigious authorships in multi-author articles. The FAOR triplet remains constant (+, +, −).

Citation and productivity analysis

Only minor differences are found between the citation rates of female and male authors (Fig. 4a). The average citation rate of all articles in this study (including articles of authors with undetected gender) is 10.0 citations/article. Articles with male first-authorships reach highest citation rates of 10.6 citations/article followed by articles with female first-authorships with 10.5 citations/article. The number of authors is crucial for citation rates. Articles with 1–3 authors, for instance, hold an average citation rate of 8.1 citations/article. Articles with male and female authors (Fig. 4b). In terms of scientific productivity, the study shows that male authors are more productive than female authors. 47% of the authors in this study's data set are male and hold 33.4% of the
Table 1. Classification by country.

| Country name         | Prestige Index | Proportion of female authorships | FAOR triplet | No. articles | No. authorships |
|----------------------|----------------|----------------------------------|--------------|--------------|-----------------|
| Netherlands          | 0.54           | 48.7%                            | (+, +, -)    | 5266         | 18,814          |
| Denmark              | 0.42           | 46.1%                            | (+, +, -)    | 1555         | 4893            |
| Sweden               | 0.39           | 54.0%                            | (+, +, -)    | 2636         | 8958            |
| Norway               | 0.28           | 51.9%                            | (+, +, -)    | 1434         | 4301            |
| Ireland              | 0.16           | 50.8%                            | (+, +, +)    | 1133         | 3052            |
| Australia            | 0.03           | 52.9%                            | (+, +, -)    | 6819         | 22,353          |
| Singapore            | 0.03           | 48.9%                            | (+, +, +)    | 495          | 1000            |
| Iran                 | -0.01          | 38.7%                            | (+, +, -)    | 2751         | 10,531          |
| Finland              | -0.03          | 58.7%                            | (+, +, -)    | 1651         | 6528            |
| India                | -0.04          | 37.2%                            | (+, +, -)    | 6667         | 18,165          |
| Brazil               | -0.05          | 59.1%                            | (+, +, -)    | 3212         | 12,986          |
| Kenya                | -0.05          | 44.1%                            | (+, +, -)    | 327          | 864             |
| Switzerland          | -0.07          | 41.8%                            | (+, +, -)    | 2327         | 6925            |
| Portugal             | -0.07          | 65.9%                            | (+, +, +)    | 776          | 2731            |
| Canada               | -0.11          | 50.7%                            | (+, +, -)    | 9373         | 30,547          |
| South Africa         | -0.11          | 46.4%                            | (+, +, -)    | 1240         | 2632            |
| New Zealand          | -0.11          | 48.0%                            | (+, +, -)    | 1083         | 2934            |
| Croatia              | -0.11          | 57.2%                            | (+, +, +)    | 305          | 1072            |
| United States        | -0.13          | 47.9%                            | (+, +, -)    | 64186        | 260,726         |
| United Kingdom       | -0.13          | 45.7%                            | (+, +, +)    | 11851        | 30,885          |
| Germany              | -0.13          | 36.3%                            | (+, +, -)    | 6265         | 22,293          |
| Tunisia              | -0.14          | 56.7%                            | (+, +, -)    | 199          | 831             |
| Turkey               | -0.15          | 46.3%                            | (+, +, +)    | 7473         | 34,112          |
| Austria              | -0.16          | 42.7%                            | (+, +, -)    | 1265         | 3765            |
| Chile                | -0.18          | 55.8%                            | (+, +, -)    | 550          | 1738            |
| Belgium              | -0.26          | 50.1%                            | (+, +, -)    | 1883         | 4955            |
| Pakistan             | -0.29          | 33.3%                            | (+, +, -)    | 310          | 823             |
| Egypt                | -0.30          | 40.6%                            | (+, +, -)    | 1296         | 3587            |
| Serbia               | -0.31          | 63.0%                            | (+, +, -)    | 297          | 1207            |
| France               | -0.32          | 49.8%                            | (+, +, -)    | 4088         | 17,225          |
| Mexico               | -0.33          | 47.4%                            | (+, +, -)    | 683          | 2510            |
| Israel               | -0.37          | 43.7%                            | (+, +, -)    | 2685         | 10,009          |
| Poland               | -0.37          | 62.8%                            | (+, +, -)    | 1291         | 4924            |
| Argentina            | -0.40          | 59.5%                            | (+, +, -)    | 786          | 3487            |
| Czech Republic       | -0.41          | 47.1%                            | (+, +, -)    | 445          | 1271            |
| Spain                | -0.45          | 55.6%                            | (+, +, -)    | 3139         | 12,917          |
| Hungary              | -0.45          | 44.8%                            | (+, +, -)    | 409          | 1319            |
| Saudi Arabia         | -0.52          | 22.7%                            | (+, +, -)    | 832          | 1939            |
| Greece               | -0.54          | 52.4%                            | (+, +, -)    | 1150         | 4615            |
| Japan                | -0.77          | 21.8%                            | (+, +, -)    | 6012         | 34,293          |
| Colombia             | -0.80          | 46.6%                            | (+, +, -)    | 287          | 777             |
| Italy                | -0.90          | 55.2%                            | (+, +, -)    | 6748         | 33,198          |

The countries are arranged in descending order to their Prestige Index.

authorships, whereas 53% female authors hold 46.6% authorships (Fig. 4c). The least productive groups of authors publishing one and two articles are dominated by women. The study overall reveals that 64.7% of all female authors publish merely one article over the course of their medical career. In contrast, for all higher productivity levels we reveal an overrepresentation of male authors. The group of most productive authors with >12 published articles comprises 1.7% of all female authors and 3.5% of all male authors (Fig. 4c).

**DISCUSSION**

**High participation of women**

This descriptive study examines the integration of female scientists by means of scientific authorships in the academic field of pediatrics from 2008 to 2018. In contrast to other medical sub-disciplines, this analysis reveals that, in fact, the majority of authors in pediatric research are female (53%). Owing to a higher productivity of male authors, women are still slightly under-represented with a global proportion of female authorships of
Table 2. Classification by journals.

| Journal name                                | Prestige Index | Proportion of female authorships | FAOR triplet | No. of articles | No. of authorships |
|---------------------------------------------|----------------|-----------------------------------|--------------|----------------|-------------------|
| Journal of Perinatal & Neonatal Nursing     | 0.64           | 84.2%                             | (+, =, −)    | 373            | 894               |
| Journal of Pediatric Nursing—Nursing Care of Children & Families | 0.57           | 82.3%                             | (+, −, −)    | 830            | 2823              |
| Journal of Pediatric Health Care            | 0.54           | 84.8%                             | (+, =, −)    | 491            | 1614              |
| Maternal and Child Nutrition                | 0.5            | 65.8%                             | (+, −, −)    | 784            | 3685              |
| Physical & Occupational Therapy in Pediatrics | 0.44         | 81.6%                             | (+, =, −)    | 275            | 1043              |
| Birth-Issues in Perinatal Care              | 0.29           | 72.8%                             | (+, −, −)    | 444            | 1732              |
| Journal of Pediatric and Adolescent Gynecology | 0.28           | 69.7%                             | (+, −, −)    | 797            | 2869              |
| Journal of Child Health Care                | 0.25           | 71.6%                             | (+, =, =)    | 400            | 1326              |
| International Journal of Pediatrics-Mashhad  | 0.23           | 39.6%                             | (+, −, =)    | 699            | 2711              |
| Pediatrics and Neonatology                  | 0.21           | 42.8%                             | (+, −, −)    | 642            | 2142              |
| Pediatric and Perinatal Epidemiology        | 0.20           | 56.9%                             | (+, −, −)    | 678            | 3618              |
| International Journal of Pediatric Dentistry | 0.19           | 54.9%                             | (+, =, −)    | 657            | 2541              |
| Developmental Medicine and Child Neurology   | 0.18           | 57.2%                             | (+, −, −)    | 1383           | 6973              |
| European Child & Adolescent Psychiatry       | 0.18           | 54.9%                             | (+, =, −)    | 929            | 5006              |
| Journal for Specialists in Pediatric Nursing  | 0.16           | 82.4%                             | (+, =, −)    | 289            | 834               |
| Journal of Adolescent Health                 | 0.12           | 61.9%                             | (+, =, −)    | 2132           | 9897              |
| Pediatric Annals                            | 0.10           | 55.6%                             | (+, =, −)    | 782            | 1643              |
| Journal of the Pediatric Infectious Diseases Society | 0.10              | 51.6%                             | (+, =, =)    | 299            | 1950              |
| International Journal of Pediatric Obesity  | 0.09           | 54.3%                             | (+, =, −)    | 318            | 1326              |
| Pediatric Diabetes                          | 0.07           | 53.7%                             | (+, =, −)    | 1104           | 6256              |
| Pediatric Physical Therapy                  | 0.06           | 72.2%                             | (+, =, −)    | 452            | 1617              |
| Pediatric Allergy and Immunology            | 0.05           | 46.9%                             | (+, =, −)    | 1008           | 5913              |
| Journal of Tropical Pediatrics              | 0.05           | 43.7%                             | (+, =, −)    | 831            | 3269              |
| Pediatric and Developmental Pathology        | 0.05           | 49.6%                             | (+, =, −)    | 706            | 2901              |
| Pediatric Rheumatology                      | 0.05           | 55.4%                             | (+, =, −)    | 430            | 2590              |
| Breastfeeding Medicine                      | 0.04           | 67.7%                             | (+, =, −)    | 768            | 2484              |
| Jornal de Pediatría                          | 0.04           | 64.3%                             | (+, =, −)    | 661            | 3024              |
| Pediatric Transplantation                    | 0.03           | 39.1%                             | (+, =, −)    | 1715           | 9502              |
| Childhood Obesity                           | 0.03           | 70.4%                             | (+, =, −)    | 424            | 2098              |
| Pediatric Dentistry                         | 0.02           | 49.0%                             | (+, =, −)    | 667            | 2278              |
| Journal of Human Lactation                   | 0.02           | 75.2%                             | (+, =, −)    | 628            | 2347              |
| Journal of Pediatric Surgery Case Reports    | 0.01           | 30.7%                             | (+, =, −)    | 707            | 2792              |
| Case Reports in Pediatrics                  | 0.01           | 47.4%                             | (+, =, −)    | 322            | 1227              |
| Pediatric Research                          | 0.00           | 45.5%                             | (+, =, −)    | 2180           | 13,318            |
| Pediatric Dermatology                       | −0.01          | 55.5%                             | (+, =, −)    | 2257           | 8990              |
| Child and Adolescent Mental Health           | −0.01          | 63.7%                             | (−, =, =)    | 320            | 1218              |
| Child and Adolescent Psychiatry and Mental Health | −0.01          | 54.6%                             | (−, =, −)    | 248            | 1122              |
| Pediatric Blood & Cancer                    | −0.03          | 47.2%                             | (+, =, −)    | 4116           | 26,704            |
| Pediatric Surgery International             | −0.03          | 28.9%                             | (+, =, −)    | 1971           | 8499              |
| Indian Pediatrics                           | −0.03          | 40.7%                             | (−, =, −)    | 1390           | 3635              |
| Neuropediatrics                             | −0.03          | 49.1%                             | (+, =, −)    | 576            | 2092              |
| Developmental Neurorehabilitation           | −0.04          | 62.7%                             | (−, =, =)    | 500            | 2091              |
| Bmc Pediatrics                              | −0.05          | 52.5%                             | (+, =, −)    | 2008           | 10,808            |
| Jama Pediatrics                             | −0.05          | 48.8%                             | (+, =, −)    | 641            | 4887              |
| Journal of Pediatric Hematology Oncology    | −0.06          | 47.7%                             | (+, =, −)    | 2312           | 11,839            |
| Pediatric Allergy Immunology and Pulmonology | −0.07          | 56.6%                             | (+, =, −)    | 272            | 1098              |
### Table 2. continued

| Journal name                                               | Prestige Index | Proportion of female authorships | FAOR triplet | No. of articles | No. of authorships |
|------------------------------------------------------------|----------------|----------------------------------|--------------|----------------|-------------------|
| Pediatrics & Child Health                                  | -0.08          | 57.1%                            | (+, =, -)    | 434            | 1600              |
| Journal of Clinical Research in Pediatric Endocrinology    | -0.08          | 53.0%                            | (+, =, -)    | 385            | 2024              |
| Journal of Pediatrics and Child Health                    | -0.09          | 52.1%                            | (+, =, -)    | 1592           | 6507              |
| Acta Paediatrica                                           | -0.10          | 50.0%                            | (+, =, -)    | 3027           | 10,700            |
| Pediatric Neurology                                        | -0.11          | 45.9%                            | (+, =, -)    | 1713           | 8206              |
| Journal of Developmental and Behavioral Pediatrics         | -0.11          | 63.3%                            | (+, =, -)    | 776            | 3718              |
| Archives of Disease in Childhood                           | -0.12          | 49.6%                            | (+, =, -)    | 1767           | 6108              |
| Pediatric Critical Care Medicine                           | -0.12          | 40.8%                            | (+, =, -)    | 1668           | 9941              |
| Cardiology in the Young                                    | -0.13          | 35.7%                            | (+, =, -)    | 1935           | 8185              |
| Pediatric Emergency Care                                   | -0.14          | 43.6%                            | (+, +, -)    | 2078           | 8077              |
| Indian Journal of Pediatrics                               | -0.14          | 39.6%                            | (=, +, -)    | 1845           | 5415              |
| Journal of the American Academy of Child and Adolescent Psychiatry | -0.14        | 49.0%                            | (+, =, -)    | 988            | 6876              |
| Journal of Pediatrics                                      | -0.15          | 49.0%                            | (+, +, -)    | 4322           | 26,676            |
| Pediatric Nephrology                                       | -0.15          | 46.8%                            | (+, +, -)    | 1904           | 11,231            |
| Early Human Development                                   | -0.15          | 54.0%                            | (+, =, -)    | 1651           | 6896              |
| Journal of Perinatal Medicine                             | -0.15          | 41.9%                            | (+, =, -)    | 1022           | 5207              |
| Pediatric Radiology                                        | -0.16          | 40.2%                            | (+, +, -)    | 2323           | 9539              |
| Journal of Child and Adolescent Psychopharmacology        | -0.16          | 47.2%                            | (=, +, -)    | 820            | 4643              |
| Journal of Perinatology                                    | -0.17          | 45.7%                            | (=, =, =)    | 1965           | 1338              |
| Pediatric Clinics of North America                        | -0.17          | 49.0%                            | (+, =, -)    | 821            | 1704              |
| Pediatric Hematology and Oncology                          | -0.17          | 47.9%                            | (=, +, -)    | 709            | 3514              |
| Journal of Clinical Pediatric Dentistry                    | -0.17          | 46.7%                            | (=, =, -)    | 644            | 1125              |
| Pediatrics                                                 | -0.18          | 50.8%                            | (+, +, -)    | 7111           | 42,269            |
| Pediatric Infectious Disease Journal                       | -0.18          | 48.4%                            | (+, +, -)    | 3358           | 21,214            |
| Journal of Child Neurology                                 | -0.18          | 50.4%                            | (+, +, -)    | 2271           | 10,296            |
| Journal of Pediatric Endocrinology & Metabolism            | -0.18          | 52.8%                            | (+, +, -)    | 1901           | 8693              |
| Turkish Journal of Pediatrics                              | -0.18          | 52.8%                            | (+, +, -)    | 1237           | 5906              |
| Hormone Research in Pediatrics                            | -0.18          | 52.7%                            | (+, =, -)    | 901            | 4802              |
| Child Psychiatry & Human Development                       | -0.18          | 58.6%                            | (+, +, -)    | 709            | 2909              |
| Fetal and Pediatric Pathology                             | -0.18          | 50.4%                            | (+, =, -)    | 506            | 2164              |
| Clinical Pediatrics                                        | -0.19          | 55.5%                            | (+, +, -)    | 1729           | 6878              |
| Pediatric Pulmonology                                      | -0.2           | 45.3%                            | (+, +, -)    | 1882           | 9653              |
| European Journal of Pediatric Neurology                   | -0.20          | 52.9%                            | (+, +, -)    | 1007           | 5455              |
| Iranian Journal of Pediatrics                              | -0.20          | 40.0%                            | (=, +, -)    | 893            | 3332              |
| Ajp Reports                                                | -0.20          | 47.1%                            | (+, =, -)    | 215            | 986               |
| Archives of Pediatrics & Adolescent Medicine               | -0.21          | 53.1%                            | (+, =, -)    | 638            | 3231              |
| American Journal of Perinatology                          | -0.22          | 46.9%                            | (+, +, -)    | 1579           | 7859              |
| Academic Pediatrics                                        | -0.22          | 61.4%                            | (+, +, -)    | 864            | 4267              |
| Journal of Pediatric Gastroenterology and Nutrition       | -0.24          | 45.3%                            | (+, +, -)    | 2971           | 16,886            |
| Neonatology                                                | -0.24          | 43.2%                            | (+, +, -)    | 955            | 4868              |
| Journal of Pediatric Ophthalmology & Strabismus           | -0.24          | 40.2%                            | (+, =, -)    | 557            | 1932              |
| Children-Basean                                            | -0.24          | 59.4%                            | (=, =, =)    | 216            | 887               |
| Seminars in Fetal & Neonatal Medicine                    | -0.25          | 43.8%                            | (=, =, =)    | 428            | 835               |
| Pediatric Anesthesia                                       | -0.26          | 39.3%                            | (+, +, -)    | 1394           | 6292              |
| Pediatrics International                                  | -0.28          | 31.3%                            | (+, +, -)    | 2356           | 12,664            |
| Journal of Aapos                                           | -0.28          | 43.5%                            | (=, +, -)    | 1521           | 5776              |
47.9%. When set in relation to bibliometric data of the whole field of academic science with a FAP of <30%\(^1\) or other recently evaluated medical fields like research about lung-cancer (31.3%), \(^9\) prostate cancer (31.7%), \(^\text{10}\) epilepsy (39.4%), \(^\text{11}\) or dermatology (43.0%), \(^\text{12}\) pediatrics stands out with an exceptionally high evaluated medical field, \(^\text{13}\) strongly from other scientific fields, in which female authors achieve significantly less citations.\(^{12,17}\) This finding speaks against the increasing proportion of women in medicine, particularly in pediatrics.\(^{30}\)

**Gender-neutrality is partially achieved**

Increasing Prestige Indices, climaxing in 2018 with a Prestige Index of \(-0.05\), suggest an approximation to gender-neutrality regarding the distribution of prestigious authorships. Apparently, the results of the citation analysis also point to gender parity. Not only are articles with women in key authorships cited as often as articles with men in key authorships, but the proportion of female authorships also remains high in multi-author articles, which reach the highest citation rates. In this aspect, pediatric research exhibits a disparity from other scientific fields, in which female authors achieve significantly more citations.\(^{12,17}\) This finding speaks against an old boy (citation-) network in pediatric research.

**Female authors yet under-represented in leading positions**

Significantly lower female-to-male odds for last-authorships display a lack of women in senior positions in pediatric research. While many young women enter the academic field of pediatrics,\(^{37}\) they often leave the scientific career path earlier than men do.\(^{17}\) This phenomenon is known as the *leaking pipeline*.\(^{28}\) For example, in the US, the most productive country in pediatric research (Supp. Fig. 1), women are over-represented at early-career stages, with 71% female residents in pediatrics in 2018.\(^1\) However, the proportion reduces over the next career steps and only few reach senior leadership positions, reflected by a female proportion of only 27.5% of the department chairs in pediatrics in 2018.\(^1\) Career dichotomies like this can be found in most academic disciplines and have been examined in many studies.\(^{7,17,28-33}\) As research has shown, one major reason for the imbalance is that female graduate students are relatively less likely than men to aspire leadership positions due to differing life priorities, such as parenthood,\(^{38}\) caring for the family,\(^{30}\) or a satisfying life-work-balance,\(^{34}\) but also due to a lack of role models.\(^{35}\)

Nevertheless, our study reveals that growth rates for female last-authorships are higher than for other authorship types. Fishman et al.\(^5\), in contrast, detected higher growth rates for female first-authorships than for last-authorships in their study of three pediatric high-impact journals. This difference raises the question of whether the distribution of authorships is affected by the journal’s influence.

However, significantly increasing last-authorship FAORs and high growth rates for FAPs of last-authorships indicate that female scientists, yet under-represented, are on the rise to occupy senior positions in pediatric research.

**Lower female productivity due to differing lifestyle priorities**

Overall, the productivity of a scientist is crucial when it comes to funding, tenure, or promotion. Here, large publication records offer an advantage.\(^{30,36,37}\)

As van den Besselaar et al. have shown for various scientific disciplines, there are typically no significant productivity differences between male and female authors at early-career stages.\(^{30}\) A gender gap with higher male publication counts usually appears in the mid-career phase.\(^{30}\) However, at latter career stages, female publication numbers rise and can even exceed those of men.\(^{30}\)

There are multiple reasons for productivity imbalances. One reason can be found in the female underrepresentation in leading roles.
more, 12,25 with 40% of the female and only 5% of the male pediatricians working part-time.40 This period matches the less productive mid-career phase. In summary, the under-representation in leading positions and differing female lifestyle priorities are two major reasons for lower female productivity.

**Socio-cultural factors cause region-specific differences**

We revealed large region-specific differences of gender disparities in pediatric research. The findings are consistent with those of other medical disciplines.9–12,23 The Netherlands and the Scandinavian countries Sweden, Norway and Denmark lead the PI rankings in several medical disciplines9,11,12 indicating that they

| Subject area                  | Prestige Index | Proportion of female authorships | FAOR triplet | No. of articles | No. of authorships |
|-------------------------------|----------------|----------------------------------|--------------|-----------------|--------------------|
| Nursing                       | 0.33           | 78.8%                            | (+, –, –)    | 3520            | 11,656             |
| Public, Environmental & Occupational Health | 0.14 | 60.5% | (+, –, –) | 3057 | 14,060 |
| Health Care Sciences & Services | 0.12 | 83.5% | (+, –, –) | 539 | 1709 |
| Allergy                       | 0.07           | 48.4%                            | (+, –, –)    | 1299            | 7047               |
| Tropical Medicine             | 0.06           | 43.5%                            | (+, –, –)    | 1005            | 3348               |
| Psychology                    | 0.05           | 57.6%                            | (+, –, –)    | 7334            | 30,665             |
| Rehabilitation                | 0.04           | 69.7%                            | (+, –, –)    | 1338            | 4970               |
| Transplantation               | 0.03           | 39.1%                            | (+, –, –)    | 1715            | 9502               |
| Obstetrics & Gynecology       | 0.02           | 55.5%                            | (+, –, –)    | 10,779          | 37,190             |
| Rheumatology                  | 0.01           | 55.3%                            | (+, –, –)    | 450             | 2626               |
| Dentistry, Oral Surgery & Medicine | 0.00 | 51.6% | (+, –, –) | 2602 | 6430 |
| Psychiatry                    | –0.02          | 52.5%                            | (+, –, –)    | 4180            | 22,095             |
| Dermatology                   | –0.02          | 55.4%                            | (+, –, –)    | 2294            | 9044               |
| Pathology                     | –0.04          | 50.1%                            | (+, –, –)    | 1226            | 5104               |
| Hematology                    | –0.06          | 47.3%                            | (+, +, –)    | 7298            | 42,329             |
| Oncology                      | –0.07          | 47.3%                            | (+, +, –)    | 7538            | 42,921             |
| Nutrition & Dietetics         | –0.07          | 48.9%                            | (+, +, –)    | 4001            | 20,944             |
| Behavioral Sciences           | –0.07          | 63.7%                            | (+, +, –)    | 838             | 3807               |
| Immunology                    | –0.12          | 48.3%                            | (+, +, –)    | 4722            | 28,293             |
| Endocrinology & Metabolism    | –0.12          | 52.8%                            | (+, +, –)    | 4526            | 22,292             |
| Pediatrics                    | –0.13          | 46.6%                            | (+, +, –)    | 156,642         | 690,436            |
| Emergency Medicine            | –0.14          | 43.7%                            | (+, +, –)    | 2106            | 8121               |
| Infectious Diseases           | –0.16          | 48.6%                            | (+, +, –)    | 3878            | 23,750             |
| General & Internal Medicine   | –0.16          | 41.0%                            | (+, +, –)    | 2065            | 10,834             |
| Radiology, Nuclear Medicine & Medical Imaging | –0.17 | 40.1% | (+, +, –) | 2527 | 10,049 |
| Pharmacology & Pharmacy       | –0.18          | 46.6%                            | (+, +, –)    | 1130            | 5571               |
| Respiratory System            | –0.22          | 46.1%                            | (+, +, –)    | 2534            | 11,456             |
| Neurosciences & Neurology     | –0.23          | 41.5%                            | (+, +, –)    | 13,208          | 59,319             |
| Cardiovascular System & Cardiology | –0.23 | 34.8% | (+, +, –) | 4635 | 19,496 |
| Gastroenterology & Hepatology | –0.24          | 45.3%                            | (+, +, –)    | 3016            | 16,968             |
| Anesthesiology                | –0.24          | 39.7%                            | (+, +, –)    | 1507            | 6484               |
| Ophthalmology                 | –0.29          | 42.5%                            | (+, +, –)    | 2133            | 7802               |
| Otorhinolaryngology           | –0.32          | 39.3%                            | (+, +, –)    | 3884            | 14,243             |
| Urology & Nephrology          | –0.33          | 41.4%                            | (+, +, –)    | 3607            | 16,945             |
| Physiology                    | –0.33          | 38.3%                            | (+, +, –)    | 536             | 2300               |
| Sport Sciences                | –0.34          | 37.9%                            | (+, +, –)    | 615             | 2426               |
| Surgery                       | –0.39          | 30.4%                            | (+, +, –)    | 13,740          | 60,582             |
| Orthopedics                   | –0.54          | 23.3%                            | (+, +, –)    | 3373            | 12,859             |

The subject areas are arranged in descending order to their Prestige Index.
provide the best career opportunities for female researchers. The opposite applies to countries such as Japan, Italy, and Greece, most of which are at the bottom of the PI rankings. Since these findings also correlate with the Global Gender Gap Report (GGGR), it can be assumed that regional differences are not founded in characteristics of pediatric research, but are rather due to socio-cultural characteristics of the respective countries. Japan, for example, is in position 110 of all 149 countries in the GGGR 2018 and in position 40 of 42 of our study. The extremely low FAP of only 21.8% and a Prestige Index of −0.77 in Japan can most likely be seen as an expression of the country’s patriarchal and male-dominated structures.

Interestingly, no correlation of a country’s FAP and Prestige Index can be determined \( r = 0.18, P > 0.05 \), suggesting that a country with a high proportion of female authors might not necessarily offer good career opportunities for female scientists. In Italy, for instance, female authors predominate with a FAP of 55.2%, but the country provides the worst female prospects in our study with a Prestige Index of −0.9. Accordingly, the theory of critical mass, postulating that the structures of a group change in favor of a minority as soon as it exceeds a critical mass, does not apply on the country-level due to the strong influence of socio-cultural factors.

Homogeneous structures in pediatric sub-disciplines

The analysis reveals that, unsurprisingly, some pediatric sub-disciplines are clearly male-dominated (e.g., Orthopedics \( \text{FAP} = 23.3\% \)), while others are female-dominated (e.g., Nursing \( \text{FAP} = 78.8\% \)). These findings agree with the gender distribution of the respective subjects in adult medicine. Fischer et al. found an underrepresentation of women in Pediatric Orthopedics, too. However, they detected an increasing proportion of female first-authors from 13.5% in 2005 to 25.6% in 2015, indicating that women are rising in this male-dominated sub-discipline.

Regardless of the large FAP range of pediatric sub-disciplines (\( \Delta \text{FAP} = 60.2\% \)), there is a high homogeneity in terms of publication opportunities. FAOR patterns show higher female odds to hold first-authorships and lower female odds to hold last-authorships in 34 of 38 subject areas compared to male odds. The high level of uniformity is also reflected by a relatively small PI range (\( \Delta \text{PI} = 0.87 \)). The findings suggest that research group structures in almost all pediatric sub-disciplines are characterized by mainly female early-career researchers and mainly male leaders.

The strong correlation between the FAP and Prestige Index of subject areas \( r = 0.81, P < 0.01 \) implies that with an increasing proportion of female authors, the female odds to hold prestigious authorships rise in the respective subject area. In this case, the finding is consistent with the theory of critical mass.

Female integration at the journal-level

Journals differ strongly in terms of the proportion of female authors. With a FAP range of \( \Delta \text{FAP} = 65.4 \) the variation of journals is even higher than of subject areas. Nevertheless, again, we find a high degree of homogeneity regarding publication opportunities with mainly higher female odds ratios for first-authorships and higher male odds ratios for last-authorships. The parallels between pediatric sub-disciplines and journals can be explained by the assignment of subjects to partially subject-specific journals. Interestingly, on the journal-level, the PI values diverge more strongly \( (\Delta \text{PI} = 1.41) \) with deviations both upwards and downwards than on the subject-level. We suggest that socio-cultural factors lead to the stronger deviation, as some of the examined journals are country-specific. The lowest Prestige Index in the journal-specific analysis, for example, is found in the Italian Journal of Pediatrics with a PI of −0.77, which is consistent with the country-specific analysis pointing out Italy as the country with the lowest Prestige Index. The discovered correlation between the FAP and Prestige Index on the journal-level \( r = 0.74, P < 0.01 \) reveals the influence that the female share has on the distribution of prestigious authorships in journals.

The 5-Year-Impact-Factor of a journal, however, does not correlate linearly with the FAP \( r = 0.1 \) nor the Prestige Index \( r = 0.1 \) indicating that the impact of a journal does not affect the integration of female scientists in pediatric research.

Outlook

In contrast to other fields, the temporal development of pediatric research displays an explicit progression of increasing female odds to secure first- and last-authorships combined with concurrent decreasing female odds for co-authorships. A linear projection of the obtained data forecasts a rising FAP and increasing FAORs for first- and last-authorships in combination with female odds for co-authorships dropping below one (Supp. Fig. 2). This projection results in a switch of the FAOR triplet from \( (+, +, −) \) to \( (+, =, −) \) and predicts a FAP of 54.0% and a positive Prestige Index of 0.05 in 2023. Thus, further improvement in career opportunities for women in pediatric research can be expected. However, leading positions will still be predominantly occupied by men in the coming years.

Methodical limitations

The applied method offers the possibility to algorithmically analyze high amounts of data independent of the examiner. As

Fig. 2 Correlation of parameters in subject areas. The Prestige Index and the proportion of female authorships (FAP) are strongly correlated.

Fig. 3 Female authorships by authors per article. With an increasing number of authors per article, the proportion of female authorships remains almost constant. In contrast, the Prestige Index decreases in multi-authored articles due to a female disadvantaged shift of prestigious authorships.
it is frequently used, values like gender-specific odds ratios or Prestige Indices can easily be compared to other medical disciplines.

For articles published before 2007, the method is not feasible, since the author names were predominantly abbreviated with initial letters, making first-name-based gender determination impracticable. 25 Shared first- or last-authorships cannot be detected by Gendermetrics.Net and were therefore not taken into account. 11 As already mentioned by other studies, 12,17,25 variables, such as the academic rank, employment status and age of the author, were not examined due to lack of information. Moreover, it should be noted that also the profession of the author is not considered. Since journals assigned to pediatrics build the data basis, articles of pediatrics faculty published in non-pediatric journals are not included in the analysis. Furthermore, a change of the last name owing to marriage could not be taken into account in the articles-per-author sub-analysis. In addition, China and South Korea were excluded from the country-specific analysis because of the large proportion of unisex names.

The limitations that result from the software-supported analysis can be addressed in further research by individual investigations, particularly on author attributes. Besides, a disclosure of the authors gender in the submitting process could support investigations on gender disparities.

CONCLUSION

In the present study, it was shown that the integration of female scientists is advanced in pediatric research, compared to other scientific disciplines. 12,17 With nearly balanced publication counts between female and male authors in 2018, similar citation rates, and a Prestige Index which is approaching an almost equal distribution of prestige-associated authorships, the gender gap has narrowed over time. Nevertheless, for pediatric research, as for most scientific fields, 7,12 a gender-based career-dichotomy could be observed, with relatively more female first-authors at early-career stages and mainly male last-authors in leadership positions. According to linear projections, improving career opportunities for women in pediatric research can be expected in the coming years. Further investigations in the future will reveal whether a ceiling effect occurs or whether gender parity is achieved in pediatric research. It is up to working groups and journals to question their structures and discuss if or how they want to contribute to closing the gender gap.

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