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**Geschlechterdisparitäten in der pädiatrischen Forschung:
Eine deskriptive bibliometrische Studie über wissenschaftliche
Autorenschaften**

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2 Zusammenfassung

Seit Beginn des 20. Jahrhunderts verzeichnete das ärztliche Berufsfeld einen steten Zuwachs von Frauen. Gegenwärtig weist insbesondere die Pädiatrie einen besonders hohen Frauenanteil auf. Es ist jedoch zu beobachten, dass ungeachtet dessen, Führungspositionen weiterhin vorwiegend von Männern besetzt bleiben.

Vor diesem Hintergrund wurden in der vorliegenden Studie Geschlechterdisparitäten in der pädiatrischen Forschung anhand von wissenschaftlichen Autorenschaften für den Zeitraum von 2008 bis 2018 untersucht.

Insgesamt wurden 690 436 Autorenschaften aus 156 642 englischsprachigen Originalartikeln für die Untersuchung herangezogen. Die Analyse umfasste den Anteil weiblicher Autorenschaften (Female Authorship Proportion, FAP), die Verteilung auf Erst-, Co- und Letzt-Autorenschaften, geschlechtsspezifische Zitationsraten, eine Produktivitätsanalyse sowie Untersuchungen zu Journalen, Ländern und pädiatrischen Teildisziplinen.

Insgesamt betrug der Anteil weiblicher Autorenschaften 46,6%. Dabei fanden sich Autorinnen auf 52,0% der Erst-, 47,6% der Co- und 37,5% der Letzt-Autorenschaften. Auch die Odds Ratio weiblicher Autorenschaft (Female Authorship Odds Ratio, FAOR) war jeweils am höchsten für die Erst-Autorenschaft (1,30) und am niedrigsten für die Letzt-Autorenschaft (0,63). Auf prestigeträchtigen Erst- und Letzt-Autorenschaften waren Frauen mit einem Prestige-Index (PI) von -0,13 insgesamt unterrepräsentiert. Der zeitliche Verlauf offenbarte einen Zuwachs weiblicher Autorenschaften, mit Akzentuierung auf Erst- und Letzt-Autorenschaften.

In den Teilanalysen von einzelnen Ländern, Journalen und pädiatrischen Teildisziplinen konnte jeweils eine erhebliche Spannbreite der FAP sowie des PI festgestellt werden. Dabei wiesen beinahe alle Länder und Journale sowie sämtliche pädiatrischen Teildisziplinen eine signifikante Unterrepräsentation von Frauen auf Letztautorenschaften auf. Zwischen dem Einfluss eines Journals und dessen FAP oder PI konnte keine lineare Korrelation nachgewiesen werden.

Die Produktivitätsanalyse ergab, dass männliche Autoren im Schnitt mehr Artikel veröffentlichten als weibliche Autoren. Der Großteil der Autorinnen (64,7%) veröffentlichte während des untersuchten Zeitraums einen einzigen wissenschaftlichen Artikel. Zitationszahlen sowie die Repräsentanz in Multiautorenartikeln zeigten sich jeweils annähernd geschlechterneutral.

Die erzielten Resultate dieser Analyse ließen Rückschlüsse auf die Integration von Frauen in der pädiatrischen Forschung zu. Insgesamt war die weibliche Repräsentanz in der Pädiatrie, insbesondere in Relation zu anderen Wissenschaftsbereichen, hoch. Der sukzessive Anstieg der FAP über den untersuchten Zeitraum spiegelte den zunehmenden Anteil von Frauen in der Pädiatrie wider. In den Bereichen Zitationsraten und Prestige-Index kam eine annähernde Geschlechterparität zum Ausdruck.

Deutliche Disparitäten wurden dahingegen bei Betrachtung der Verteilungsmuster von weiblichen Erst-, Co- und Letzt-Autorenschaften aufgedeckt. Hier zeigte sich eine Karrieredichotomie: Frauen waren auf Erst-Autorenschaften überrepräsentiert, was vornehmlich dem Karrierebeginn entspricht. Männer waren dahingegen auf Letzt-Autorenschaften überrepräsentiert, was wiederum mit leitenden Positionen assoziiert ist.

Interessanterweise konnten auf globaler Ebene hohe Wachstumsraten der FAP für Letzt-Autorenschaften und eine deutlich ansteigende FAOR für eine Letzt-Autorenschaft festgestellt werden. Diese Ergebnisse implizieren, dass Wissenschaftlerinnen vermehrt, Führungspositionen besetzten. Linearen Hochrechnungen zufolge ist in den kommenden Jahren mit verbesserten Karrierechancen für Frauen in der pädiatrischen Forschung zu rechnen.

3 Summary

Since the beginning of the 20th century, the number of women in medicine has steadily increased. Especially pediatrics has a particularly high proportion of women. Yet, it can be observed that leadership positions are predominantly occupied by men.

In this context, we examined gender disparities in pediatric research based on scientific authorships for the period from 2008 to 2018.

A total of 690,436 authorships from 156,643 English-language pediatric original research articles were examined in this study.

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.

The results revealed a global proportion of female authorships of 46.6%. Female authors held 52.0% first-, 47.6% co- and 37.5% last-authorships. Correspondingly, the female authorship odds ratio (FAOR) was highest for first-authorship (1.30) and lowest for last-authorship (0.63). Concerning prestigious first- and last-authorships, women were underrepresented with a Prestige Index (PI) of -0.13. The time trend showed an increase of female authorships, with accentuation on first- and last-authorships.

In the investigations of countries, journals, and pediatric sub-disciplines, large ranges of the FAP and the PI were identified. Furthermore, almost all countries and journals as well as all pediatric sub-disciplines were characterized by an underrepresentation of women at last-authorships. Remarkably, there was no linear correlation between the influence of a journal and its corresponding FAP or PI.

The productivity analysis showed that on average male authors published more articles than female authors. The majority of female authors (64.7%) published merely one article during the analyzed period.

Citation rates as well as the representation in multi-author articles were almost gender neutral.

The results obtained from this study allowed conclusions concerning the integration of women in pediatric research. In summary, female representation in pediatrics was high, especially in relation to other scientific fields. The growth of the FAP over the analyzed time period reflected the increasing proportion of women in pediatrics. With regard to citation rates and the Prestige Index, gender parity was partially achieved.

In contrast, the distribution patterns of authorship types revealed distinct gender disparities with an emerging career dichotomy: Women were overrepresented at first-authorships, corresponding to early career stages. Men, on the other hand, were overrepresented at last-authorships, associated with leadership positions.

Interestingly, we revealed high FAP growth rates for last-authorships as well as increasing FAOR for last-authorship. These results implied that women increasingly occupied leadership positions. Linear projections indicated improving career opportunities for women in pediatric research in the coming years.

4 Abkürzungsverzeichnis

AAGR: Average Annual Growth Rate (durchschnittliche jährliche Wachstumsrate)

GGGR: Global Gender Gap Report

FAP: Female Authorship Proportion (Anteil weiblicher Autorenschaften)

FAOR: Female Authorship Odds Ratio. (Odds Ratio weiblicher Autorenschaft)

OR: Odds Ratio

PI: Prestige-Index

5 Übergreifende Zusammenfassung

5.1 Einleitung

Die Pädiatrie ist ein numerisch von Frauen dominiertes Fach.¹ Historisch gesehen hatten es Ärztinnen verhältnismäßig leicht, Einzug in die Pädiatrie zu halten, da die Versorgung von Kindern der gesellschaftlichen Rolle der Frau zugeschrieben wurde.² Im Laufe der Jahrzehnte kam es zu einem stetigen Zuwachs von Frauen in der Pädiatrie, welche schließlich die Mehrheit bildeten. So waren im Jahr 2018 in den USA 71% der pädiatrischen Assistenzärzte* Frauen.¹

Vor diesem Kontext stellten sich drei zentrale Fragen. Erstens, spiegelt sich die relative Zunahme des Frauenanteils auch in der pädiatrischen Forschung wider? Zweitens, welche zeitliche Dynamik hat die weibliche Repräsentation in der akademischen Pädiatrie? Drittens, bildet sich das Wachstum auch in der Besetzung von Führungspositionen ab?

Um diesen konkreten Fragestellungen nachzugehen, analysierten wir die Integration von Frauen in der pädiatrischen Forschung anhand wissenschaftlicher Autorenschaften von Originalartikeln. Dabei beruhte die Analyse zum einen auf der Prämisse, dass Erstautoren meist Wissenschaftler zu Beginn der Karriere und Letztautoren in der Regel Personen in Führungspositionen sind.³⁻⁵ Zum anderen setzten wir voraus, dass Erst- sowie Letzt-Autorenschaften mit einem höheren Prestige als Co-Autorenschaften einhergehen.^{3,6} Anhand der geschlechtsspezifischen Verteilung ließen sich folglich Rückschlüsse auf die hinter den Autorenschaften stehenden hierarchischen Strukturen ziehen.

Um repräsentative Ergebnisse zu erhalten, analysierten wir mehr als 690 000 Autorenschaften von pädiatrischen Originalartikeln, die zwischen 2008 und 2018 in insgesamt 400 Journalen publiziert wurden. Die Analyse umfasste den Anteil weiblicher Autorschaften, die Verteilung und Odds Ratio auf Erst-, Co- und Letzt-Autorenschaften sowie einen Prestige-Index. Dabei wurden die

* Aus Gründen der besseren Lesbarkeit wurde in der vorliegenden Arbeit das generische Maskulinum genutzt, welches männliche und weibliche Personen gleichermaßen einschließt.

zeitliche Entwicklung und geschlechtsspezifische Zitationszahlen ausgewertet und die Geschlechterverteilungen von Ländern, Journalen und pädiatrischen Teildisziplinen verglichen. Abschließend wurde eine lineare Prognose für das Jahr 2023 abgegeben.

5.2 Materialien und Methoden

Datenerfassung

Als Grundlage dieser Studie dienten pädiatrische englischsprachige Originalforschungsarbeiten, die zwischen dem 1. Januar 2008 und dem 31. Dezember 2018 veröffentlicht wurden. Die Daten akquirierten wir über die Kategorie „Pediatrics“ aus der Web of Science Core Collection. Die Integration, bibliometrische Analyse und algorithmische Geschlechterbestimmung wurden mittels der Software Gendermetrics.Net⁷ durchgeführt. Insgesamt wurden 156 642 Artikel von 363 518 Autoren aus 400 Journalen ermittelt. Anhand der Vornamen konnten 146 453 (= 40,3%) weibliche und 129 729 (= 35,7%) männliche Autoren identifiziert werden. Autoren mit geschlechtsneutralem Vornamen (16 673 = 4,6%) und nicht identifiziertem Vornamen (70 663 = 19,4%) wurden mit ihren entsprechenden Autorenschaften (162 400 Autorenschaften) von der Geschlechteranalyse ausgeschlossen. Die zugeordneten 690 436 männlichen und weiblichen Autorenschaften bildeten somit die Grundlage der Geschlechteranalyse.

Anteil weiblicher Autorenschaften und Odds Ratio weiblicher Autorenschaft

Im Rahmen der Analyse wurden Erst-, Co- und Letzt-Autorenschaften betrachtet. Dabei bezeichneten Co-Autorenschaften alle Autorenschaften, die sich zwischen einer Erst- und einer Letzt-Autorenschaft befanden. Einzelautorenschaften wurden als Erst-Autorenschaften gewertet.⁸

Analysierte Parameter waren der Anteil weiblicher Autorenschaften (Female Authorship Proportion, FAP) und die Odds Ratio weiblicher zu männlicher Autorenschaft (Female Authorship Odds Ratio, FAOR). Beide Kenngrößen wurden auf die Besetzung von Erst-, Co- und Letzt-Autorenschaften angewandt.

Die FAP bildet den Anteil weiblicher Autorenschaften an allen männlichen und weiblichen Autorenschaften ab und wird in Prozent angegeben.⁹

Die FAOR beschreibt die Odds Ratio von Frauen im Verhältnis zu Männern auf eine spezifische Autorenposition. Um beispielsweise die FAOR von Erst-Autorenschaft zu bestimmen, wird der Quotient von weiblichen zu männlichen Odds für eine Erst-Autorenschaft gebildet.⁹ Eine FAOR > 1 stellt dabei eine relative Überrepräsentation von Frauen für die entsprechende Autorenposition dar.¹⁰ Zur Veranschaulichung wurde ein FAOR-Triplett verwendet, um die jeweilige Repräsentation zu demonstrieren. Ein Triplett aus (+, =, -) beispielsweise, dokumentiert für weibliche Autoren signifikant höhere (+) Odds für eine Erst-Autorenschaft, gleiche (=) Odds für eine Co-Autorenschaft und signifikant niedrigere (-) Odds für eine Letzt-Autorenschaft.¹¹

Prestige-Index

Der Prestige-Index (PI) wurde als Maß für die Verteilung prestigeträchtiger Autorenschaften zwischen weiblichen und männlichen Autoren verwendet.¹¹ Die Berechnung des PI erfolgte aus den FAOR der Autorenschaftstypen. Hierbei wurden prestigeträchtige Erst- und Letzt-Autorenschaften positiv (+1) und Co-Autorenschaften negativ (-1) gewichtet. Ein PI von 0 charakterisierte eine geschlechtsneutrale Prestigeverteilung, während ein positiver (negativer) Prestige-Index anzeigt, dass Frauen relativ häufiger (weniger) prestigeträchtige Autorenschaften als Männer innehatten.¹¹

Datenanalyse

Durchschnittliche jährliche Wachstumsraten (Average Annual Growth Rates, AAGR) wurden durch die Bildung des Mittelwerts von n Jahreswachstumsraten ermittelt.¹² Die Berechnungen dienten als Grundlage für die lineare Prognose.⁹ Zur Sicherstellung der statistischen Signifikanz musste jede Subgruppe in den einzelnen Teilanalysen (Länder, Journale, pädiatrische Teildisziplinen) eine Geschlechtsdetektionsrate von mindestens 60% und mindestens 750 identifizierte männliche bzw. weibliche Autorenschaften aufweisen.¹¹ Durch die Anwendung dieser Kriterien wurden die Länder China und Südkorea sowie 287 Journale aus den jeweiligen Teilanalysen ausgeschlossen.

Die Korrelationskoeffizienten dieser Analyse wurden nach Pearson berechnet.

5.3 Ergebnisse

Status quo und zeitliche Entwicklung der weiblichen Repräsentation

Anhand unserer Daten konnten wir ermitteln, dass Frauen in der pädiatrischen Forschung mit einer FAP von 46,6% insgesamt unterrepräsentiert waren (Fig.1a). Autorinnen fanden sich auf 52,0% der Erst-, 47,6% der Co- und 37,5% der Letzt-Autorenschaften. Die jeweils zugehörige FAOR betrug 1,30 für eine Erst-Autorenschaft (KI: 1,28–1,32), 1,11 für eine Co-Autorenschaft (KI: 1,1–1,12) und 0,63 für eine Letzt-Autorenschaft (KI: 0,62–0,64). Das korrespondierende FAOR-Muster entsprach damit dem Triplet (+, +, -).

Bei der Betrachtung der Verteilung von prestigeträchtigen Autorenschaften zeigte sich ein negativer PI von -0,13. Dieser implizierte, dass Frauen hinsichtlich prestigeträchtiger Autorenschaften unterrepräsentiert waren.

Weiterhin konnten wir über den untersuchten Zeitraum hinweg eine zunehmende FAOR, sowohl für eine Erst-, als auch für eine Letzt-Autorenschaft feststellen. Bei einer zeitgleich abnehmenden FAOR für eine Co-Autorenschaft führte dies insgesamt zu einem Anstieg des PI auf -0,05 im Jahr 2018. Auch die FAP stieg in der untersuchten Dekade stetig von 42,5% im Jahr 2008 bis auf 49,9% im Jahr 2018 mit einer AAGR von 1,6% (Fig.1b). Bemerkenswerterweise wiesen Letzt- und Erst-Autorenschaft mit 2,2% und 2,0% die höchsten durchschnittlichen jährlichen Zuwachsraten auf.

Länderebene

Bei dem Vergleich der Länder (Table 1) fanden wir eine FAP, die zwischen 21,8% in Japan und 65,9% in Portugal divergierte. Auch bezüglich des PI zeigte sich hier eine große Spannweite. Den niedrigsten PI wies Italien mit -0,90 auf, der höchste PI wurde von den Niederlanden mit 0,54 erreicht. Bei Betrachtung der Autorenschaftstypen fiel auf, dass Frauen auf Letzt-Autorenschaften in beinahe allen Ländern unterrepräsentiert waren. Lediglich in Irland hatten Frauen höhere Odds als Männer für eine Letzt-Autorenschaft. Die Odds Ratio von Erst- und Co-Autorenschaften dahingegen zeigte überwiegend eine Überrepräsentation von Frauen oder war geschlechtsneutral.

Eine lineare Korrelation zwischen der FAP eines Landes und seinem PI konnte nicht nachgewiesen werden ($r = 0,18$, $P > ,05$).

Journalebene

Auf Journalebene (Table 2) imponierte die größte FAP-Spanne zwischen dem Journal of Pediatric Orthopaedic-Part B mit 19,4% und dem Journal of Pediatric Health Care mit 84,8% weiblicher Autorenschaften. Der PI divergierte zwischen -0,77 im Italian Journal of Pediatrics und 0,64 im Journal of Perinatal & Neonatal Nursing. Auch in dieser Teilanalyse zeigte die Odds Ratio bezüglich Erst- und Co-Autorenschaft überwiegend eine Überrepräsentation von Frauen oder war geschlechtsneutral. Trotz der zum Teil hohen FAP und PI Werte hatten Frauen in keinem einzigen Journal höhere Odds für eine Letzt-Autorenschaft als Männer.

Weiterhin konnte eine starke Korrelation von FAP und PI der pädiatrischen Fachjournale nachgewiesen werden ($r(101) = 0,74$, $P < ,01$, Supp. Fig. 3). Es fand sich allerdings kein linearer Zusammenhang zwischen dem 5-Year-Impact-Factor eines Journals und der jeweiligen FAP ($r(101) = 0,1$, $P > ,05$) oder dem PI ($r(101) = 0,1$, $P > ,05$).

Pädiatrische Teildisziplinen

In der Analyse von pädiatrischen Teildisziplinen (Table 3) wies die Gesundheitswissenschaft mit 83,5% die höchste FAP auf. Der höchste PI wurde von der pädiatrischen Krankenpflege mit 0,33 erreicht. Die Orthopädie stach in dieser Teilanalyse besonders hervor: Mit 23,3% bot sie sowohl die niedrigste FAP als auch den niedrigsten PI mit -0,54. Zudem zeigte sich in der Orthopädie, mit einem FAOR-Triplett von (-, +, -), auch die für Frauen ungünstigste Verteilung prestigeträchtiger Autorenschaften. In beinahe allen anderen Disziplinen hatten Frauen signifikant höhere Odds für eine Erstautorenschaft. Zusätzlich fiel auf, dass Männer in ausnahmslos allen pädiatrischen Teildisziplinen in Letzt-Autorenschaften signifikant stärker repräsentiert waren als Frauen.

Weiterhin zeigte sich eine starke Korrelation zwischen der FAP und dem PI einer Teildisziplin ($r(36) = 0,81$, $P < ,01$, Fig. 2).

Multiautorenartikel

Die Untersuchung von Multiautorenartikeln (Fig. 3) ergab, dass die Anzahl der Autoren pro Artikel kaum einen Einfluss auf die Repräsentation von Frauen

hatte. Konkret konnten wir zeigen, dass die FAP in Artikeln mit ein bis drei Autoren mit 45,7% ähnlich hoch war, wie in Artikeln mit >12 Autoren mit 47,0%. Allerdings konnte mit zunehmender Autorenanzahl ein dezenter Anstieg der FAOR für Co-Autorenschaft und gleichzeitiger Abfall der FAOR für Erst- und Letzt-Autorenschaft festgestellt werden. Dies führte zu einer akzentuierten Unterrepräsentation von Frauen in Bezug auf prestigeträchtige Autorenschaften in Multiautorenartikeln (>12 Autoren/Artikel) mit einem PI von -0,22 (vgl. 1-3 Autoren/Artikel PI = -0,1).

Zitations- und Produktivitätsanalyse

Ähnlich wurden auch die Zitationszahlen nur marginal vom Geschlecht der Erst- und Letztautoren beeinflusst (Fig. 4a). Die höchsten Zitationsraten wurden von Artikeln mit männlichen Erst- und weiblichen Letztautoren mit 11,1 Zitationen pro Artikel erreicht. Artikel mit umgekehrt weiblichen Erst- und männlichen Letztautoren erreichten eine ähnlich hohe Rate von 10,9 Zitationen pro Artikel. Hinsichtlich der wissenschaftlichen Produktivität konnten wir eine niedrigere Produktivität weiblicher Autoren im Vergleich zu männlichen Autoren nachweisen. Der Großteil der weiblichen Autoren (64,7%, Fig.4c) veröffentlichte im untersuchten Zeitraum einen einzigen Artikel. Während Frauen in den Gruppen von Autoren, welche ein oder zwei Artikel publizierten, überrepräsentiert waren, wurden alle höheren Produktivitätsstufen von Männern dominiert.

5.4 Diskussion

Vergleichsweise hohe weibliche Partizipation

In der pädiatrischen Forschung zeigte sich die Partizipation von Frauen und Männern beinahe ausgeglichen (FAP = 47,9%, Frauenanteil aller Autoren = 53%). In Relation zu bibliometrischen Daten der globalen akademischen Wissenschaft mit einer FAP von rund 30%¹³ oder medizinischen Bereichen wie Lungenkrebsforschung (FAP = 31,3%),¹⁴ Ophthalmologie (FAP = 34,9%)¹⁵ oder Dermatologie (FAP = 43,0%),⁸ stach die Pädiatrie durch eine außergewöhnlich hohe Beteiligung von Frauen hervor. Eine über die Zeit ansteigende FAP spiegelte den zunehmenden Anteil von Frauen in der Pädiatrie wider.¹⁶

Partielle Geschlechterparität

Neben der nahezu ausgeglichenen Partizipation, wies die Pädiatrie auch in anderen Aspekten Geschlechterparität auf. So unterlagen Zitationsraten keiner signifikanten Beeinflussung durch das Geschlecht der Schlüsselautoren. Auch ein steigender und 2018 beinahe geschlechtsneutraler PI von -0,05 zeigte eine insgesamt annähernd ausgeglichene Verteilung prestigeträchtiger Autorenschaften zwischen Männern und Frauen an.

Weibliche Unterrepräsentation in Führungspositionen

Bei der Betrachtung der Verteilungsmuster weiblicher Erst-, Co- und Letzt-Autorenschaften, wurden Geschlechterdisparitäten deutlich. Die durch uns detektierte erhöhte weibliche Repräsentation hinsichtlich einer Erst-Autorenschaft, ist Ausdruck einer Überrepräsentation von Frauen zu Karrierebeginn. Klassischerweise kommt es im weiteren Verlauf zum Phänomen der "leaking pipeline".¹⁷ Nachdem viele junge Frauen den wissenschaftlichen Karrierepfad betreten haben, verlassen sie ihn früher als ihre männlichen Kollegen. So kommt es auf Ebene von Führungspositionen zu einer Unterrepräsentation von Frauen. In unserer Studie kam dies durch eine weibliche Unterrepräsentation bezüglich Letzt-Autorenschaften zum Ausdruck. Karrieredichotomien wie diese sind in den meisten akademischen Disziplinen zu finden. Die Ursachen wurden bereits in zahlreichen Studien untersucht.^{6,13,17-24} So konnte unter anderem gezeigt werden, dass weibliche Hochschulabsolventen seltener als ihre männlichen Kollegen Führungspositionen anstreben.¹⁷ Gründe liegen unter anderem in einer höheren Priorisierung von Familienleben^{17,19} und einer zufriedenstellenden Work-Life-Balance,²⁵ aber auch im Fehlen von Vorbildern.²⁶

Bemerkenswerterweise ging aus unserer Analyse hervor, dass der Anteil weiblicher Publikationen insbesondere im Bereich der Letzt-Autorenschaften mit einer AAGR von 2,2% über besonders hohe Zuwachsraten verfügte (vergleiche AAGR 2,0% für Erst- und 1,3% für Co-Autorenschaften). Diese hohen Wachstumsraten der Letzt-Autorenschaft-FAP sowie eine deutlich ansteigende Letzt-Autorenschaft-FAOR zeigten an, dass Wissenschaftlerinnen in der pädiatrischen Forschung vermehrt Führungspositionen besetzten.

Wissenschaftliche Produktivitätsdifferenzen

Dass Frauen im Durchschnitt weniger Artikel publizierten als Männer, ist nicht nur für die Pädiatrie charakteristisch. Auch in anderen Disziplinen konnte ein Geschlechtergefälle festgestellt werden, welches insbesondere die frühe bis mittlere Karrierephase betraf.^{19,27} Reed et al.²⁷ kamen in einer retrospektiven Längsstudie unter langjährig tätigen Ärzten beispielsweise zu dem Ergebnis, dass Frauen pro Jahr 1,74 Publikationen weniger als Männer veröffentlichten. Ein Faktor, der zu niedrigeren Publikationsraten führte, ist eine kumulativ geringere von Frauen geleistete Arbeitszeit, da weibliche Angestellte signifikant häufiger als ihre männlichen Kollegen einer Teilzeitbeschäftigung nachgingen.²⁸ Hinzu kam, dass Frauen mitunter aufgrund von Schwangerschaften und Geburten zumindest kurzzeitig beruflich freigestellt wurden.¹⁹ Auch die Unterrepräsentation von Frauen in Führungspositionen stellt eine weitere Ursache für die Produktivitätsdifferenz dar. Dies begründet sich darin, dass ein hoher akademischer Rang mit der Betreuung und Veröffentlichung wissenschaftlicher Arbeiten und auch mit der Teilnahme an (Zitations-) Netzwerken verbunden ist.^{8,27,29} Zu bemerken ist hierbei, dass die wissenschaftliche Produktivität wiederum entscheidend ist, wenn es um die Besetzung hoher akademischer Positionen geht und eine niedrigere Produktivität somit auch eine Unterrepräsentation in Führungspositionen bedingen kann.^{27,30,31}

Einfluss soziokultureller Faktoren auf weibliche Integration

Wie unsere Länderanalyse zeigte, gab es große regionale Diskrepanzen in der Repräsentation von Frauen in der pädiatrischen Forschung. Da unsere Ergebnisse mit dem Global Gender Gap Report (GGGR)³² korrelierten, ist davon auszugehen, dass regionale Unterschiede kein Charakteristikum der Pädiatrie sind, sondern auf soziokulturelle Besonderheiten der jeweiligen Länder zurückzuführen sind. Ähnlich wie in anderen medizinischen Disziplinen,^{8,15,33} boten die Niederlande sowie die skandinavischen Länder Schweden, Norwegen und Dänemark die besten Karrierechancen für Frauen in der Pädiatrie. Interessanterweise korrelierte der PI nicht linear mit der FAP ($r = 0,18$, $P > 0,05$). Dies ließ den Schluss zu, dass ein Land mit einem hohen Anteil an Autorinnen nicht unbedingt gute Karrierechancen für Frauen bietet und ist

somit Ausdruck eines starken Einflusses von soziokulturellen Faktoren auf die Integration von Frauen in den Wissenschaftsbetrieb.

Homogene Strukturen in pädiatrischen Teildisziplinen

Pädiatrische Teildisziplinen wiesen eine große FAP-Spanne auf ($\Delta FAP = 60,2\%$). Dabei gab es sowohl Fächer mit einem deutlichen Frauenüberschuss, wie Kinderkrankenpflege (FAP = 78,8%), als auch Fächer mit einem deutlichen Männerüberschuss, wie Kinderorthopädie (FAP = 23,3%). Im Hinblick auf Publikationsmöglichkeiten kam dahingegen eine ausgeprägte Homogenität zum Ausdruck. Zum einen zeigten FAOR-Muster in 34 von 38 Teildisziplinen eine weibliche Überrepräsentation auf Erst-Autorenschaft bei gleichzeitiger weiblicher Unterrepräsentation auf Letzt-Autorenschaft. Zum anderen spiegelte auch die relativ kleine PI-Spanne ($\Delta PI = 0,87$) diese Homogenität wider. Zusammenfassend deuteten diese Ergebnisse darauf hin, dass die Forschungsgruppenstrukturen in fast allen pädiatrischen Teildisziplinen von überwiegend weiblichen Nachwuchswissenschaftlern und überwiegend männlichen Führungskräften geprägt waren. Die starke Korrelation zwischen FAP und PI der Teildisziplinen ($r = 0,81$, $P < ,01$) implizierte weiterhin, dass die weiblichen Karrierechancen vom Frauenanteil in der jeweiligen Teildisziplin beeinflusst wurden.

Disparitäten auf Journalebene

In der Untersuchung von Journalen fanden wir eine größere FAP- und PI-Spanne ($\Delta FAP = 65,4\%$, $\Delta PI = 1,41$) als auf Ebene der Teildisziplinen. Die Akzentuierung der Disparität kam durch die Kombination soziokultureller und fachlicher Einflussfaktoren der einerseits länderbezogenen Journalen, andererseits fachbezogenen Journalen zustande. So bot beispielsweise das *Italian Journal of Pediatrics* analog zur Länderanalyse die schlechtesten Publikationsmöglichkeiten für Frauen.

Auf Journalebene konnten wir eine lineare Korrelation von FAP und PI nachweisen ($r = 0,74$, $P < ,01$). Hatte ein Journal also einen hohen Anteil weiblicher Autoren, so standen diese auch häufig in prestigeträchtigen Autorenschaftspositionen. Bemerkenswerterweise konnte keine Korrelation zwischen dem 5-Year-Impact-Factor und der FAP ($r = 0,1$, $P > ,05$) oder dem PI

($r = 0,1$, $P > ,05$) eines Journals festgestellt werden. Demnach wurde die Integration von Frauen in der pädiatrischen Forschung nicht von der Stellung eines Journals beeinflusst. Dieses Ergebnis sprach gegen die Existenz eines dominanten "old boys' network", welches die Publikationsmöglichkeiten von Frauen negativ beeinflussen kann. Hierin hoben sich die pädiatrischen Journale deutlich von anderen hochrangigen Wissenschaftsjournalen ab, für welche Bendels et al.⁹ eine negative Korrelation des PI und 5-Year-Impact-Factor nachweisen konnten.

Zeitliche Prognose

Anhand der vorgestellten Daten konnte eine lineare Prognose für 2023 abgegeben werden (Supp. Fig. 2). Steigende FAP und FAOR für Erst- und Letzt-Autorenschaft in Kombination mit sinkenden FAOR für Co-Autorenschaft würden demnach zu einem Wechsel des FAOR-Triplets von (+, +, -) auf (+, =, -) führen. Außerdem prognostizierten wir einen positiven PI von 0,05 für das Jahr 2023. Somit ist mit einer Verbesserung der Karrierechancen von Frauen in der pädiatrischen Forschung zu rechnen. Die männliche Überrepräsentation in Führungspositionen bleibt dabei voraussichtlich bestehen.

Fazit

Die Ergebnisse dieser Studie veranschaulichen, dass die Integration von Frauen in der pädiatrischen Forschung im Vergleich zu anderen wissenschaftlichen Disziplinen^{9,12-15,34,35} fortgeschritten ist. Mit nahezu ausgeglichenen Publikationszahlen und Zitationsraten sowie einer beinahe geschlechtsneutralen Verteilung prestigeträchtiger Autorenschaften, wird in einigen Bereichen Geschlechterparität erreicht. Jedoch besteht eine geschlechtsspezifische Karrieredichotomie mit überwiegend Frauen in frühen Karrierephasen und überwiegend Männern in Führungspositionen. Die zeitliche Dynamik bildet einen insgesamt zunehmenden Anteil von Frauen mit relativer Akzentuierung in Führungspositionen ab. Linearen Hochrechnungen zufolge ist mit sich zunehmend verbessernden Karrierechancen für Frauen in der pädiatrischen Forschung zu rechnen. Die Möglichkeiten können auf Länderebene jeweils deutlich differieren. Zukünftige Untersuchungen werden zeigen, ob der "Gender-Gap" in der pädiatrischen Forschung geschlossen wird.

6 Übersicht über die Publikation

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

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SPECIAL ARTICLE **OPEN**



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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IMPACT:

- There is a measurable progress in the integration of female scientists.
- Gender-neutrality is partially achieved in pediatric research with yet a female underrepresentation in leading positions.
- Our descriptive study presents gender-related dynamics in pediatric research that forecast improving career opportunities for female scientists.

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.² 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.⁴⁻⁶ 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.^{12,21,22} 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.⁵ 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

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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,²⁴ a SQL server-based software.²⁴ 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).²⁴

Gender determination

The gender determination was algorithmically conducted through Gendermetrics.Net by evaluation of the authors' first name(s).²⁴ 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 a least 60% male and female authorships were included.¹³ The application of the stated criteria led to an 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.¹¹ Single authorships were rated as first-authorships, authorships of articles with two authors were counted as first- and last-authorship.¹¹ Co-authorships described all authorships between one first- and one last-authorship.¹¹

The female authorship proportion (FAP) is the percentage of female authorships out of all female and male authorships ($FAP = \frac{\text{Authorships}_{\text{female}}}{\text{Authorships}_{\text{female}} + \text{Authorships}_{\text{male}}}$).¹²

In contrast, the female authorship odds ratio (FAOR) describes the relative distribution of female authors over first-, co- and last-authorships compared to men.¹² 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 ($FAOR_{\text{first}} = \frac{\text{Female Odds}_{\text{first}}}{\text{Male Odds}_{\text{first}}}$).¹² 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.²⁵ FAORs are determined with a confidence level of 95%.¹³

To provide a good overview, a FAOR triplet is used to present the relative chance distributions.¹³ 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.¹³

Summarized, the FAP measures the proportion of female authorships, whereas the FAOR gives information about distribution odds over first-, co- and last-authorships.¹¹

Prestige Index

The Prestige Index (PI) is a measure of the distribution of prestigious authorships between male and female authors.¹³ Bendels et al.¹³ introduced and defined the Prestige Index "as the prestige-weighted average of the FAOR excess ϵ_t that is calculated over all authorship types t [...] with the weighting factor w_t ".¹² It was computed by $\epsilon_t = w_t (FAOR_t - 1)$ if $FAOR_t \geq 1$ and $\epsilon_t = w_t (1 - 1/FAOR_t)$ if $FAOR_t < 1$.¹² Since first- and last-authorships are associated with a high reputation they are weighted positively with $w_{\text{first}} = w_{\text{last}} = 1$, while co-authorships are weighted with $w_{\text{co}} = -1$.^{6,13} 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.¹⁰ 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.¹³ 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.¹² Significance thresholds were set at 0.05.¹²

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, 63.0% in Serbia, and 65.9% 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 =

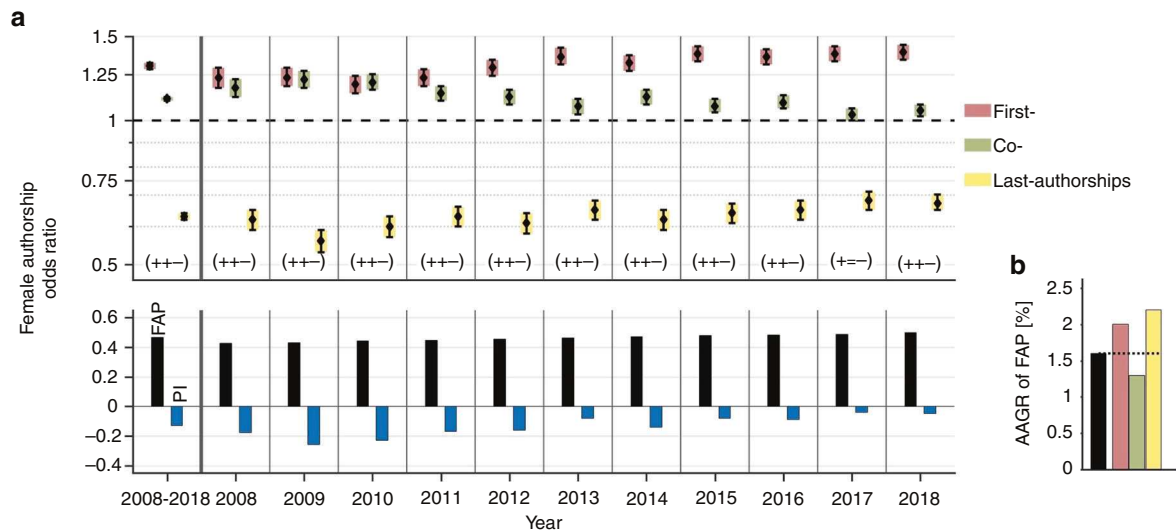


Fig. 1 Time trend of female authorships on the global level. **a** The female authorship odds ratio (FAOR, top) with associated FAOR triplets, the proportion of female authorships (FAP, bottom) and the Prestige Index (PI, bottom) are depicted averaged over time and by year from 2008 to 2018. The average 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. **b** The average annual growth rate (AAGR) of the FAP exhibits a yearly increase of 1.6% on average with highest growth rates for last- and first-authorships, which are associated with a higher prestige.

-0.77), *Journal of Neurosurgery—Pediatrics* ($PI = -0.64$), and *Journal of Pediatric Orthopedics* ($PI = -0.57$). In contrast, the best female odds for prestigious authorships are found in the *Journal of Pediatric Health Care* ($PI = 0.54$), *Journal of Pediatric Nursing—Nursing Care of Children & Families* ($PI = 0.57$), and *Journal of Perinatal & Neonatal Nursing* ($PI = 0.64$).

Regarding FAORs, the journals are characterized by almost uniform authorship distributions. In 94 out of 113 journals, we find higher or equal female odds for first- and co-authorships and lower odds for women to hold last-authorships. Three journals (*Child And Adolescent Mental Health*, *Developmental Neurorehabilitation* and *Journal Of Perinatology*) stand out with a gender-neutral authorship distribution ($=, =, =$). Three other journals (*Childs Nervous System*, *Journal of Pediatric Orthopedic*, and *Journal of Pediatric Orthopedic-Part B*) show the most unfavorable FAOR triplet $(-, +, -)$. These journals are also characterized by low Prestige Indices ($PI = -0.49, -0.57, -0.43$) and relatively low FAPs ($FAP = 29\%, 25.3\%, 19.4\%$).

Indeed, the journal's FAP and Prestige Index correlate strongly ($r(101) = 0.74, P < 0.01$) (Supp. Fig. 3). Interestingly, no linear correlation is found between a journal's 5-Year-Impact-Factor and (a) FAP ($r(101) = 0.1, P > 0.05$) or (b) Prestige Index ($r(101) = 0.1, P > 0.05$).

Differences among subject areas

On the level of subject areas, the FAP values yield between 23.3% in *Orthopedics*, 30.5% in *Surgery*, and 34.8% *Cardiovascular System & Cardiology* and 69.7% in *Rehabilitation*, 78.8% in *Nursing*, and 83.5% in *Health Care Sciences & Services* (Table 3).

Lowest odds ratios for women to hold prestigious authorships are found in the subject areas *Orthopedics* ($PI = -0.54$), *Surgery* ($PI = -0.39$), and *Sport Sciences* ($PI = -0.34$). In contrast, the highest Prestige Indices are found in *Health Care Sciences & Services* ($PI = 0.12$), *Public, Environmental & Occupational Health* ($PI = 0.14$), and *Nursing* ($PI = 0.33$).

A gender-neutral distribution of prestigious authorships ($PI = 0$) is found at the subject area *Dentistry, Oral Surgery & Medicine*, that interestingly also has an almost balanced FAP of 51.6%.

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 FAP 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 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 per article, while articles with >12 authors achieve an average citation rate of 17.8 citations/article (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 53.4% 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%	(+, -, -)	3263	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%	(=, =, =)	485	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,^{9-11,13} this analysis reveals that, in fact, the majority of authors in pediatric research are female (53.0%). 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 Pediatria	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-Basel	-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

Table 2. continued

Journal name	Prestige Index	Proportion of female authorships	FAOR triplet	No. of articles	No. of authorships
Pediatric Cardiology	-0.30	34.1%	(+, +, -)	2329	10,422
International Journal of Pediatric Otorhinolaryngology	-0.31	39.5%	(+, +, -)	3813	14,151
European Journal of Pediatric Surgery	-0.31	35.3%	(+, =, -)	838	2372
European Journal of Pediatrics	-0.33	48.4%	(+, +, -)	2161	11,267
Pediatric Exercise Science	-0.33	38.3%	(=, +, -)	536	2300
Pediatrics and International Child Health	-0.33	45.3%	(+, =, -)	310	1025
Archives of Disease in Childhood-Fetal and Neonatal Edition	-0.35	46.9%	(=, +, -)	871	3454
Frontiers in Pediatrics	-0.36	47.6%	(=, +, -)	599	3149
World Journal of Pediatrics	-0.36	38.5%	(=, +, -)	587	1949
Clinics in Perinatology	-0.36	43.3%	(=, =, -)	557	1163
Congenital Anomalies	-0.39	31.6%	(=, =, -)	260	1357
Journal of Pediatric Surgery	-0.4	34.3%	(+, +, -)	4960	24,729
Pediatric Neurosurgery	-0.41	23.4%	(=, +, -)	612	2411
Seminars in Pediatric Surgery	-0.42	31.4%	(=, +, -)	500	1176
Journal of Pediatric Orthopedics-Part B	-0.43	19.4%	(-, +, -)	997	3700
Childs Nervous System	-0.49	29.0%	(-, +, -)	2488	10,485
Journal of Pediatric Urology	-0.51	30.7%	(=, +, -)	1557	5407
Archivos Argentinos de Pediatría	-0.51	59.9%	(=, +, -)	392	2042
Journal of Pediatric Orthopedics	-0.57	25.3%	(-, +, -)	1889	8288
Journal of Neurosurgery—Pediatrics	-0.64	24.5%	(=, +, -)	2038	10,457
Italian Journal of Pediatrics	-0.77	53.4%	(=, +, -)	655	3727

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

47.9%. When set in relation to bibliometric data of the whole field of academic science with a FAP of <30%¹⁷ or other recently evaluated medical fields like research about lung-cancer (31.3%),⁹ prostate cancer (31.7%),¹⁰ epilepsy (39.4%),¹³ or dermatology (43.0%),¹¹ pediatrics stands out with an exceptionally high participation of women. The continuously rising FAP reflects the increasing proportion of women in medicine, particularly in pediatrics.²⁶

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 differs strongly from other scientific fields, in which female authors achieve significantly less 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,²⁷ they often leave the scientific career path earlier than men do.^{1,7} 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,²⁸ 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.³⁶

There are multiple reasons for productivity imbalances. One reason can be found in the female underrepresentation in leading

Table 3. Classification by journals' subject areas.

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.

positions. Since higher academic rank is associated with high levels of supervision and publication of scientific work and participation in (citation-) networks,^{11,36} female underrepresentation leads to fewer authorships.³⁸ Another reason for productivity differences might be found in the fact that young female scientists are often absent from work for at least a small period of time due to child bearing.³⁰ In addition, female pediatricians have more household responsibilities than their male colleagues³⁹ and more than one-third of female pediatricians in the US work part-time.⁴⁰ Interestingly, the gender-related difference in part-time work accentuates at ages 40–49, 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 underrepresentation 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.^{9–12,25} The Netherlands and the Scandinavian countries Sweden, Norway and Denmark lead the PI rankings in several medical disciplines,^{9,11,12} indicating that they

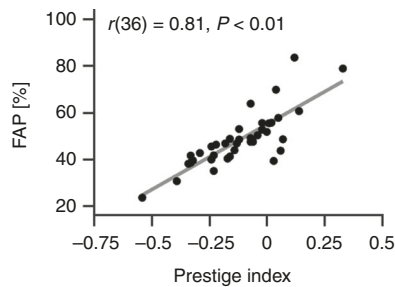


Fig. 2 Correlation of parameters in subject areas. The Prestige Index and the proportion of female authorships (FAP) are strongly correlated.

provide the best career opportunities for female researchers.⁵ The opposite applies to countries such as Japan, Italy, and Greece, most of which are at the bottom of the PI rankings.^{9–12,25}

Since these findings also correlate with the Global Gender Gap Report (GGGR),⁴¹ 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.¹³ 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.³¹

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,⁴² 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* FAP = 23.3%), while others are female-dominated (e.g., *Nursing* FAP = 78.8%). These findings agree with the gender distribution of the respective subjects in adult medicine.^{1,43} Fischer et al.¹⁹ found an underrepresentation of women in Pediatric Orthopedics, too.¹⁹ 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.¹⁹

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.⁴²

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

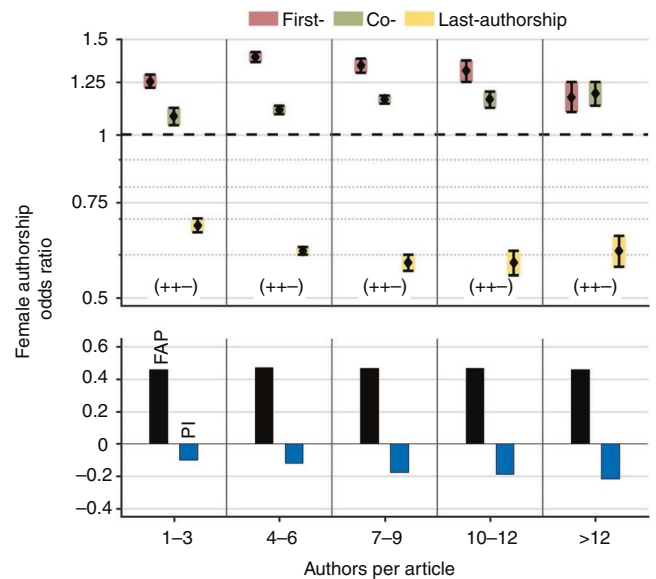


Fig. 3 Female authorships by authors per article. With an increasing number of authors per article, the proportion of female authorships (FAP) remains almost constant. In contrast, the Prestige Index (PI) decreases in multi-authored articles due to a female disadvantaged shift of prestigious authorships.

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 ($r = 0.1$, $P > 0.05$) nor the Prestige Index ($r = 0.1$, $P > 0.05$), indicating that the impact of a journal does not affect the integration of female scientists in pediatric research.

Outlook

In contrast to other fields,^{7,12} 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

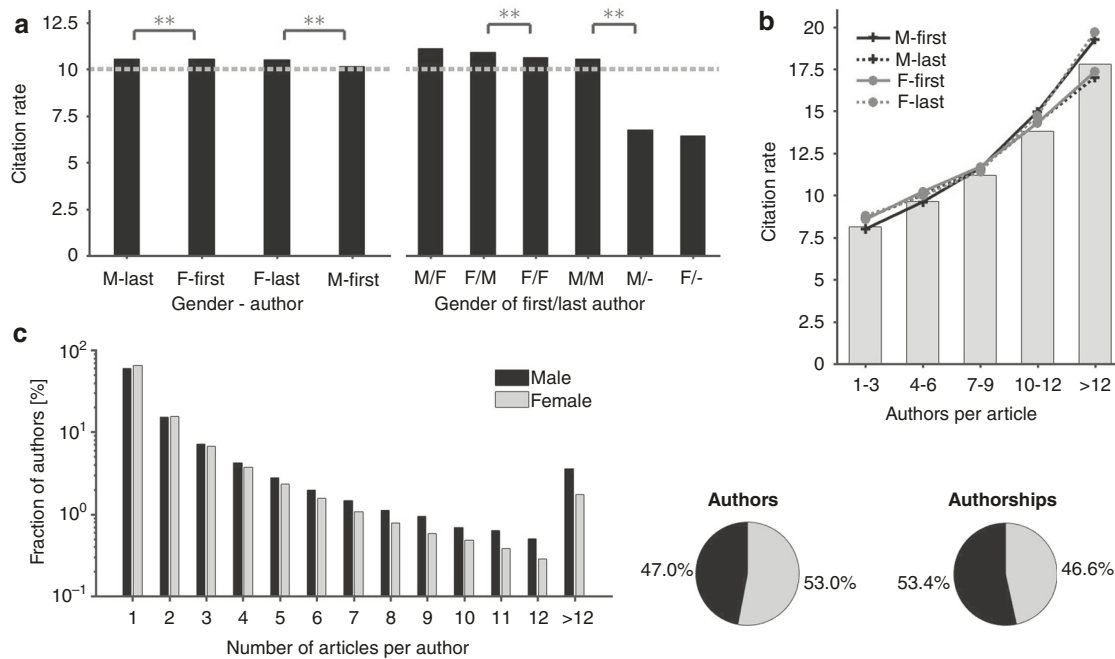


Fig. 4 Gender-specificity of citations and scholarly productivity. **a** (left) The descending ordered citation rates reveal only marginal differences between the two genders. The citation rates range from 10.1 citations/article (male first-author) to 10.6 citations/article (male last-author). The dotted line marks the average citation rate of 10.0 citations/article. **a** (right) The analysis of combined authorships reveals that interestingly, mixed key authorships reach significantly higher citation rates than articles with unisex key authorships. Articles published by only one author attract lowest citation rates. **b** The average citation rates by authors per article are depicted ungrouped (bar) and grouped by gender of the key authorships (lines). Citation rates increase with the number of contributing authors. Gender-specific differences in citation rates are minor. **c** (left) Articles per author by gender. Female authors are over-represented in the groups of authors with only one or two published articles, while male authors dominate all other subgroups. **c** (right) The higher productivity of male authors is shown by the fact that 53.4% of all authorships are held by 47% male authors.

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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AUTHOR CONTRIBUTIONS

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The authors declare no competing interests.

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8 Darstellung des eigenen Anteils an der Publikation

Katja Böhme

- Literaturrecherche
- Datenanalyse und Interpretation
- Verfassung des Artikels
- Journalwahl und Einreichung des Artikels
- Korrespondierende Autorin und Revisionen

Doris Klingelhöfer

- Anmerkungen zur Interpretation

David A. Groneberg

- Anmerkungen zur Interpretation

Michael H. K. Bendels

- Konzept und Design der Studie
- Datenakquise durch die Gendermetrics Software
- Erstellung von Abbildungen und Tabellen
- Anmerkungen zur Datenanalyse und Interpretation

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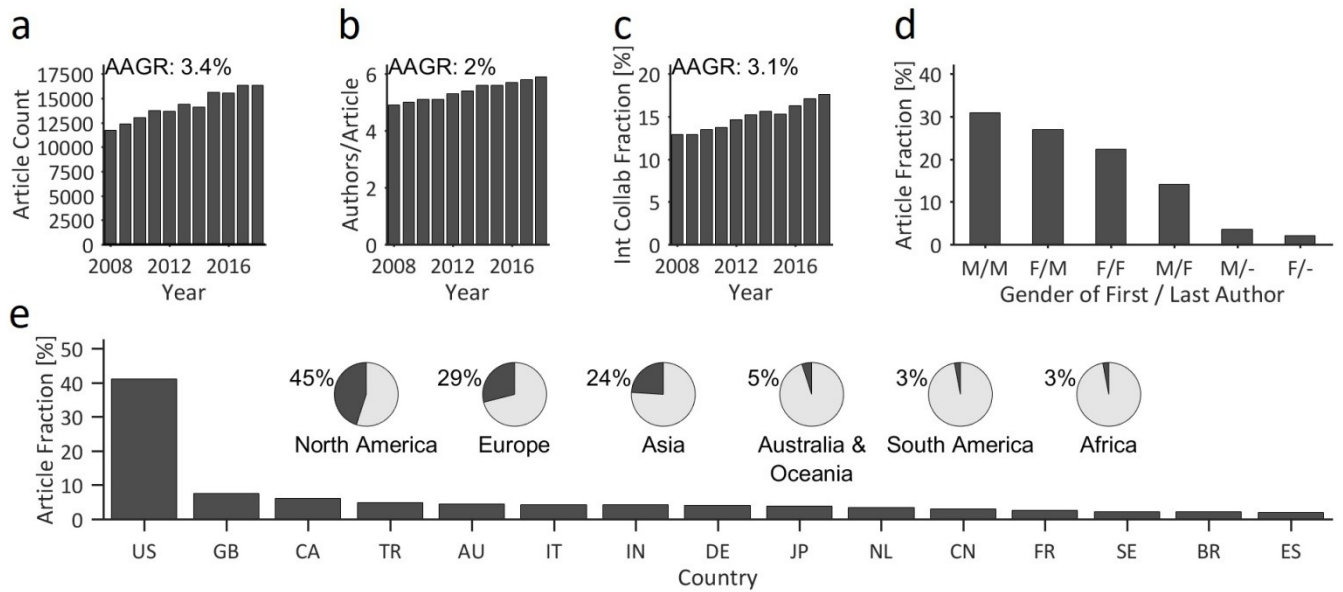
10 Anhang:

Supplementary figures

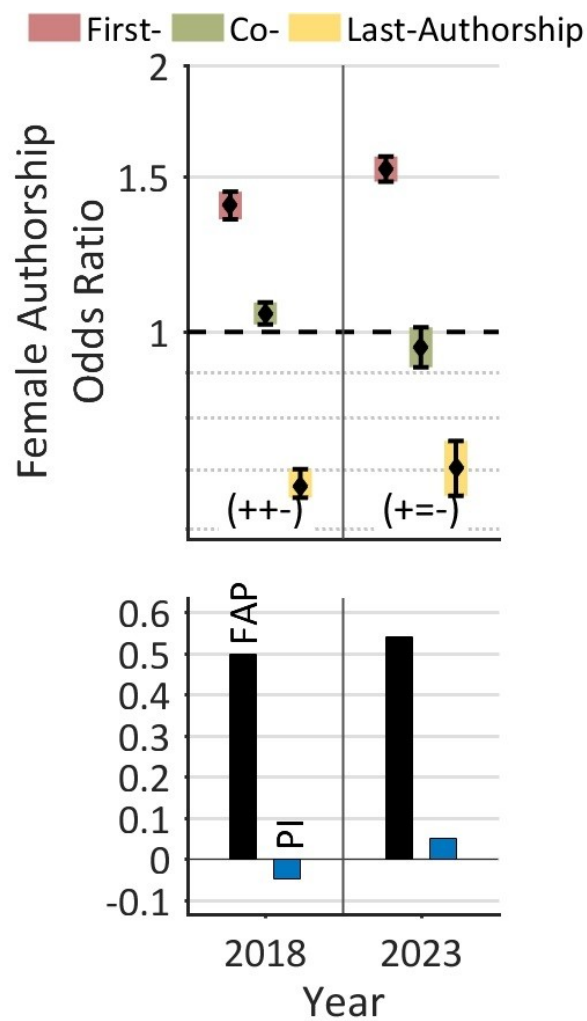
Supp. Figure 1: Overview of published articles worldwide

Supp. Figure 2: Linear projection

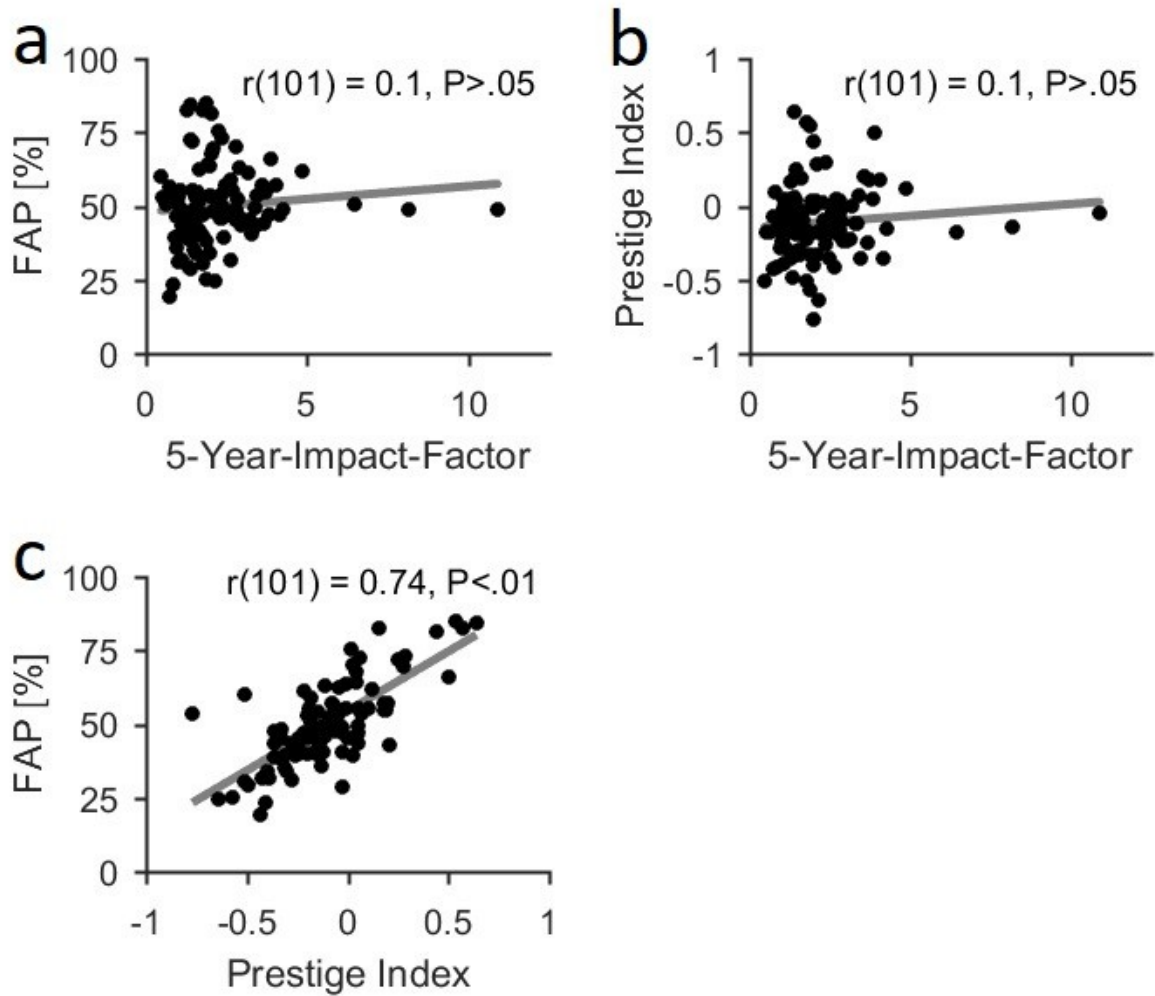
Supp. Figure 3: Correlation of journal parameters



Supp. Figure 1: Overview of published articles worldwide. (a) The number of published articles in the academic field of pediatrics increases from year to year with an average annual growth rate of 3.4%. While in 2008 only 11,741 original articles were published, 16,315 articles were released in 2018. **(b)** The number of authors per article has been ascending from 2008 to 2018. **(c)** A clear tendency of a growing fraction of collaboration articles is exhibited. **(d)** With 30.9% the highest proportion of articles is published by male scientists in key authorships. More male than female researchers publish articles as single authors. **(e)** The fraction of articles is displayed by continents and countries. By far North America, is the leading continent with a share of 45% of all published articles in the field of pediatric research, comprising the US with an overall article fraction of 41%. The second highest productive continent is Europe followed by Asia. Australia & Oceania, South America and Africa stand behind with a fraction of 5% or less.



Supp. Figure 2: Linear projection. The prognosis forecasts that the proportion of female authorships (FAP) will continue growing up to 54.0% in 2023. The female odds ratios for first- and last-authorships will increase, while the odds ratios for co-authorships of women will drop below one, resulting in a switch of the FAOR-triplet from (+, +, -) to (+, =, -) and a positive Prestige-Index (PI) of 0.05 in 2023.



Supp. Figure 3: Correlation of journal parameters. (a, b) There is no linear correlation of a journals 5-Year-Impact-Factor and it's proportion of female authorships (FAP) or Prestige-Index found. (c) A strong correlation is revealed between the Prestige-Index and the FAP of journals.

11 Schriftliche Erklärung

Ich erkläre ehrenwörtlich, dass ich die dem Fachbereich Medizin der Johann Wolfgang Goethe-Universität Frankfurt am Main zur Promotionsprüfung eingereichte Dissertation mit dem Titel

Geschlechterdisparitäten in der pädiatrischen Forschung: Eine deskriptive bibliometrische Studie über wissenschaftliche Autorenschaften

Im Institut für Arbeits-, Sozial- und Umweltmedizin der Goethe Universität Frankfurt unter Betreuung und Anleitung von PD Dr. Dr. Michael H. K. Bendels mit Unterstützung durch Prof. Dr. Dr. h.c. mult. David A. Groneberg ohne sonstige Hilfe selbst durchgeführt und bei der Abfassung der Arbeit keine anderen als die in der Dissertation angeführten Hilfsmittel benutzt habe. Darüber hinaus versichere ich, nicht die Hilfe einer kommerziellen Promotionsvermittlung in Anspruch genommen zu haben.

Ich habe bisher an keiner in- oder ausländischen Universität ein Gesuch um Zulassung zur Promotion eingereicht. Die vorliegende Arbeit wurde bisher nicht als Dissertation eingereicht.

Vorliegende Ergebnisse der Arbeit wurden in folgendem Publikationsorgan veröffentlicht:

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(Ort, Datum)

(Unterschrift)