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Gender disparities in high-quality dermatology research - a study on scientific authorships

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List of Abbreviations

AAGR: Average Annual Growth Rate

FAOP: Proportion of Female Authorships

FAP: Female Authorship Ratio

PI: *Prestige Index*

Abstract

Objective: The present study aims to elucidate the state of gender equality in high-quality dermatological research by analyzing the representation of female authorships from January, 2008 to May, 2017.

Design: Retrospective, descriptive study.

Setting: 113,189 male and female authorships from 23,373 research articles published in twenty-three dermatological Q1 journals were analyzed with the aid of the Gendermetrics Platform.

Results: 43.0% of all authorships and 50.2% of the first-, 43.7% of the co- and 33.1% of the last-authorships are held by women. The corresponding female-to-male odds ratios are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The annual growth rates are 1.74% overall and 1.45% for first authorships, 1.53% for co-authorships, and 2.97% for last authorships. Women are slightly underrepresented at prestigious authorships compared to men. The underrepresentation remains stable in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals. Multi-author articles with male key authors are only slightly more frequently cited than those with female key authors. Women publish slightly fewer papers compared to men (47.2% women hold 43.0% of the authorships). At the level of individual journals, there is a high degree of uniformity in gender-specific authorship odds. By contrast, distinct differences at country level were revealed. The prognosis for the next decades forecasts a consecutive harmonization of authorship odds between the two genders.

Conclusions: Female scholars are well-represented in the field of high-quality dermatological research compared to other medical disciplines. A gender gap consists mainly in the form of a career dichotomy, with many female early career researchers and few women in academic

leadership positions. However, this gender gap has been narrowed in the last decade and will likely be further reduced in the future.

Keywords: odds ratio; prestige; citations; productivity; career

Strengths and limitations of this study

- Methodically, our purely bibliometric and algorithmic approach enables us to analyze large volumes of data standardized and independent of the examiner, and thus with a minimized interindividual variability.
- However, it is limited by the absence of information concerning equally distributed authorships, corresponding authors, as well as data providing information about the scholar's academic degree, their position (e.g. Associate Professor vs. Full Professor)[1], age, employment status and their participation on editorial boards [24,40].
- Furthermore, the investigation period is technically limited to articles that are published after 2007 due to the predominance of initials preventing a correct gender identification by first names in older articles [18].

Introduction

The past decades have seen an enormous increase in the number of women entering medicine[1]: While in 1969, 6.9% of the U.S. medical graduates were women, the percentage reached a value of 47.5% in 2014[2]. The enrollment in U.S. medical school in 2016 was almost evenly divided between women (49.8%) and men (50.2%)[3]. Despite this enormous increase of women entering the field of medicine, "across medicine and dermatology, this influx has not been accompanied by a parallel progress by female faculty with academic credentials or in leadership roles", as stated by an editorial of Alexa Kimball[4] and many articles have addressed different gender and generational aspects in academic dermatology in the past years [5-7 8 9]. In 2012, Sadeghpour et al. published results from a national survey on the role of sex in academic dermatology[1]. They assessed whether there is an association between gender and academic rank. They came to the conclusion that sex-based differences in academic dermatology, including career track, academic rank distribution, leadership, and career satisfaction, persist[1]. Of a total of 259 full-time US academic dermatologists (38.6% were female), they found that men held more senior positions even after adjustment for age and number of years since completion of residency[1]. Working hours did not differ significantly. While most men (90.3%) and women (82.8%) were satisfied with their career, women were 24.6% more likely than men to consider leaving academia[1].

Bearing these gender issues in mind, we here focused on the following question: When gender disparities are present in academic rank, how is gender balanced in the academic community that undertakes and publishes high-quality clinical, translational and basic research in dermatology worldwide?

As stated previously, an indicator for the balance between integration of female and male

dermatologists and scientists is the quantification of their scholastic activity as represented by “authorship” in scientific publications[10-13]. In general, authorships represent the currency system of research and academic community[14]. In original medical articles, the assignment of authorship follows, by convention, the rule that "the first author indicates the person whose work underlies the paper as a whole"[15], whereas the last authorship "indicates a person whose work or role made the study possible without necessarily doing the actual work" [15]. Thus, the assignment of authorships differs considerably from, for example, economics or mathematics, where authors are usually listed in alphabetical order [14]. One consequence is that an early-career researcher normally publishes as first or co-author, whereas a senior researcher prefers the last author position in original research articles[16,17]. A further consequence of this assignment rule is that the different types of authorships are associated with different prestige. Specifically, first and last authorships have a significantly higher reputation than co-authorships[16].

Based on these consideration, we here applied the recently established Gendermetrics Platform [18] to analyze the integration of women in high-quality dermatological research by assessing 113,189 male and female authorships from twenty-three dermatological Q1 journals.

Conceptually, we determined the proportion of female first, co- and last authorships and quantified the relative distribution of female authorships among the different authorships compared to men by applying odds ratios. Moreover, we used the *Prestige Index* to analyze the distribution of prestigious authorships between the two genders. The analysis includes global status and temporal development, differences across countries and the role women tend to have in articles with many authors, e.g. collaboration on articles [12]. Moreover, a

gender-specific analysis of scholarly productivity and citation rate was conducted. The study concludes with a ten-year forecast regarding the development of gender disparities in the field of high-quality dermatological research.

Methods

Data acquisition & integration

The data analysis was conducted using Gendermetrics.NET[18], a SQL-Server based Platform for analyzing bibliometric data with a special emphasis on gender aspects. Research articles from high impact dermatology journals listed in the Scimago Journal & Country Rank database (http://www.scimagojr.com/journalrank.php?category=2708) were acquired on May 15, 2017 from the Web of Science Core Collection (Thomson Reuters). The journals constitute the subset of dermatological Q1 journals representing the top 25% of the corresponding impact factor distribution. The journals '*Fibrogenesis and Tissue Repair*', '*Infectious Diseases in Obstetrics and Gynecology*' and '*Dermatology and Therapy*' were not considered because there were not indexed in the Web of Science database. The journals *'Aids Research and Treatment*', '*BMC Dermatology*', '*Clinics in Dermatology*', '*Dermato-Endocrinology*' and '*HIV/AIDS-Research and Palliative Care*' were excluded from analysis due to a low number of articles (< 200 articles). Furthermore, the journals '*British Journal of Dermatology*' and *'Journal of the European Academy of Dermatology and Venereology*' had to be excluded from analysis due to the predominant usage of initials instead of full first names, which prevents the correct gender determination. In total, 23 of the 33 dermatological Q1-journals with 23,373 articles written by 74,354 authors remain for analysis.

Gender determination

The algorithmic gender determination operates on the basis of a data table containing the gender of 77,818 forenames (male, female or unisex), see Bendels et al.[18]. By applying the algorithm, 30,538 (= 41.1%) male authors, 27,261 (= 36.7%) female authors, 5,509 (= 7.4%) unisex authors and 11,046 (= 14.9%) undefined authors were determined with a relatively little inter-annual variability (supplementary Fig. 2). The Unisex and undefined authors and

their authorships were not taken into consideration (in total 27,182 authorships). As a result, 113,189 male and female authorships affiliated to institutions from 150 countries were analyzed. The research output of a country was thereby benchmarked by considering the authorships of the related institutions[12]. It is important to note, that the quality of gender detection depends on the authorships country as illustrated by supplementary Fig. 3. In order to ensure the validity of the *country-specific* analysis, we set a threshold criterion for the country-specific analysis (supplementary Fig. 3), as recently described in Bendels et al. [18]. In particular, only countries with a detection rate of at least 79.3% male or female authorships were considered. As a result, among the top 20 most productive countries, the Asian countries China, South Korea (with high rates of unisex names) and India (with many undefined names) were excluded. A bibliometric overview is given in supplementary Fig. 1.

Proportion of Female Authorships (FAP) & Female Authorship Odds Ratio (FAOR)

In this study, first-, co- and last-authorships were considered, whereby co-authorships encompasses all authorships between *one* first- and *one* last-authorship. Equally distributed authorships were not considered due to a lack of information. The ***proportion of female authorships*** (***FAP***) is defined as the quotient between the female authorship count and the total sum of male and female authorships. The FAP is presented as a percentage to improve the textual readability. The female to male odds ratios for first-, co- and last-authorships were determined (***female authorship odds ratio***, ***FAOR***) with the corresponding confidence intervals at a confidence level of 95%[12]. The FAOR measures the female odds of securing a particular authorship type compared to men. A FAOR of e.g. 2.0 or 0.5 means that women or men, respectively, have twice the odds of holding a particular authorship compared to respective other gender[12]. For a simplified representation, a triplet is used to indicate the sign of the *significant* female odds ratio excess to get a particular authorship. For example,

the FAOR-triplet **(-, =, +)** indicates that women have *significantly* lower odds ratios for first-, equal odds ratios for co- and significantly higher odds ratios for last-authorships compared to men[12]. In summary, the FAP measures the quantitative representation of female authorships, whereas the FAORs quantify the relative distribution of female authorships among the different authorships[12]. To increase the statistical significance, the FAP/FAOR-classification is only conducted for subjects (e.g. countries) with at least 750 male or female authorships.

Prestige Index

The *Prestige Index* measures the female odds of holding prestigious authorships compared to men[12]. It is defined as the prestige-weighted average of the FAOR excess ε_t that is calculated over all authorship types t (i.e. for first, co- and last authorships), $\varepsilon_t = w_t\,(FAOR_t - 1)$, if $FAOR_t \geq 1$, otherwise $\varepsilon_t = w_t\,(1 - 1/FAOR_t)$ with the weighting factor w_t[12]. In medical science, the prestige of scholarships follows a ranked order with a higher reputation of first and last authorships and a lower reputation of co-authorships [16]. Specifically, a potentially alphabetical ordering of the author list was excluded by an additional test (supplementary Fig. 5). Therefore, co-authorships were weighted negatively ($w_{co} = -1$), whereas first and last authorships were weighted positively ($w_{first} = w_{last} = 1$)[12]. This definition implies that the *Prestige Index* is e.g. lowered by both higher odds for co-authorships and lower odds for first and last authorships. A value of 0 characterizes a balanced distribution of prestigious authorships between the two genders, whereas a value above (below) 0 indicates an excess (lack) of prestigious authorships held by women.

Analysis of data

Average annual growth rates (AAGR) were applied to characterize annual growth rates[12]. The AAGRs of both, FARs and number of authorships were used to make a linear prognosis of the

temporal development of FAP, FAOR and *Prestige Index* for the coming decade. The Pearson correlation was applied to evaluate the linear association between the FAP, the *Prestige Index* and the Scimago Journal Rank Index (SJRI). The latter index was applied as an indicator for the scientific impact of the journals. The null hypothesis, whether the *non-normally* distributed gendered citation rates (supplementary Fig. 4) stem from the same distribution, was tested by a Kruskal-Wallis-test and a post-hoc multi-comparison test. The significance threshold was set at .05.

Results

Female authorships on a global level

In a first step, we analyzed the representation of female authorships on a global level. The analysis reveals an underrepresentation of female authorships with a FAP of 43.0% (Fig. 1A, bottom), relatively more first-authorships (50.2%), an almost equal proportion of female co-authorships (43.7%) and a substantially less fraction of last-authorships (33.1%). The corresponding FAORs (Fig. 1A) are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The differences are statistically significant (P<.05) for all types of authorships between the two genders. Thus, the global FAOR-pattern is characterized by the FAOR-triplet (+, +, -), i.e. women have significant higher odds for first and co-authorships and significant lower odds for last-authorships. The *Prestige Index* is on average -0.11, indicating a minor lack of prestigious authorships held by women (Fig. 1A, bottom).

The FAP exhibits a relatively high increase over the evaluation period (39.5% in 2008, 46.1% in 2017, Fig. 1B) with an AAGR of 1.74%. The subanalysis reveals a disproportionally high annual growth for last authorships (2.97%) and disproportionally low values for co- (1.53%) and first authorships (1.45%). Overall, this led to more gender-neutrality in authorships odds during the recent years, as also indicated by the *Prestige Index* (-0.19 in 2008 and -0.11 in 2017).

Differences across countries

When we refined our analysis from global to country-specific level, we identified among the most productive countries a wide range of FAPs that extent from 66.7% in Finland to 25.3% in Japan (Table 1). Different FAOR-patterns were identified ranging from *unfavorable* with the FAOR-triplet (=, +, -) identified in Poland, Italy, and Spain to *favorable* with the FAOR-triplet (+, -, =) in Denmark, Finland and the Netherlands (Table 1). Israel provides gender-

neutrality with respect to all authorships (FAOR-triplet (=, =, =)). The majority of the countries exhibit FAOR-patterns that are characterized by lower female odds for last and higher female odds for first authorships compared to men. Remarkably, there is not a single country where women have currently higher odds for a last authorship compared to men.

When considering the distribution of prestigious authorships, we found countries with very high *Prestige Indices*, like Denmark (*Prestige Index* = 0.60), Finland (0.54), and the Netherlands (0.42). In these countries, women have higher odds to hold a prestigious authorship compared to men. By contrast, Italy (*Prestige Index* = -0.46), Spain (-0.50), Japan (-0.51) and Austria (-0.58) are characterized by a lack of prestigious authorships held by women. Remarkably, we found no significant correlation between the FAP of a country and its *Prestige Index* (r(18)=0.36, P>.05).

Differences across journals

At the level of individual journals, the FAP ranges from 53.4% in *Sexually Transmitted Diseases* to 32.9% in *Lasers in Surgery and Medicine* (Table 2). The predominant FAOR-pattern is characterized by the FAOR-triplet (+, =, -). Moreover, in almost all journals (with the exception of *Contact Dermatitis*) women have significant lower odds for last-authorships. Furthermore, no single journal currently exists, where a) male scholars have significantly higher odds for first authorships compared to their female counterparts, and b) where women have higher odds to secure last authorships than men.

The *Prestige Index* value range is from -0.50 to 0.19 (Table 2): Best odds for women to secure prestigious authorships are given in *Contact Dermatitis* (*Prestige Index* = 0.19) and *Acta Dermato-Venereologica* (0.11), whereas *Dermatology* (-0.5) and *Mycoses* (-0.41) provide best odds for male scholars. We found no significant correlation between the a) FAP of the

journal and its *Prestige Index* (r(21)=0.08, P>.05), b) the FAP and the SJRI (r(21)=0.28, P>.05), and c) the SJRI and the *Prestige Index* (r(21)=0.30, P>.05).

Female authorships by authors per article

We also assess the role women tend to have in articles with many authors, e.g. collaborative articles. The FAP fluctuates between 40.9% (1-3 authors/article) and 43.7% (7-9 authors/article) and exhibits no significant correlation to the number of authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article) (Fig. 2). In addition, the FOAR for co-authorships shows no significant relationship to the author rate. As a consequence, the *Prestige Index* fluctuates between -0.02 (13-15 authors/article) and -0.21 (>15 authors/article). To summarize, FAP, FAORs and *Prestige Index* show no clear correlation to the number of authors per article.

Citation & Productivity Analysis

The analysis reveals that articles with male key authors are more frequently cited than articles with female authors (Fig. 3A). However, the differences are very low as articles with a male last or first author have average citation rates of 9.7 citations/article and 9.6 citations/article, respectively and articles with a female first or last author exhibit citation rates of 9.1 citations/article and 9.0 citations/article, respectively. Statistically significant differences in the distributions of citation rates were only found between articles with male last authors and all other article groups (Kruskal-Wallis-Test, P<.05). Articles with a female first or last authorship were on average below the mean citation rate of 9.2 citations/article.

The analysis of combined authorships shows that male-first/female-last and male-first/male-last articles have on average the highest citation rates with 10.1 citations/article and 9.9

citations/article, respectively, followed by female-first/male-last (9.5 citations/article) and female-first/female-last (8.5 citations/article) articles (Figure 3A, right). Single-authored articles have the lowest citation rates with slightly higher citation rates for male-authored articles (6.8 citations/article vs. 6.5 citations/articles).

The analysis further demonstrates that statistically the citation rate of an article gets higher the more authors are involved, e.g. articles with 1-3 authors are on average cited 7.8 times, whereas articles with more than 15 authors are cited 15.9 times on average (Fig. 3B). Furthermore, the revealed differences in the citation rates between articles with male or female key authors are not preserved when articles are grouped by the length of their author list, as shown by Fig. 3B. In this grouping scheme, articles with female last authors and more than 15 authors attract the highest citation rates of on average 18.6 citations per article.

Considering the gender-specific distribution of the article count per author, we found, that the subgroups 'author of 1 article' and 'author of 2 articles' are relatively dominated by women. In particular, 71.5% of the female authors, but only 68.1% of the male authors had published a single article in our data set (Fig. 3C). By contrast, all other subgroups with three or more articles per author show a relative overrepresentation of male authors. Particularly, the subgroup of most productive authors ('author of more than 10 articles') is considerably dominated by men (2.4% of the male authors vs. 1.2% of the female authors). This finding results in a slightly higher productivity of male authors, as 53.0% of male authors hold 57.0% of all authorships (Fig. 3C).

Discussion

Advanced integration of women

The field of high-quality dermatological research is characterized by a moderate underrepresentation of female authorships with an FAP of 43.0%. This value is considerably higher than the previously determined FAPs, which were found for the whole area of science (30%) [11], for six high-quality medical journals (34%)[19], and for similar studies from the research fields of epilepsy (39.4%)[12], schizophrenia (37.6%)[10], stroke research (36.3%, unpublished data), and lung cancer research (31.3%)[20].

Female scholars are inhomogeneously distributed across the different authorships: We found many female first authorships and a significantly lower proportion of female last authorships. Evidently, this finding illustrates the well-known, gender-specific career dichotomy as first- or co-authorships are usually held by early career researchers, whereas last authorships are regularly preserved for institutional heads or principal investigators [16]. Such a discrepancy in leadership positions has been described for the most scientific disciplines [11], including various medical research fields[1,10,12,21-24]. What are the reasons for such a striking career dichotomy between the two genders? Differences in career preferences between men and women are one reason that can be cited in this regard[25]. Specifically, it has been shown that men were more likely to occupy investigative career tracks (26.5% vs. 11.1%), whereas women predominantly occupied clinical educator tracks (81.5% vs. 50.0%) in U.S. dermatology [1]. Other reasons include altered life priorities like family planning[11], the lack of role models[24], an insufficient work-life balance[24], women's increased likelihood to occupy part-time positions[1], and the consistently high influx of female medical students and graduates[24].

Interestingly, low female odds for last-authorships are numerically compensated by high female odds for first-authorships. This constellation leads to an almost gender neutral distribution of prestigious authorships on the global level. This finding is important, since academic publishing at prestigious authorships is one of the core elements of career advancement in science[10,26-28]. However, the underrepresentation of last authorships potentially reduces the further career advancement of the female scientists[29], since last authorships are often taken as a major indicator of successful leadership, e.g. by committees making this a criterion in granting and hiring[16]. In line with this, a cross-sectional survey from 2009 revealed a clear sex difference in academic *senior* ranks of U.S. dermatologists, as it was reported that "women were predominantly at the assistant professor level (50.0%) compared with men (24.3%), whereas men were predominantly at the full professor level (47.4%) compared with women (14.9%)"[1]. Evidently, in dermatology, the proportion of female faculty members declined as academic rank increased.

Stable representation of women in multi-author articles results in almost gender-neutral citation rates

Remarkably, we found no significant relationship between the representation of female authorships and the number of authors per article. Specifically, the representation of female authorships remains also stable for articles with high numbers of authors (e.g. collaboration articles), which statistically attract the highest citation rates (Fig. 3B)[30]. This is an important result, since it provides a good explanation for the almost equal citation rates of articles that were grouped by the gender of their keys authors. This is particularly remarkable, since for all other disciplines we have examined so far, we find a) an accentuating underrepresentation of women at prestigious authorships with an increasing number of authors per article and b) significantly higher citation rates of articles with male key authors. Moreover, previous studies from various disciplines also reported about substantially higher

citation rates for articles with male key authors[11,27,29,31,32]. To summarize, well-balanced citation rates between the two genders suggest that the integration of women in dermatological science is well-advanced. Methodically, it is important to note that the determined citation rates describe essentially the situation from the early phase of investigation (2008-2010), since older articles have a stronger impact on the citation statistics than newer articles ("Cited Half-Life")[33].

Structural position affects productivity

The lower productivity of female scholars (47% female authors hold 43% of the authorships) is in line with reports from other scientific fields and medical disciplines[10-12,21-23,34]. Interestingly, we were able to reproduce the clear male overrepresentation at levels of higher productivity (Fig. 3C), as already shown for the fields of ecology and evolutionary biology[32], and the medical research fields of schizophrenia[10] and epilepsy[12]. It is reasonable to assume that the primary factors affecting women's productivity are not higher rejection rates as explicitly shown for the journals *Cortex*[35] and *Nature Neuroscience*[36], but rather, due to the position of women within the scientific system[26]. In practice, the mainly male senior scientists are often associated to more or less fruitful (citation) networks, whereas "women are more likely to work as adjuncts or at teaching-intensive institutions with limited resources" [26]. This assumption is confirmed by a previous study from Sadeghpour et al.[1] documenting no differences in the number of publications of full-time academic dermatologists after adjustment for academic rank. Moreover, it has been shown by Reed at al. [34] that women's publication rates start to increase later in their career.

Distinct regional differences

Apart from these global findings, distinct regional differences were found with best-balanced authorship odds between the two genders in Israel (FAOR-triplet (=, =, =), *Prestige Index* = -0.01). When taking the chance of holding a prestigious authorship as a general surrogate

parameter for career advancement in science [12], Denmark, Finland, and the Netherlands provide the best conditions for female authors. By contrast, Italy, Spain, Japan, and Austria offer optimal conditions for men in dermatological research. This finding correlates quite well with the results of the Global Gender Gap Report 2016 as the countries Finland, the Netherlands and Denmark were ranked 2nd, 16th, and 19th, respectively, whereas the countries Spain, Italy, Austria, and Japan were ranked 29th, 50th, 52nd and 111th, respectively, out of a total of 144 countries in the world [37]. It is plausible to assume that these regional differences are not caused by discipline-specific characteristics, but rather, are primarily due to socio-cultural surroundings, as, for example, Japan is characterized by a strong sense of patriarchy and traditional gender roles in society[38]. This is all the more relevant, since similar constellations were found in most of our studies[10,12]. Overall, the given information supplies women operating in the field of dermatology with a solid basis for decision-making for professional reorientation or career planning.

As in all our previous studies, we did not find a significant correlation between the FAP of a country and the distribution of prestigious authorships between the two genders[10]. This means, countries with a high FAP can also provide disadvantageous career opportunities for women and vice versa. A valuable example is Italy with a high rate of FAP (54.2%) and a negative *Prestige Index* (-0.46). Interestingly, this finding is contrary to the socio-cultural theory of the critical mass[39], postulating a self-sustained harmonization of gender aspects once the participation of women has exceeded a critical threshold value of about 30% to 35%.

Journals with a high degree of uniformity

At the level of individual journals, we reveal a striking uniformity of gender-specific authorship odds, as in 19 out of 23 journals women have significantly higher odds for first

authorships and lower odds for last authorships. Evidently, the global gender-specific hierarchy of research groups is mapped to the related journals. This finding explains also the relatively small value range of the journals' Prestige Index compared to that of other countries (Δ*Prestige Index*: 0.69 vs. 1.18). Remarkably, we do not find a significant correlation between the impact of a journal (characterized by the SJRI) and the revealed Prestige Index measuring the distribution of prestigious authorships between the two genders. Interestingly, this finding is contrary to a previously unpublished study analyzing the female authorship odds in fifty-four of *highest-quality* research journals listed in the Nature Index, which covers the journal categories *Life Science*, *Multidisciplinary*, *Earth & Environmental* and *Chemistry*. In this study a clear negative correlation between the 5-year-impact factor of a journal and its Prestige Index ($r(52)=-0.63$, $P<.01$) was revealed. In contrast to academic dermatology, in this cross-discipline group of highest-impact journals, the female underrepresentation is accentuated in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals. To conclude, uniformity of authorship odds as well as stable representation of women regardless of the journal impact speak for an advanced integration of women and against the predominance of "old boys' networks" in the field of high-quality dermatology research and its related journals[12].

Conclusion & Outlook

In conclusion, a) the relatively high FAP, b) the almost gender-neutral citation rates, and c) the stable representation of female scholars in both articles with many authors as well as highest impact journals can be considered indicators for a well-advanced integration of women in high-quality dermatological research. However, a considerable career dichotomy is still present, with many female researchers at the beginning of their career and few

women in academic leadership positions. Since there is a clear time-dependence present in authorship hierarchy - current early career researchers may be future research leaders – it is plausible to prognosticate a considerable increase of women in academic leadership positions in the next decade. This trend will likely be intense due to the high annual increase of female authorships (1.74%) with the highest rates for the last author position (2.97%), and the global trend of more and more female physicians entering the field of medicine [2]. In line with this perspective, a linear prognosis of the temporal development of female authorships prognosticates not only an FAP of 54.3% for the year 2026, but also increasing female odds for last authorships and decreasing female odds for co-authorships (Fig. 4). This harmonization in authorship odds results in a Prestige Index that is forecast to become almost gender-neutral in 2026 (*Prestige Index* = -0.03). On this basis, we expect a deeper integration of female scientists with a growing number of women in academic leadership positions in the next decade. However, it should be critically mentioned that, contrary to this prediction, various studies recently report about a striking persistence of gender inequalities regarding academic leadership positions despite a considerable increase in female first authorships [22-24,41].

In view of this, the present analysis may define a starting point: Continuous monitoring over the next years will elucidate if female career dichotomy will break down, leading to a more balanced distribution of research leaders between both genders in dermatological research.

CONTRIBUTORSHIP STATEMENT

MHB and DAG designed the study. MHB and MCD collected and performed the analysis. MHB, MCD, DB, GMO, NS and DAG interpreted the result. MHB wrote the first draft of manuscript. MHB, MCD, DB, GMO, NS and DAG contributed to and have approved the final manuscript.

DATA SHARING STATEMENT

No additional data available.

COMPLIANCE WITH ETHICAL STANDARDS

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Table 1: Country Classification. Countries are descendingly ordered by their *Prestige Index*. The number of considered male and female authorships is given by #Authorships.

Country Name	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Denmark	43.4%	(+, -, =)	0.60	637	2,392
Finland	66.7%	(+, -, =)	0.54	177	787
Netherlands	44.8%	(+, -, =)	0.42	941	3,400
Brazil	56.1%	(+, -, -)	0.14	959	4,141
Turkey	45.2%	(+, =, =)	0.08	518	1,930
Sweden	53.7%	(+, =, -)	0.07	630	2,118
Israel	38.3%	(=, =, =)	-0.01	331	1,032
Canada	42.1%	(+, =, -)	-0.04	816	2,160
Germany	37.6%	(+, =, -)	-0.09	2,498	10,438
Australia	42.6%	(+, =, -)	-0.10	817	3,016
United States	42.9%	(+, +, -)	-0.14	8,391	33,510
Belgium	51.2%	(+, =, -)	-0.16	378	1,001
France	48.9%	(+, =, -)	-0.17	1,171	5,566
United Kingdom	45.8%	(+, +, -)	-0.18	1,751	4,825
Switzerland	34.3%	(+, =, -)	-0.26	560	1,659
Poland	54.2%	(=, +, -)	-0.39	257	967
Italy	54.2%	(=, +, -)	-0.46	1,269	6,455
Spain	48.8%	(=, +, -)	-0.50	711	3,073
Japan	25.3%	(+, +, -)	-0.51	1,564	8,126
Austria	38.6%	(+, +, -)	-0.58	475	1,760

Table 2: Journal Classification. Journals are descendingly ordered by their *Prestige Index*.

Country Name	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Contact Dermatitis	49.5%	(+, -, =)	0.19	721	3,623
Acta Dermato-Venereologica	47.4%	(+, =, -)	0.11	834	4,749
Sexually Transmitted Infections	50.1%	(+, =, -)	0.06	1,110	4,369
Wound Repair and Regeneration	38.1%	(+, =, -)	0.03	847	4,354
Journal of Dermatological Science	33.4%	(+, =, -)	0.03	727	3,763
Journal of the American Academy of Dermatology	44.9%	(+, =, -)	-0.01	2,103	11,338
Sexually Transmitted Diseases	53.4%	(+, =, -)	-0.05	1,370	7,500
Journal of Investigative Dermatology	42.1%	(+, =, -)	-0.06	2,392	16,865
Lasers in Medical Science	40.1%	(+, =, -)	-0.1	1,550	6,130
American Journal of Clinical Dermatology	47.5%	(+, =, -)	-0.13	263	981
Melanoma Research	44.6%	(+, =, -)	-0.14	616	3,845
Dermatologic Surgery	35.9%	(+, =, -)	-0.16	1,715	6,473
Archives of Dermatological Research	41.6%	(+, =, -)	-0.16	799	3,355
Lasers in Surgery and Medicine	32.9%	(+, =, -)	-0.17	938	4,161
Pigment Cell & Melanoma Research	42.9%	(+, =, -)	-0.18	510	3,199
Experimental Dermatology	41.9%	(+, +, -)	-0.19	1,644	8,732
International Wound Journal	37.1%	(=, +, -)	-0.21	891	3,877
JAMA Dermatology	47.2%	(+, +, -)	-0.27	491	3,163
Journal of Dermatological Treatment	45.1%	(+, +, -)	-0.3	655	2,590
Dermatologic Clinics	47.3%	(+, +, -)	-0.35	569	1,205
Clinics In Dermatology	43.6%	(=, +, -)	-0.39	743	1,732
Mycoses	47.0%	(=, +, -)	-0.41	974	3,710
Dermatology	41.7%	(+, +, -)	-0.5	911	3,475

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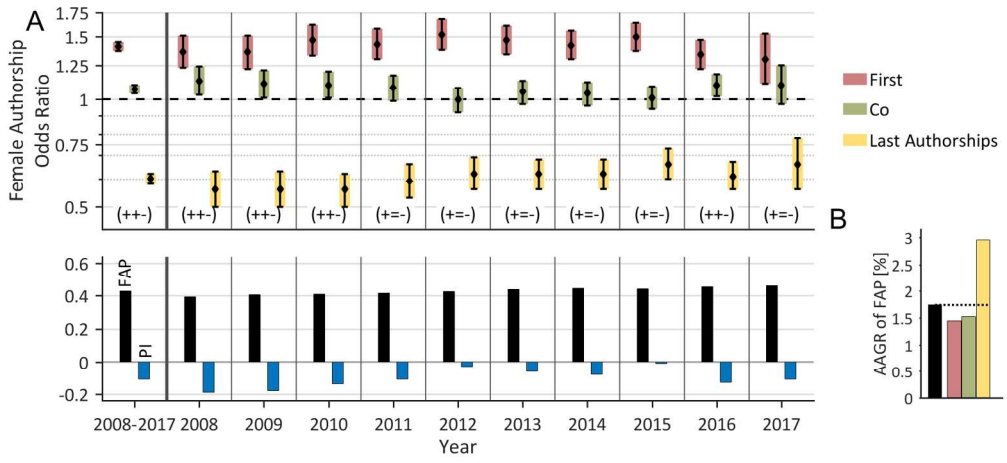
Figure Legends

Fig 1: Time trend of female authorships on the global level. (**A**) The relative frequency of female authorships (FAP, bottom), the pattern of FAORs (with FAOR-triplet, top) and its associated Prestige Index (PI) are depicted by year and averaged over time. The averaged FAOR distribution is characterized by the FAOR-pattern (+, +, -), i.e. women have significantly higher odds for first and co-authorships and significantly lower odds for last-authorships. The slightly negative PI indicates a lack of prestigious authorships held by women. (**B**) The FAP exhibits a relatively high increase as documented by its average annual growth rate (AAGR) of 1.74% per year with the highest rate for last authorships (2.97%). Overall, this led to more gender-neutrality in authorships odds during the recent years.

Fig 2: Female authorships by authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article). FAP, FAORs and Prestige Index show no clear correlation to the number of authors per article.

Fig 3: Gender-specificity of citations & scholarly productivity. (**A**) The descendingly ordered citation rates show that articles with male key authorships are slightly more frequently cited than articles with female key authorships. The mean citation rate of 9.2 citations/article is depicted by a dotted line (Kruskal-Wallis test, (*): P<.05 (**): P<.01). (**B**) Average citation rates of ungrouped articles (bars) and articles that were grouped by the gender of their key authorships (lines), depicted as a function of the number of authors. Statistically, the citation rate of an article is higher the more authors are involved. The gender-specific differences in citation rates are not preserved across the different levels of author count. (**C**) Gender-specific distribution of the article count per author. Women dominate the sub-groups 'author has one or two article(s)'. All other sub-groups are characterized by a relatively over-representation of male authors. This finding correlates with the higher productivity of male authors, as 52.8% male authors are responsible for 57.0% of all authorships.

Fig 4: Linear projection of the development of female authorships on the global level. The prognosis for the next decades forecasts a further harmonization of authorship odds between the two genders with an almost gender-neutral distribution of prestigious authorships in 2026 (*Prestige Index* = -0.03). An FAP of 54.3% is prognosticated for the year 2026.



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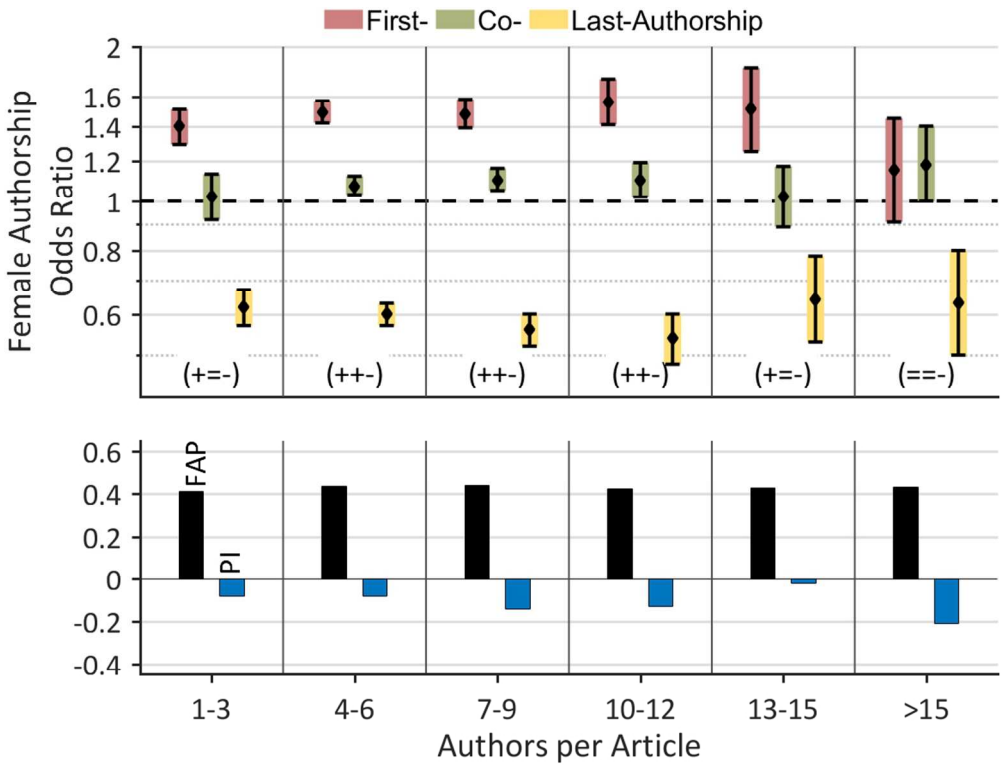

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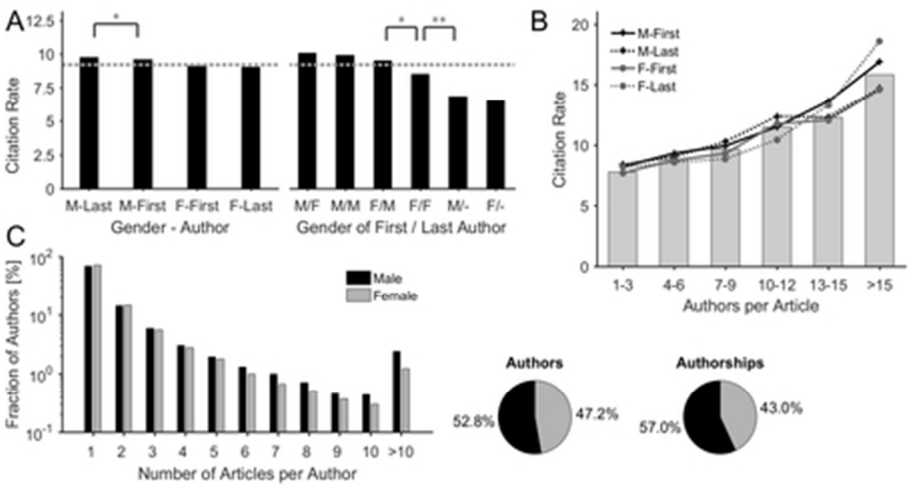

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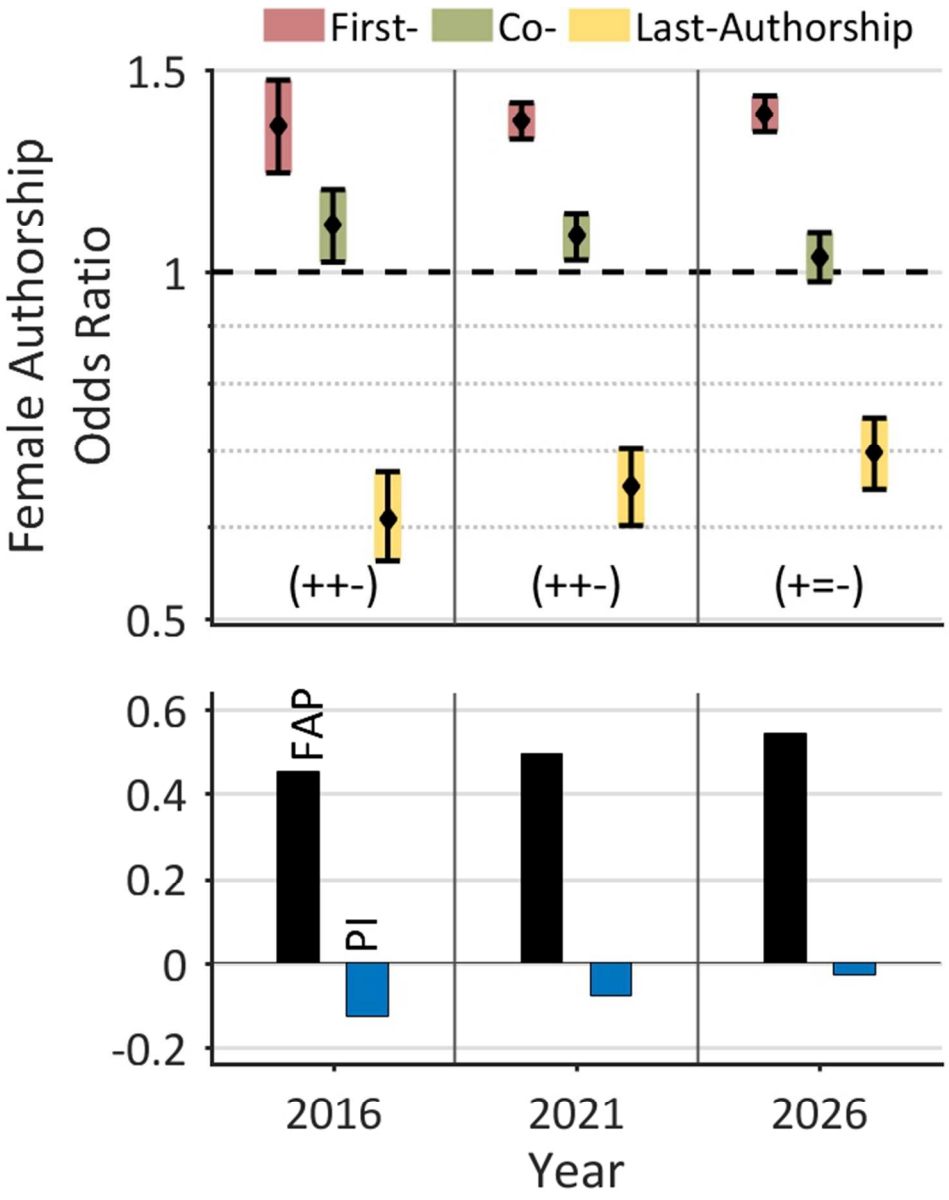

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59x74mm (300 x 300 DPI)

Online Supplement

Gender disparities in high-quality dermatology research - a study on scientific authorships

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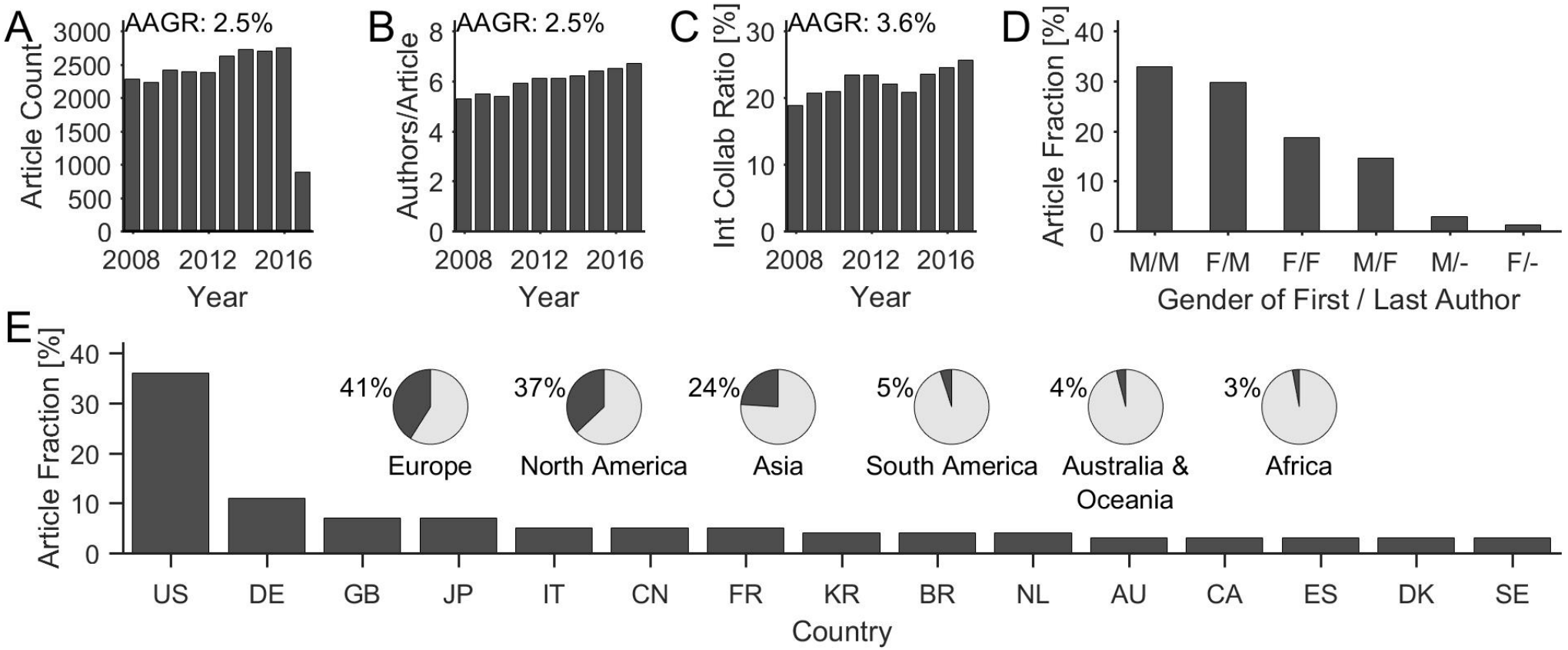
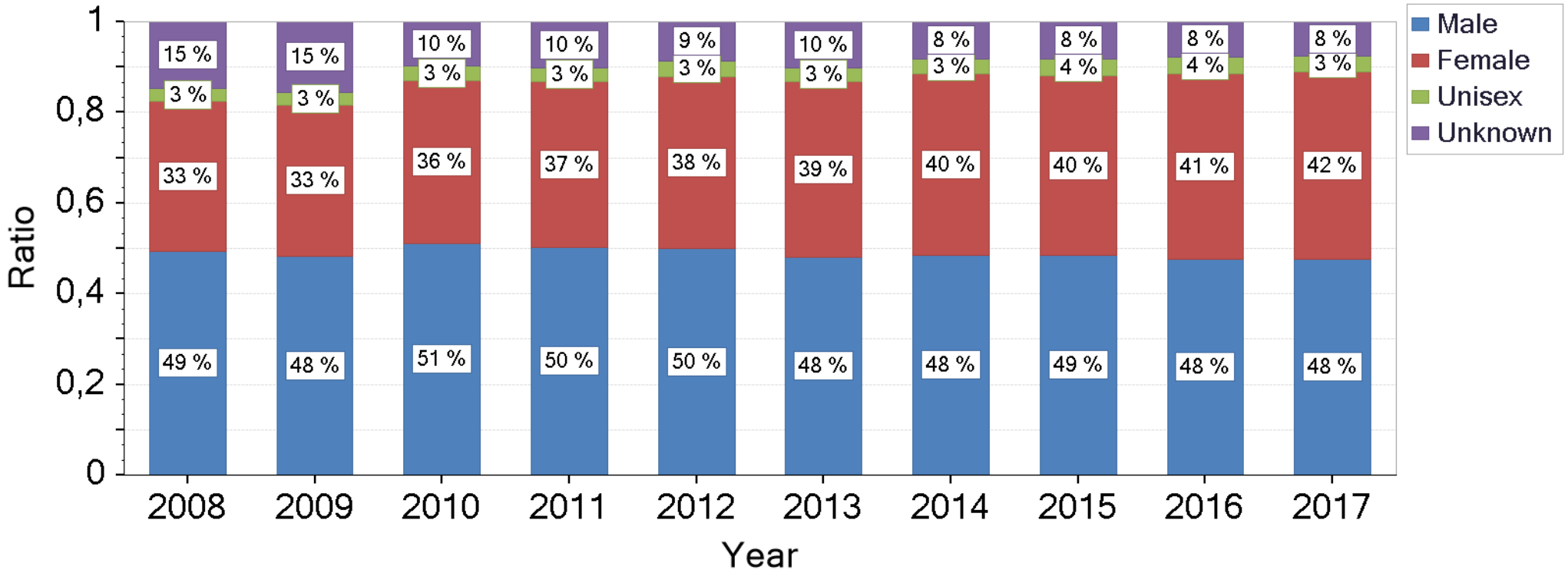
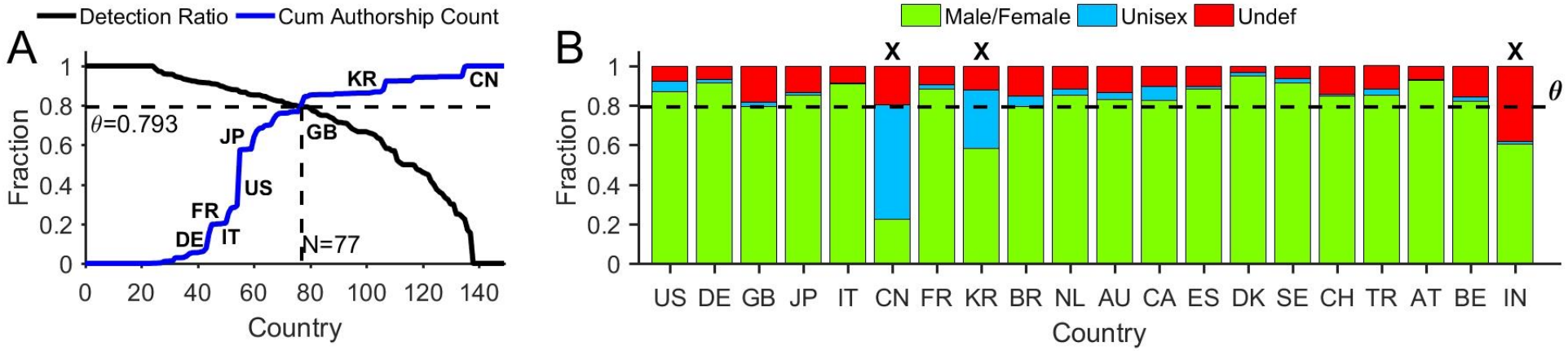


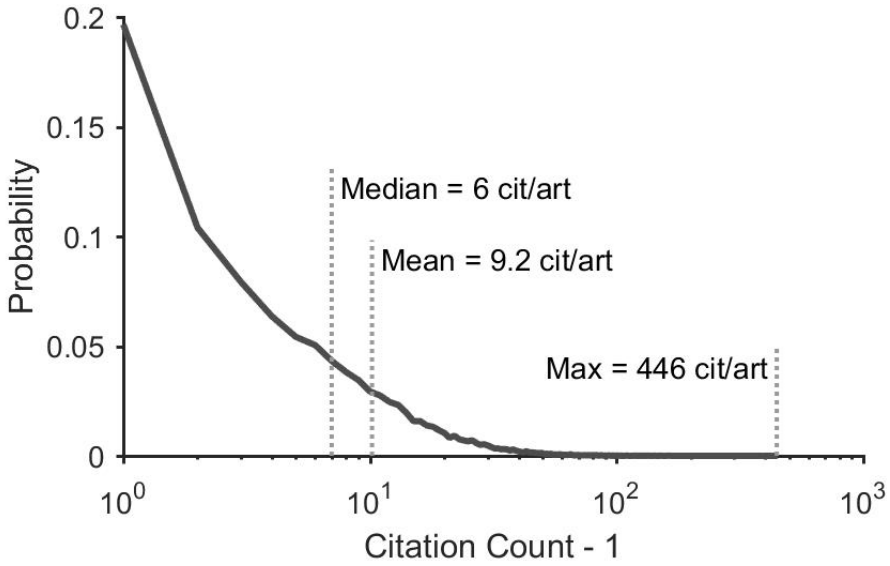
SFig 1: Bibliometric overview. (A) The article count increases from 2,281 in 2008 to 2,750 in 2015; the average annual growth rate (AAGR) is 2.5%. (B) The number of authors per article increases from 5.3 authors/article in 2008 to 6.7 authors/article in 2017. (C) The percentage of international collaboration articles increases from 18.9% in 2008 to 25.6% in 2017 with an AAGR of 3.6%. (D) The fraction of articles grouped the gender of their key authors' documents a quantitative superiority of articles with male last authorships. (E) The fraction of articles is depicted by country (bar plot) and by continent (pie charts). Please note that the sum of percentages is greater than one due to international collaborations. AU=Australia, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IT=Italy, KR=South Korea, NL=Netherlands, SE=Sweden, US=United States.



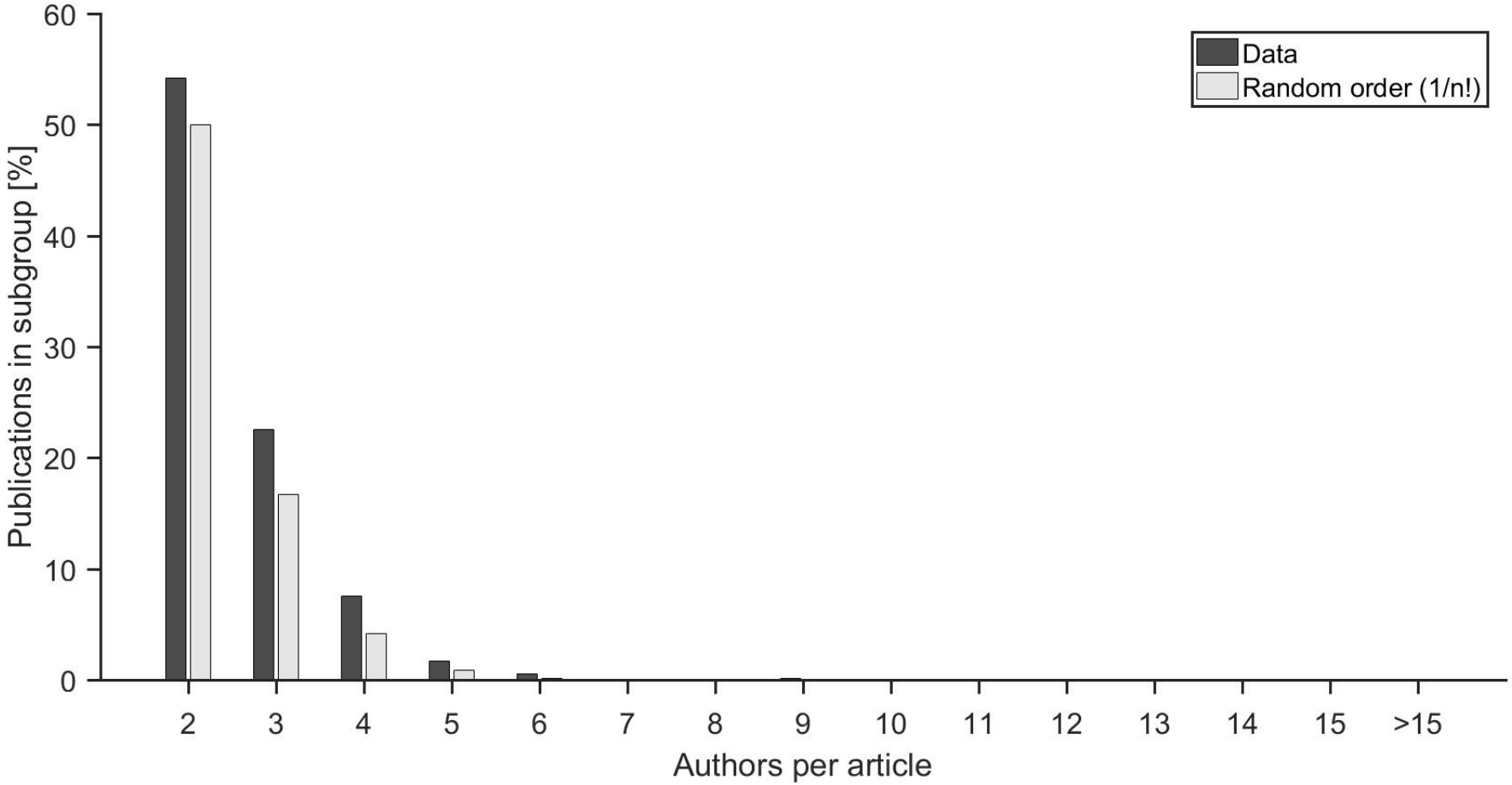
SFig 2: Gender Detection Output by Time. The ratios of detected male, female, unisex and undefined authorships ordered by publication year document a relatively small inter-annual variability.



SFig 3: Quality of algorithmic gender detection by country. (**A**) An adaptive threshold country criterion θ for the inclusion of a country in the country-specific gender analysis was defined by a ROC-like curve incorporating both detection ratio and cumulative author count [1]. In this study, countries with a detection rate of at least θ = 0.793 male + female authors (i.e. 79.3% of all authorships) from N=77 countries were included in the country-specific analysis. Countries with a large amount of authors are indicated by country code. (**B**) The result of the algorithmic gender detection - classified as male/female, unisex or undefined - grouped by countries that are ordered in descending order by their publication count, documents a relative high frequency of male/female authors for most of the top 20 countries, with the exception of the Asian countries China (CN), South Korea (KR), and India (IN). The latter countries are characterized by a high frequency of unisex (CH, KR) or unknown names (IN) and are excluded (**X**) from analysis due to the threshold criterion θ (dotted line). AU=Australia, AT=Austria, BE=Belgium, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IL=Israel, IN=India, IT=Italy, JP=Japan, KR=South Korea, NL=Netherlands, SG=Singapore, SE=Sweden, TR=Turkey, US=United States.



SFig 4: Probability density function of the citation rate. The semi-logarithmic plot of the citation count per article (=citation rate) exhibits an exponential-like decreasing probability density function with a mean citation rate of 9.2 citations/article.



SFig 5: Test for alphabetical ordering of the author list. The proportion of publications with an alphabetic ordered author list is depicted with respect to the authors per article (blue). The values correspond very closely to those obtained for randomly ordered author lists (yellow).

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Secondary Subject Heading:	Medical publishing and peer review
Keywords:	odds ratio, prestige, citations, productivity, career

Gender disparities in high-quality dermatology research - a study on scientific authorships

Michael H. K. Bendels[1], Michelle C. Dietz[1], Dörthe Brüggmann[1], Gerhard M. Oremek[1], Norman Schöffel[1*], and David A. Groneberg[1*]

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List of Abbreviations

AAGR: Average Annual Growth Rate

FAOP: Proportion of Female Authorships

FAP: Female Authorship Ratio

PI: *Prestige Index*

Abstract

Objective: The present study aims to elucidate the state of gender equality in high-quality dermatological research by analyzing the representation of female authorships from January, 2008 to May, 2017.

Design: Retrospective, descriptive study.

Setting: 113,189 male and female authorships from 23,373 research articles published in twenty-three dermatological Q1 journals were analyzed with the aid of the Gendermetrics Platform.

Results: 43.0% of all authorships and 50.2% of the first-, 43.7% of the co- and 33.1% of the last-authorships are held by women. The corresponding female-to-male odds ratios are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The annual growth rates are 1.74% overall and 1.45% for first authorships, 1.53% for co-authorships, and 2.97% for last authorships. Women are slightly underrepresented at prestigious authorships compared to men (Prestige Index = -0.11). The underrepresentation remains stable in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals. Multi-author articles with male key authors are only slightly more frequently cited than those with female key authors. Women publish slightly fewer papers compared to men (47.2% women hold 43.0% of the authorships). At the level of individual journals, there is a high degree of uniformity in gender-specific authorship odds. By contrast, distinct differences at country level were revealed. The prognosis for the next decades forecasts a consecutive harmonization of authorship odds between the two genders.

Conclusions: In high-quality dermatological research, the integration of female scholars is advanced as compared to other medical disciplines. A gender gap consists mainly in the form of a career dichotomy, with many female early career researchers and few women in

academic leadership positions. However, this gender gap has been narrowed in the last decade and will likely be further reduced in the future.

Keywords: odds ratio; prestige; citations; productivity; career

Strengths and limitations of this study

- The Gendermetrics Platform is a well-established system to analyze gender disparities in science by considering the gender-specific distribution of first, co- and last authorships.
- The purely bibliometric and algorithmic approach allows analyses of large volumes of data standardized and independent of the examiner, and thus with a minimized interindividual variability.
- Our analysis is limited by the absence of information concerning equally distributed authorships, corresponding authors, as well as data providing information about the scholar's academic degree, their position, age, employment status and their participation on editorial boards.
- The investigation period is technically limited to articles that are published after 2006 due to the predominance of initials preventing a correct gender identification by first names in older articles.

Introduction

The past decades have seen an enormous increase in the number of women entering medicine[1]: While in 1969, 6.9% of the U.S. medical graduates were women, the percentage reached a value of 47.5% in 2014[2]. The enrollment in U.S. medical school in 2016 was almost evenly divided between women (49.8%) and men (50.2%)[3]. Despite this enormous increase of women entering the field of medicine, "across medicine and dermatology, this influx has not been accompanied by a parallel progress by female faculty with academic credentials or in leadership roles", as stated by an editorial of Alexa Kimball[4] and many articles have addressed different gender and generational aspects in academic dermatology in the past years [5-9]. In 2012, Sadeghpour et al. published results from a national survey on the role of gender in academic dermatology[1]. They assessed whether there is an association between gender and academic rank. They came to the conclusion that gender-based differences in academic dermatology, including career track, academic rank distribution, leadership, and career satisfaction, persist[1]. Of a total of 259 full-time US academic dermatologists (38.6% were female), they found that men held more senior positions even after adjustment for age and number of years since completion of residency[1]. Working hours did not differ significantly. While most men (90.3%) and women (82.8%) were satisfied with their career, women were 24.6% more likely than men to consider leaving academia[1]. In line with these findings, Shi et al. conducted in 2017 a cross-sectional observational study of dermatology departments and divisions in the U.S. revealing that women account for 47.9% of dermatology residency program directors (PD) but comprise only 23.5% of chairpersons/chiefs[10]. Another recent study investigates the influence of women in academic dermatology by assessing the number of women acting as editors-in-chief of prominent dermatology journals[11]. The study revealed that there have been 26 female editors and at least 128 male editors in the considered 25 dermatology journals and that

45.8% of journals have not yet had a female editor[11]. Moreover, the study clearly showed that in the last decades there has been an increase in the number of women holding these prestigious positions.

As stated previously, an indicator for the balance between integration of female and male dermatologists and scientists is the quantification of their scholastic activity as represented by “authorship” in scientific publications[12-15]. In general, authorships represent the currency system of research and academic community[16]. In original medical articles, the assignment of authorship follows, by convention, the rule that "the first author indicates the person whose work underlies the paper as a whole"[17], whereas the last authorship "indicates a person whose work or role made the study possible without necessarily doing the actual work" [17]. Thus, the assignment of authorships differs considerably from, for example, economics or mathematics, where authors are usually listed in alphabetical order [16]. One consequence is that an early-career researcher normally publishes as first or co-author, whereas a senior researcher prefers the last author position in original research articles[18,19]. A further consequence of this assignment rule is that the different types of authorships are associated with different prestige. Specifically, first and last authorships have a significantly higher reputation than co-authorships[18].

Based on these consideration, we here applied the recently established Gendermetrics Platform[20] to analyze the integration of women in high-quality dermatological research by assessing 113,189 male and female authorships from twenty-three dermatological Q1 journals.

Conceptually, we determined the proportion of female first, co- and last authorships and quantified the relative distribution of female authorships among the different authorships

compared to men by applying odds ratios. Moreover, we used the *Prestige Index* to analyze the distribution of prestigious authorships between the two genders. The analysis includes global status and temporal development, differences across countries and the role women tend to have in articles with many authors, e.g. collaboration on articles [14]. Moreover, a gender-specific analysis of scholarly productivity and citation rate was conducted. The study concludes with a ten-year forecast regarding the development of gender disparities in the field of high-quality dermatological research.

Methods

Data acquisition & integration

The data analysis was conducted using Gendermetrics.NET[20], a SQL-Server based Platform for analyzing bibliometric data with a special emphasis on gender aspects. Research articles from high impact dermatology journals listed in the Scimago Journal & Country Rank database (http://www.scimagojr.com/journalrank.php?category=2708) were acquired on May 15, 2017 from the Web of Science Core Collection (Thomson Reuters). The journals constitute the subset of dermatological Q1 journals in 2016 representing the top 25% of the corresponding impact factor distribution. The journals '*Fibrogenesis and Tissue Repair*', '*Infectious Diseases in Obstetrics and Gynecology*' and '*Dermatology and Therapy*' were not considered because there were not indexed in the Web of Science database. The journals *'Aids Research and Treatment*', '*BMC Dermatology*', '*Clinics in Dermatology*', '*Dermato-Endocrinology*' and '*HIV/AIDS-Research and Palliative Care*' were excluded from analysis due to a low number of articles (< 200 articles). Furthermore, the journals '*British Journal of Dermatology*' and *'Journal of the European Academy of Dermatology and Venereology*' had to be excluded from analysis due to the predominant usage of initials instead of full first names, which prevents the correct gender determination. In total, 23 of the 33 dermatological Q1-journals with 23,373 articles written by 74,354 authors remain for analysis.

Gender determination

The algorithmic gender determination operates on the basis of a data table containing the gender of 77,818 forenames (male, female or unisex), see Bendels et al.[20]. By applying the algorithm, 30,538 (= 41.1%) male authors, 27,261 (= 36.7%) female authors, 5,509 (= 7.4%) unisex authors and 11,046 (= 14.9%) undefined authors were determined with a relatively little inter-annual variability (supplementary Fig. 1). The Unisex and undefined authors and

their authorships were not taken into consideration (in total 27,182 authorships). As a result, 113,189 male and female authorships affiliated to institutions from 150 countries were analyzed. The research output of a country was thereby benchmarked by considering the authorships of the related institutions[14]. It is important to note, that the quality of gender detection depends on the authorships country as illustrated by supplementary Fig. 2. In order to ensure the validity of the *country-specific* analysis, we set a threshold criterion for the country-specific analysis (supplementary Fig. 2), as recently described in Bendels et al. [20]. In particular, only countries with a detection rate of at least 79.3% male or female authorships were considered. As a result, among the top 20 most productive countries, the Asian countries China, South Korea (with high rates of unisex names) and India (with many undefined names) were excluded. A bibliometric overview is given in supplementary Fig. 3.

Proportion of Female Authorships (FAP) & Female Authorship Odds Ratio (FAOR)

In this study, first-, co- and last-authorships were considered, whereby co-authorships encompasses all authorships between *one* first- and *one* last-authorship. Equally distributed authorships were not considered due to a lack of information. The ***proportion of female authorships*** (***FAP***) is defined as the quotient between the female authorship count and the total sum of male and female authorships. The FAP is presented as a percentage to improve the textual readability. The female to male odds ratios for first-, co- and last-authorships were determined (***female authorship odds ratio***, ***FAOR***) with the corresponding confidence intervals at a confidence level of 95%[14]. The FAOR measures the female odds of securing a particular authorship type compared to men. A FAOR of e.g. 2.0 or 0.5 means that women or men, respectively, have twice the odds of holding a particular authorship compared to respective other gender[14]. For a simplified representation, a triplet is used to indicate the sign of the *significant* female odds ratio excess to get a particular authorship. For example,

the FAOR-triplet **(-, =, +)** indicates that women have *significantly* lower odds ratios for first-, equal odds ratios for co- and significantly higher odds ratios for last-authorships compared to men[14]. In summary, the FAP measures the quantitative representation of female authorships, whereas the FAORs quantify the relative distribution of female authorships among the different authorships[14]. To increase the statistical significance, the FAP/FAOR-classification is only conducted for subjects (e.g. countries, journals) with at least 750 male or female authorships.

Prestige Index

The *Prestige Index* measures the female odds of holding prestigious authorships compared to men[14]. It is defined as the prestige-weighted average of the FAOR excess ε_t that is calculated over all authorship types t (i.e. for first, co- and last authorships), $\varepsilon_t = w_t\,(FAOR_t - 1)$, if $FAOR_t \geq 1$, otherwise $\varepsilon_t = w_t\,(1 - 1/FAOR_t)$ with the weighting factor w_t[14]. In medical science, the prestige of scholarships follows a ranked order with a higher reputation of first and last authorships and a lower reputation of co-authorships [18]. Specifically, a potentially alphabetical ordering of the author list was excluded by an additional test (supplementary Fig. 4). Therefore, co-authorships were weighted negatively ($w_{co} = -1$), whereas first and last authorships were weighted positively ($w_{first} = w_{last} = 1$)[14]. This definition implies that the *Prestige Index* is e.g. lowered by both higher odds for co-authorships and lower odds for first and last authorships. A value of 0 characterizes a balanced distribution of prestigious authorships between the two genders, whereas a value above (below) 0 indicates an excess (lack) of prestigious authorships held by women.

Analysis of data

Average annual growth rates (AAGR) were applied to characterize annual growth rates[14]. The AAGRs of both, FARs and number of authorships were used to make a linear prognosis of the

temporal development of FAP, FAOR and *Prestige Index* for the coming decade. The Pearson correlation was applied to evaluate the linear association between the FAP, the *Prestige Index* and the journals' mean impact factor. The latter was calculated over the years 2008 to 2016/2017. The null hypothesis, whether the *non-normally* distributed gendered citation rates (supplementary Fig. 5) stem from the same distribution, was tested by a Kruskal-Wallis-test and a post-hoc multi-comparison test. The significance threshold was set at .05.

Results

Female authorships on a global level

In a first step, we analyzed the representation of female authorships on a global level. The analysis reveals an underrepresentation of female authorships with a FAP of 43.0% (Fig. 1A, bottom), relatively more first-authorships (50.2%), an almost equal proportion of female co-authorships (43.7%) and a substantially less fraction of last-authorships (33.1%). The corresponding FAORs (Fig. 1A) are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The differences are statistically significant (P<.05) for all types of authorships between the two genders. Thus, the global FAOR-pattern is characterized by the FAOR-triplet (+, +, -), i.e. women have significant higher odds for first and co-authorships and significant lower odds for last-authorships. The *Prestige Index* is on average -0.11, indicating a minor lack of prestigious authorships held by women (Fig. 1A, bottom).

The FAP exhibits a relatively high increase over the evaluation period (39.5% in 2008, 46.1% in 2017, Fig. 1B) with an AAGR of 1.74%. The subanalysis reveals a disproportionally high annual growth for last authorships (2.97%) and disproportionally low values for co- (1.53%) and first authorships (1.45%). Overall, this led to more gender-neutrality in authorships odds during the recent years, as also indicated by the *Prestige Index* (-0.19 in 2008 and -0.11 in 2017).

Differences across countries

When we refined our analysis from global to country-specific level, we identified among the most productive countries a wide range of FAPs that extent from 66.7% in Finland to 25.3% in Japan (Table 1). Different FAOR-patterns were identified ranging from *unfavorable* with the FAOR-triplet (=, +, -) identified in Poland, Italy, and Spain to *favorable* with the FAOR-triplet (+, -, =) in Denmark, Finland and the Netherlands (Table 1). Israel provides gender-

neutrality with respect to all authorships (FAOR-triplet (=, =, =)). The majority of the countries exhibit FAOR-patterns that are characterized by lower female odds for last and higher female odds for first authorships compared to men. Remarkably, there is not a single country where women have currently higher odds for a last authorship compared to men.

When considering the distribution of prestigious authorships, we found countries with very high *Prestige Indices*, like Denmark (*Prestige Index* = 0.60), Finland (0.54), and the Netherlands (0.42). In these countries, women have higher odds to hold a prestigious authorship compared to men. By contrast, Italy (*Prestige Index* = -0.46), Spain (-0.50), Japan (-0.51) and Austria (-0.58) are characterized by a lack of prestigious authorships held by women. Remarkably, we found no significant correlation between the FAP of a country and its *Prestige Index* (r(18)=0.36, P>.05).

Differences across journals

At the level of individual journals, the FAP ranges from 53.4% in *Sexually Transmitted Diseases* to 32.9% in *Lasers in Surgery and Medicine* (Table 2). The predominant FAOR-pattern is characterized by the FAOR-triplet (+, =, -). Moreover, in almost all journals (with the exception of *Contact Dermatitis*) women have significant lower odds for last-authorships. Furthermore, in our analysis, there is no journal, where a) male scholars have significantly higher odds for first authorships compared to their female counterparts, and b) where women have higher odds to secure last authorships than men.

The *Prestige Index* value range is from -0.50 to 0.19 (Table 2): Best odds for women to secure prestigious authorships are given in *Contact Dermatitis* (*Prestige Index* = 0.19) and *Acta Dermato-Venereologica* (0.11), whereas *Dermatology* (-0.5) and *Mycoses* (-0.41) provide best odds for male scholars. We found no significant correlation between the a) FAP of the

journal and its Mean Impact Factor (r(21)=0.08, P>.05), b) the *Prestige Index* and the Mean Impact Factor (r(21)=0.37, P>.05), and c) the FAP and the *Prestige Index* (r(21)=0.08, P>.05).

Female authorships by authors per article

We also assess the role women tend to have in articles with many authors, e.g. collaborative articles. The FAP fluctuates between 40.9% (1-3 authors/article) and 43.7% (7-9 authors/article) and exhibits no significant correlation to the number of authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article) (Fig. 2). In addition, the FOAR for co-authorships shows no significant relationship to the author rate. As a consequence, the *Prestige Index* fluctuates between -0.02 (13-15 authors/article) and -0.21 (>15 authors/article). To summarize, FAP, FAORs and *Prestige Index* show no clear correlation to the number of authors per article.

Citation & Productivity Analysis

The analysis reveals that articles with male key authors are more frequently cited than articles with female authors (Fig. 3A). However, the differences are very low as articles with a male last or first author have average citation rates of 9.7 citations/article and 9.6 citations/article, respectively and articles with a female first or last author exhibit citation rates of 9.1 citations/article and 9.0 citations/article, respectively. Statistically significant differences in the distributions of citation rates were only found between articles with male last authors and all other article groups (Kruskal-Wallis-Test, P<.05). Articles with a female first or last authorship were on average below the mean citation rate of 9.2 citations/article.

The analysis of combined authorships shows that male-first/female-last and male-first/male-last articles have on average the highest citation rates with 10.1 citations/article and 9.9

citations/article, respectively, followed by female-first/male-last (9.5 citations/article) and female-first/female-last (8.5 citations/article) articles (Figure 3A, right). Single-authored articles have the lowest citation rates with slightly higher citation rates for male-authored articles (6.8 citations/article vs. 6.5 citations/articles).

The analysis further demonstrates that statistically the citation rate of an article gets higher the more authors are involved, e.g. articles with 1-3 authors are on average cited 7.8 times, whereas articles with more than 15 authors are cited 15.9 times on average (Fig. 3B). Furthermore, the revealed differences in the citation rates between articles with male or female key authors are not preserved when articles are grouped by the length of their author list, as shown by Fig. 3B. In this grouping scheme, articles with female last authors and more than 15 authors attract the highest citation rates of on average 18.6 citations per article.

Considering the gender-specific distribution of the article count per author, we found, that the subgroups 'author of 1 article' and 'author of 2 articles' are relatively dominated by women. In particular, 71.5% of the female authors, but only 68.1% of the male authors had published a single article in our data set (Fig. 3C). By contrast, all other subgroups with three or more articles per author show a relative overrepresentation of male authors. Particularly, the subgroup of most productive authors ('author of more than 10 articles') is considerably dominated by men (2.4% of the male authors vs. 1.2% of the female authors). This finding results in a slightly higher productivity of male authors, as 53.0% of male authors hold 57.0% of all authorships (Fig. 3C).

Discussion

Advanced integration of women

The field of high-quality dermatological research is characterized by a moderate underrepresentation of female authorships with an FAP of 43.0%. This value is considerably higher than the previously determined FAPs, which were found for the whole area of science (30%) [13], for six high-quality medical journals (34%)[21], and for similar studies from the research fields of epilepsy (39.4%)[14], schizophrenia (37.6%)[12], stroke research (36.3%, unpublished data), and lung cancer research (31.3%)[22], see Table 3.

Female scholars are inhomogeneously distributed across the different authorships: We found many female first authorships and a significantly lower proportion of female last authorships. Evidently, this finding illustrates the well-known, gender-specific career dichotomy as first- or co-authorships are usually held by early career researchers, whereas last authorships are regularly preserved for institutional heads or principal investigators [18]. Such a discrepancy in leadership positions has been described for the most scientific disciplines [13], including various medical research fields[1,12,14,23-26]. What are the reasons for such a striking career dichotomy between the two genders? Differences in career preferences between men and women are one reason that can be cited in this regard[27]. Specifically, it has been shown that men were more likely to occupy investigative career tracks (26.5% vs. 11.1%), whereas women predominantly occupied clinical educator tracks (81.5% vs. 50.0%) in U.S. dermatology [1]. Other reasons include altered life priorities like family planning[13], the lack of role models[26], an insufficient work-life balance[26], women's increased likelihood to occupy part-time positions[1], and the consistently high influx of female medical students and graduates[26].

Interestingly, low female odds for last-authorships are numerically compensated by high female odds for first-authorships. This constellation leads to an almost gender neutral distribution of prestigious authorships on the global level. This finding is important, since academic publishing at prestigious authorships is one of the core elements of career advancement in science[12,28-30]. However, the underrepresentation of last authorships potentially reduces the further career advancement of the female scientists[31], since last authorships are often taken as a major indicator of successful leadership, e.g. by committees making this a criterion in granting and hiring[18]. In line with this, a cross-sectional survey from 2009 revealed a clear gender difference in academic *senior* ranks of U.S. dermatologists, as it was reported that "women were predominantly at the assistant professor level (50.0%) compared with men (24.3%), whereas men were predominantly at the full professor level (47.4%) compared with women (14.9%)"[1]. Evidently, in dermatology, the proportion of female faculty members declined as academic rank increased.

Stable representation of women in multi-author articles results in almost gender-neutral citation rates

Remarkably, we found no significant relationship between the representation of female authorships and the number of authors per article. Specifically, the representation of female authorships remains also stable for articles with high numbers of authors (e.g. collaboration articles), which statistically attract the highest citation rates (Fig. 3B)[32]. This is an important result, since it provides a good explanation for the almost equal citation rates of articles that were grouped by the gender of their keys authors. This is particularly remarkable, since for all other disciplines we have examined so far, we find a) an accentuating underrepresentation of women at prestigious authorships with an increasing number of authors per article and b) significantly higher citation rates of articles with male key authors. Moreover, previous studies from various disciplines also reported about substantially higher

citation rates for articles with male key authors[13,29,31,33-35]. To summarize, well-balanced citation rates between the two genders suggest that the integration of women in dermatological science is well-advanced. Methodically, it is important to note that the determined citation rates describe essentially the situation from the early phase of investigation (2008-2010), since older articles have a stronger impact on the citation statistics than newer articles ("Cited Half-Life")[36].

Structural position affects productivity

The lower productivity of female scholars (47% female authors hold 43% of the authorships) is in line with reports from other scientific fields and medical disciplines[12-14,23-25,37]. Interestingly, we were able to reproduce the clear male overrepresentation at levels of higher productivity (Fig. 3C), as already shown for the fields of ecology and evolutionary biology[34], the medical research fields of schizophrenia[12] and epilepsy[14], and for the field of high-quality research from the areas life science, earth & environmental, multidisciplinary and chemistry[35]. It is reasonable to assume that the primary factors affecting women's productivity are not higher rejection rates as explicitly shown for the journals *Cortex*[38] and *Nature Neuroscience*[39], but rather, due to the position of women within the scientific system[28,35]. In practice, the mainly male senior scientists are often associated to more or less fruitful (citation) networks, whereas "women are more likely to work as adjuncts or at teaching-intensive institutions with limited resources" [28]. This assumption is confirmed by a previous study from Sadeghpour et al.[1] documenting no differences in the number of publications of full-time academic dermatologists after adjustment for academic rank. Moreover, it has been shown by Reed at al. [37] that women's publication rates start to increase later in their career.

Distinct regional differences

Apart from these global findings, distinct regional differences were found with best-balanced authorship odds between the two genders in Israel (FAOR-triplet (=, =, =), *Prestige Index* = -0.01). When taking the chance of holding a prestigious authorship as a general surrogate parameter for career advancement in science [14], Denmark, Finland, and the Netherlands provide the best conditions for female authors. By contrast, Italy, Spain, Japan, and Austria offer optimal conditions for men in dermatological research. This finding correlates quite well with the results of the Global Gender Gap Report 2016 as the countries Finland, the Netherlands and Denmark were ranked 2nd, 16th, and 19th, respectively, whereas the countries Spain, Italy, Austria, and Japan were ranked 29th, 50th, 52nd and 111th, respectively, out of a total of 144 countries in the world [40]. It is plausible to assume that these regional differences are not caused by discipline-specific characteristics, but rather, are primarily due to socio-cultural surroundings, as, for example, Japan is characterized by a strong sense of patriarchy and traditional gender roles in society[41]. This is all the more relevant, since similar constellations were found in most of our studies[12,14]. Overall, the given information supplies women operating in the field of dermatology with a solid basis for decision-making for professional reorientation or career planning.

As in all our previous studies, we did not find a significant correlation between the FAP of a country and the distribution of prestigious authorships between the two genders[12]. This means, countries with a high FAP can also provide disadvantageous career opportunities for women and vice versa. A valuable example is Italy with a high rate of FAP (54.2%) and a negative *Prestige Index* (-0.46). Interestingly, this finding is contrary to the socio-cultural theory of the critical mass[42], postulating a self-sustained harmonization of gender aspects

once the participation of women has exceeded a critical threshold value of about 30% to 35%.

Journals with a high degree of uniformity

At the level of individual journals, we reveal a striking uniformity of gender-specific authorship odds, as in 19 out of 23 journals women have significantly higher odds for first authorships and lower odds for last authorships. Evidently, the global gender-specific hierarchy of research groups is mapped to the related journals. This finding explains also the relatively small value range of the journals' Prestige Index compared to that of other countries (Δ*Prestige Index*: 0.69 vs. 1.18). Remarkably, we do not find a significant correlation between the impact of a journal (characterized by the SJRI) and the revealed Prestige Index measuring the distribution of prestigious authorships between the two genders. Interestingly, this finding is contrary to our recent study analyzing the female authorship odds in fifty-four of *highest-quality* research journals listed in the Nature Index, which covers the journal categories *Life Science*, *Multidisciplinary*, *Earth & Environmental* and *Chemistry*. In this study a clear negative correlation between the 5-year-impact factor of a journal and its Prestige Index ($r(52)=-0.63$, $P<.01$) was revealed[35]. In contrast to academic dermatology, in this cross-discipline group of highest-impact journals, the female underrepresentation is accentuated in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals (Table 3). To conclude, uniformity of authorship odds as well as stable representation of women regardless of the journal impact speak for an advanced integration of women and against the predominance of "old boys' networks" in the field of high-quality dermatology research and its related journals[14].

Methodical Limitations

Methodically, our purely bibliometric and algorithmic approach enables us to analyze large volumes of data standardized and independent of the examiner, and thus with a minimized interindividual variability. However, as already mentioned in Bendels et al. [14], it is limited by the absence of information concerning equally distributed authorships, corresponding authors, as well as data providing information about the scholar's academic degree, their position (e.g. Associate Professor vs. Full Professor)[1], age, employment status and their participation on editorial boards [26,43]. Furthermore, the investigation period is technically limited to articles that are published after 2006 due to the predominance of first names initials preventing a correct gender identification in older articles[20]. Another limitation of the gender determination by first names is the fact that we had to exclude some countries from the *country-specific* analysis due to a relative high fraction of unisex names (primarily the Asian countries China and South Korea participating at 5% and 4%, respectively, of the articles).

Conclusion & Outlook

In conclusion, a) the relatively high FAP, b) the almost gender-neutral citation rates, and c) the stable representation of female scholars in both articles with many authors as well as highest impact journals can be considered indicators for an advanced integration of women in high-quality dermatological research compared to other (medical) disciplines (Table 3). However, a considerable career dichotomy is still present, with many female researchers at the beginning of their career and few women in academic leadership positions. Since there is a clear time-dependence present in authorship hierarchy - current early career researchers may be future research leaders – it is plausible to prognosticate a considerable increase of women in academic leadership positions in the next decade. This trend will likely be intense due to the high annual increase of female authorships (1.74%) with the highest rates for the

last author position (2.97%), and the trend of more and more female physicians entering the field of medicine in many Western countries[2,44]. In line with this perspective, a linear prognosis of the temporal development of female authorships prognosticates not only an FAP of 54.3% for the year 2026, but also increasing female odds for last authorships and decreasing female odds for co-authorships (Fig. 4). This harmonization in authorship odds results in a Prestige Index that is forecast to become almost gender-neutral in 2026 (*Prestige Index* = -0.03). On this basis, we expect a deeper integration of female scientists with a growing number of women in academic leadership positions in the next decade. However, it should be critically mentioned that, contrary to this prediction, various studies recently report about a striking persistence of gender inequalities regarding academic leadership positions despite a considerable increase in female first authorships [24-26,45].

In view of this, the present analysis may define a starting point: Continuous monitoring over the next years will elucidate if female career dichotomy will break down, leading to a more balanced distribution of research leaders between both genders in dermatological research.

CONTRIBUTORSHIP STATEMENT

MB, NS and DG designed the study. MB and MD collected and performed the analysis. MB, MD, DB, GO, NS and DAG interpreted the result. MB wrote the first draft of manuscript. MB, MD, DB, GO, NS and DG contributed to and have approved the final manuscript.

DATA SHARING STATEMENT

No additional data available.

COMPLIANCE WITH ETHICAL STANDARDS

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Tables

Table 1: Country Classification. Countries are descendingly ordered by their *Prestige Index*.

The number of considered male and female authorships is given by #Authorships.

Country Name	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Denmark	43.4%	(+, -, =)	0.60	637	2,392
Finland	66.7%	(+, -, =)	0.54	177	787
Netherlands	44.8%	(+, -, =)	0.42	941	3,400
Brazil	56.1%	(+, -, -)	0.14	959	4,141
Turkey	45.2%	(+, =, =)	0.08	518	1,930
Sweden	53.7%	(+, =, -)	0.07	630	2,118
Israel	38.3%	(=, =, =)	-0.01	331	1,032
Canada	42.1%	(+, =, -)	-0.04	816	2,160
Germany	37.6%	(+, =, -)	-0.09	2,498	10,438
Australia	42.6%	(+, =, -)	-0.10	817	3,016
United States	42.9%	(+, +, -)	-0.14	8,391	33,510
Belgium	51.2%	(+, =, -)	-0.16	378	1,001
France	48.9%	(+, =, -)	-0.17	1,171	5,566
United Kingdom	45.8%	(+, +, -)	-0.18	1,751	4,825
Switzerland	34.3%	(+, =, -)	-0.26	560	1,659
Poland	54.2%	(=, +, -)	-0.39	257	967
Italy	54.2%	(=, +, -)	-0.46	1,269	6,455
Spain	48.8%	(=, +, -)	-0.50	711	3,073
Japan	25.3%	(+, +, -)	-0.51	1,564	8,126
Austria	38.6%	(+, +, -)	-0.58	475	1,760

Table 2: Journal Classification. Journals are descendingly ordered by their *Prestige Index*.

Journal Name	Mean Impact Factor 2008-2016	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Contact Dermatitis	3.85	49.5%	(+, -, =)	0.19	721	3,623
Acta Dermato-Venereologica	3.27	47.4%	(+, =, -)	0.11	834	4,749
Sexually Transmitted Infections	2.88	50.1%	(+, =, -)	0.06	1,110	4,369
Wound Repair and Regeneration	2.80	38.1%	(+, =, -)	0.03	847	4,354
Journal of Dermatological Science	3.54	33.4%	(+, =, -)	0.03	727	3,763
Journal of the American Academy of Dermatology	4.83	44.9%	(+, =, -)	-0.01	2,103	11,338
Sexually Transmitted Diseases	2.78	53.4%	(+, =, -)	-0.05	1,370	7,500
Journal of Investigative Dermatology	6.26	42.1%	(+, =, -)	-0.06	2,392	16,865
Lasers in Medical Science	2.29	40.1%	(+, =, -)	-0.1	1,550	6,130
American Journal of Clinical Dermatology	2.16	47.5%	(+, =, -)	-0.13	263	981
Melanoma Research	2.29	44.6%	(+, =, -)	-0.14	616	3,845
Dermatologic Surgery	2.04	35.9%	(+, =, -)	-0.16	1,715	6,473
Archives of Dermatological Research	2.19	41.6%	(+, =, -)	-0.16	799	3,355
Lasers in Surgery and Medicine	2.67	32.9%	(+, =, -)	-0.17	938	4,161
Pigment Cell & Melanoma Research	4.91	42.9%	(+, =, -)	-0.18	510	3,199
Experimental Dermatology	3.45	41.9%	(+, +, -)	-0.19	1,644	8,732
International Wound Journal	1.99	37.1%	(=, +, -)	-0.21	891	3,877
JAMA Dermatology	5.46	47.2%	(+, +, -)	-0.27	491	3,163
Journal of Dermatological Treatment	1.65	45.1%	(+, +, -)	-0.3	655	2,590
Dermatologic Clinics	1.74	47.3%	(+, +, -)	-0.35	569	1,205
Clinics In Dermatology	2.40	43.6%	(=, +, -)	-0.39	743	1,732
Mycoses	1.81	47.0%	(=, +, -)	-0.41	974	3,710
Dermatology	2.06	41.7%	(+, +, -)	-0.5	911	3,475

Table 3: Synopsis of different subject areas. In high-quality dermatological research, the integration of female scholars is advanced as compared to other (medical) disciplines. However, in all subject areas, a considerable career dichotomy is still present, with many female researchers at the beginning of their career and few women in academic leadership positions. Please note that the *Nature Index* offers a database for the specific analysis of high impact scientific efforts from the journal categories of multidisciplinary, earth & environmental, life science and physics[46] (physics was excluded from analysis).

Subject Area	FAP	FAOR First	FAOR Co	FAOR Last	*Prestige Index*	Female representation at prestigious authorships in		Gender-specific differences in citation rates
						multi-author articles	highest impact journals	
Q1 Dermatology	43.0%	1.41	1.07	0.60	-0.11	Stable	Stable	minor
Epilepsy[14]	39.6%	1.25	1.17	0.57	-0.22	Decline	-	major
Schizophrenia[12]	37.6%	1.30	1.20	0.57	-0.22	Sharp Decline	-	major
Lung Cancer[22]	31.3%	1.22	1.19	0.59	-0.22	Sharp Decline	-	minor
Nature Index Journals[35]	29.8%	1.19	1.35	0.47	-0.42	Sharp Decline	Decline	major

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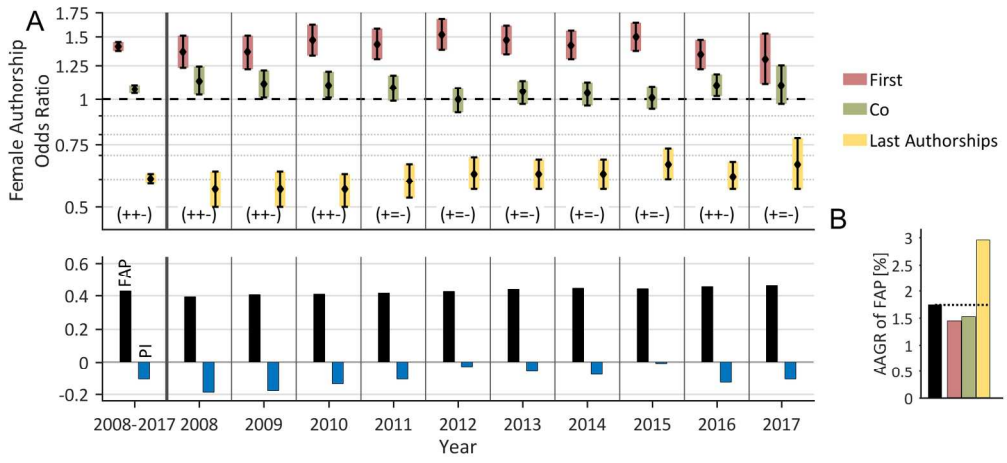
Figure Legends

Fig 1: Time trend of female authorships on the global level. (**A**) The relative frequency of female authorships (FAP, bottom), the pattern of FAORs (with FAOR-triplet, top) and its associated Prestige Index (PI) are depicted by year and averaged over time. The averaged FAOR distribution is characterized by the FAOR-pattern (+, +, -), i.e. women have significantly higher odds for first and co-authorships and significantly lower odds for last-authorships. The slightly negative PI indicates a lack of prestigious authorships held by women. (**B**) The FAP exhibits a relatively high increase as documented by its average annual growth rate (AAGR) of 1.74% per year with the highest rate for last authorships (2.97%). Overall, this led to more gender-neutrality in authorships odds during the recent years.

Fig 2: Female authorships by authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article). FAP, FAORs and Prestige Index show no clear correlation to the number of authors per article.

Fig 3: Gender-specificity of citations & scholarly productivity. (**A**) The descendingly ordered citation rates show that articles with male key authorships are slightly more frequently cited than articles with female key authorships. The mean citation rate of 9.2 citations/article is depicted by a dotted line (Kruskal-Wallis test, (*): P<.05 (**): P<.01). (**B**) Average citation rates of ungrouped articles (bars) and articles that were grouped by the gender of their key authorships (lines), depicted as a function of the number of authors. Statistically, the citation rate of an article is higher the more authors are involved. The gender-specific differences in citation rates are not preserved across the different levels of author count. (**C**) Gender-specific distribution of the article count per author. Women dominate the sub-groups 'author has one or two article(s)'. All other sub-groups are characterized by a relatively over-representation of male authors. This finding correlates with the higher productivity of male authors, as 52.8% male authors are responsible for 57.0% of all authorships.

Fig 4: Linear projection of the development of female authorships on the global level. The prognosis for the next decades forecasts a further harmonization of authorship odds between the two genders with an almost gender-neutral distribution of prestigious authorships in 2026 (*Prestige Index* = -0.03). An FAP of 54.3% is prognosticated for the year 2026.



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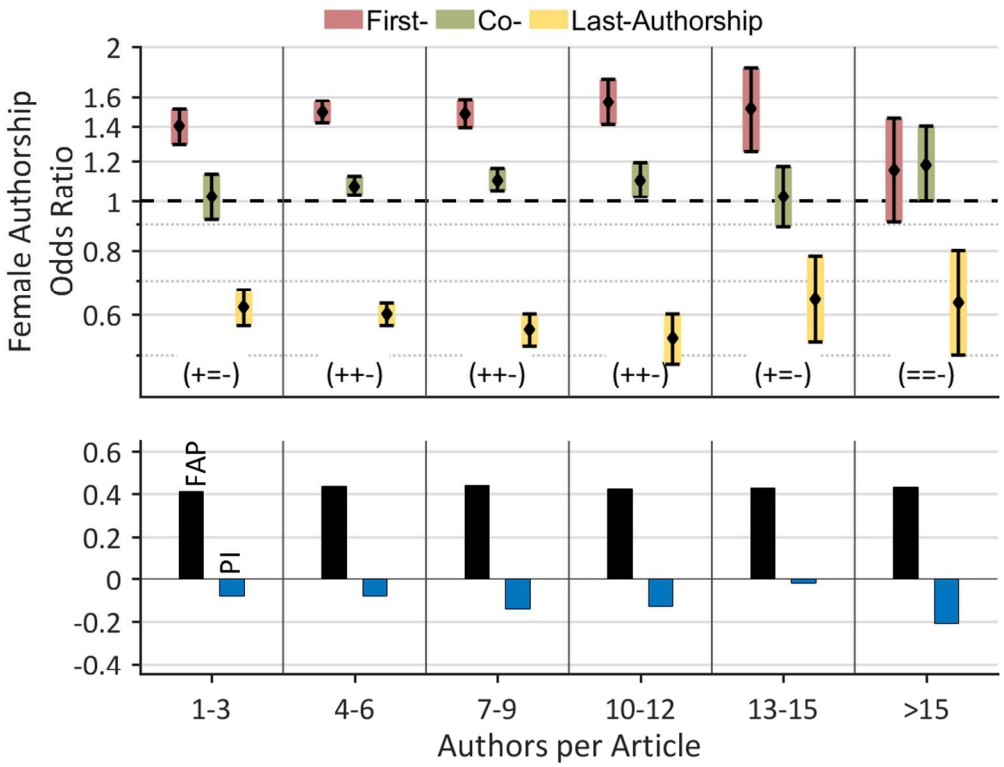

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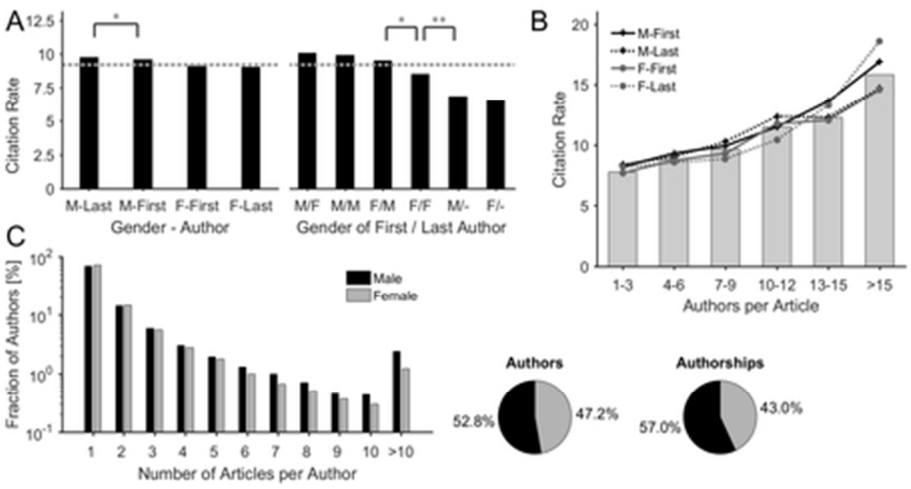

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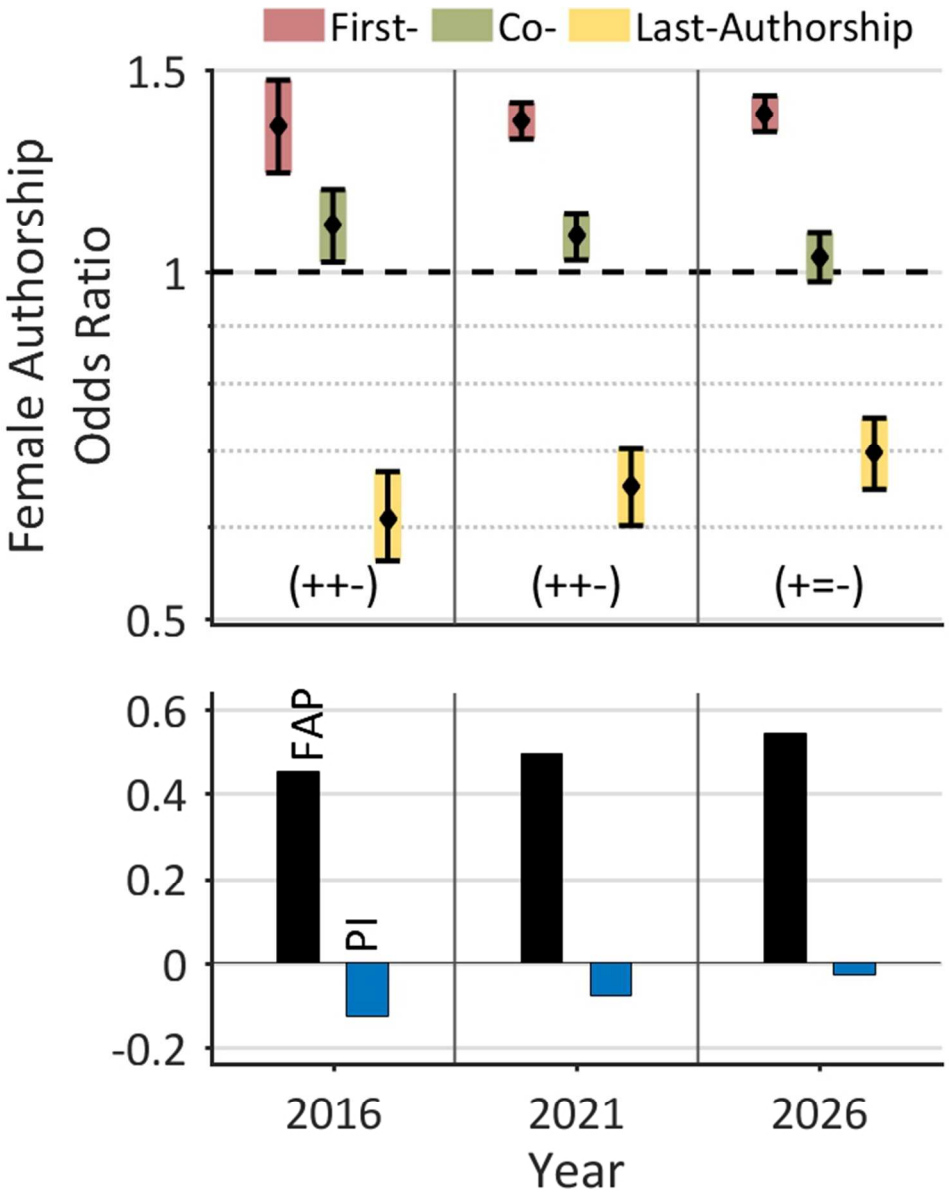

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59x74mm (300 x 300 DPI)

Online Supplement

Gender disparities in high-quality dermatology research - a study on scientific authorships

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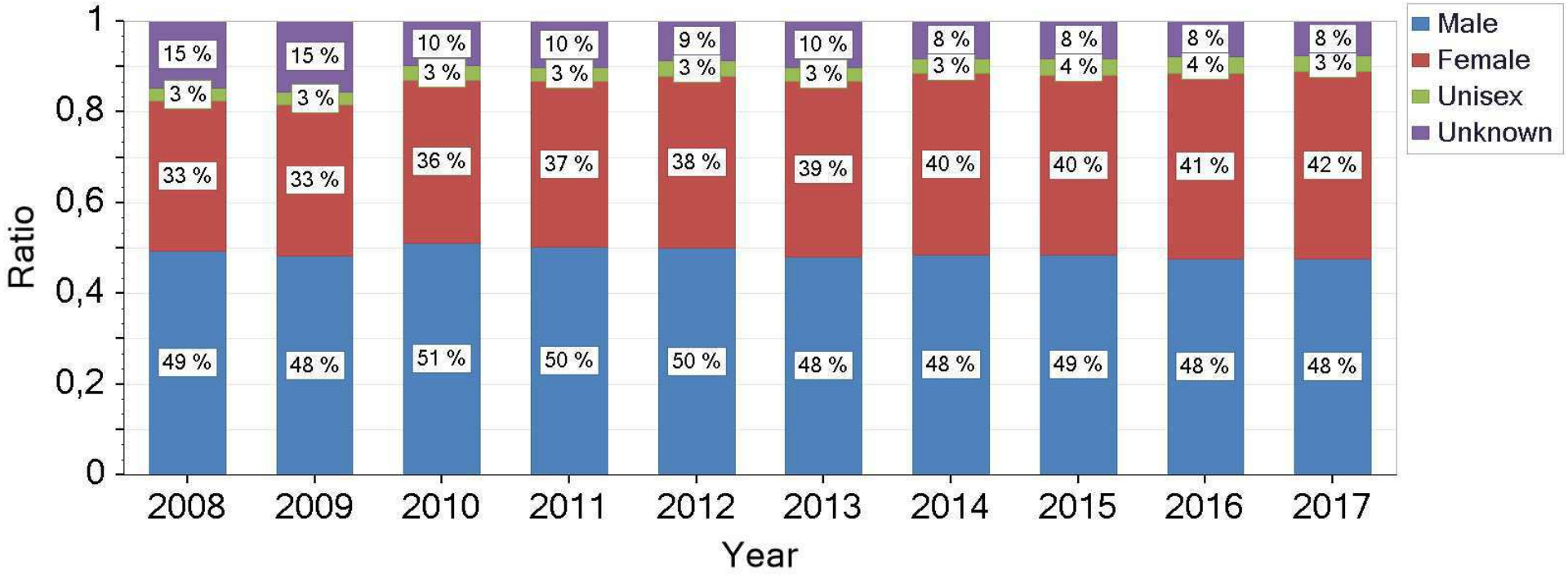
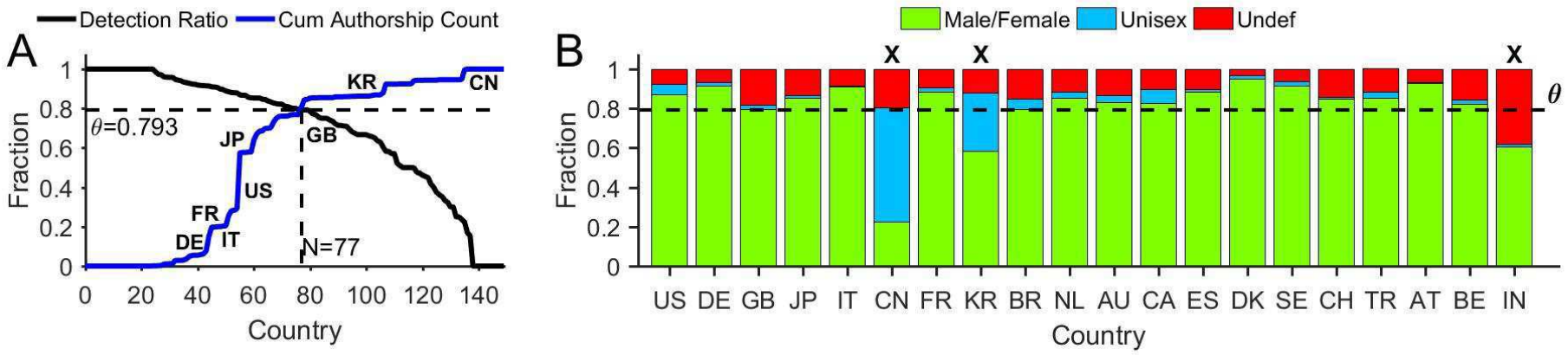
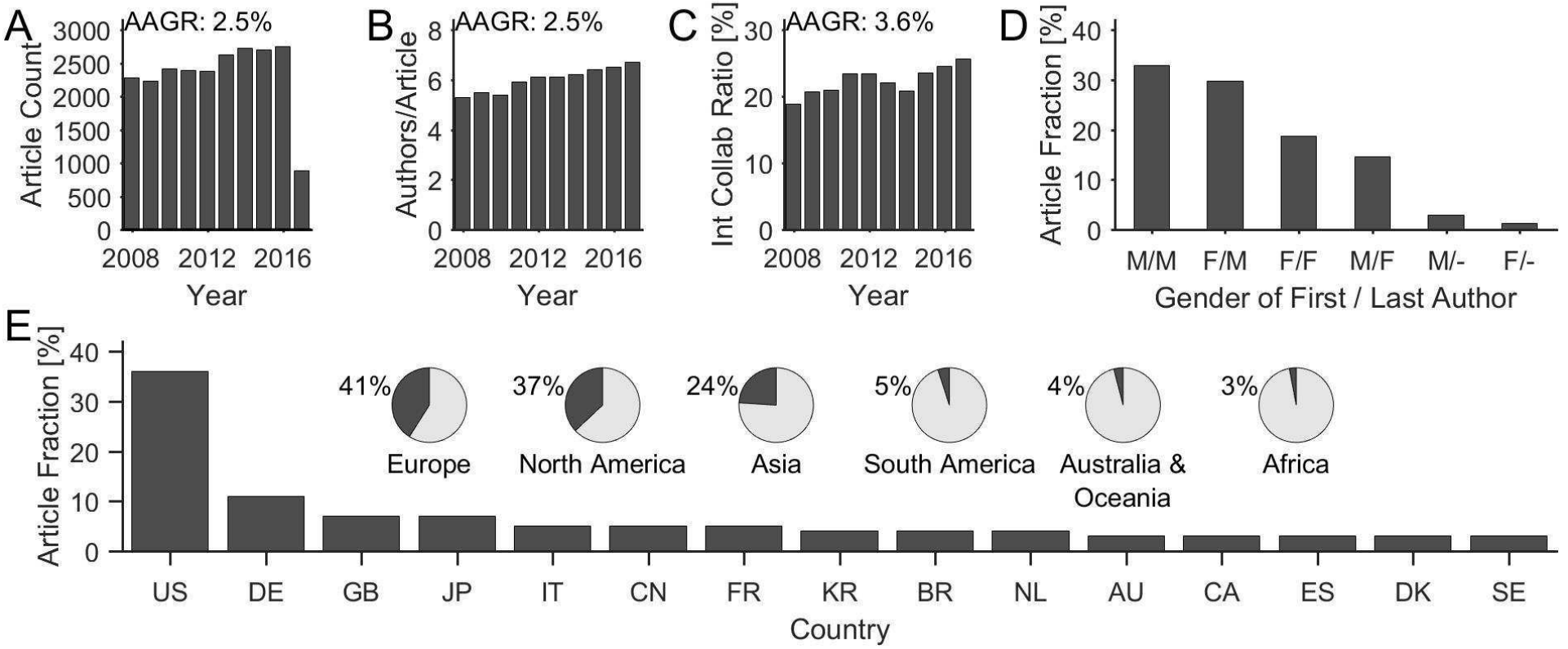


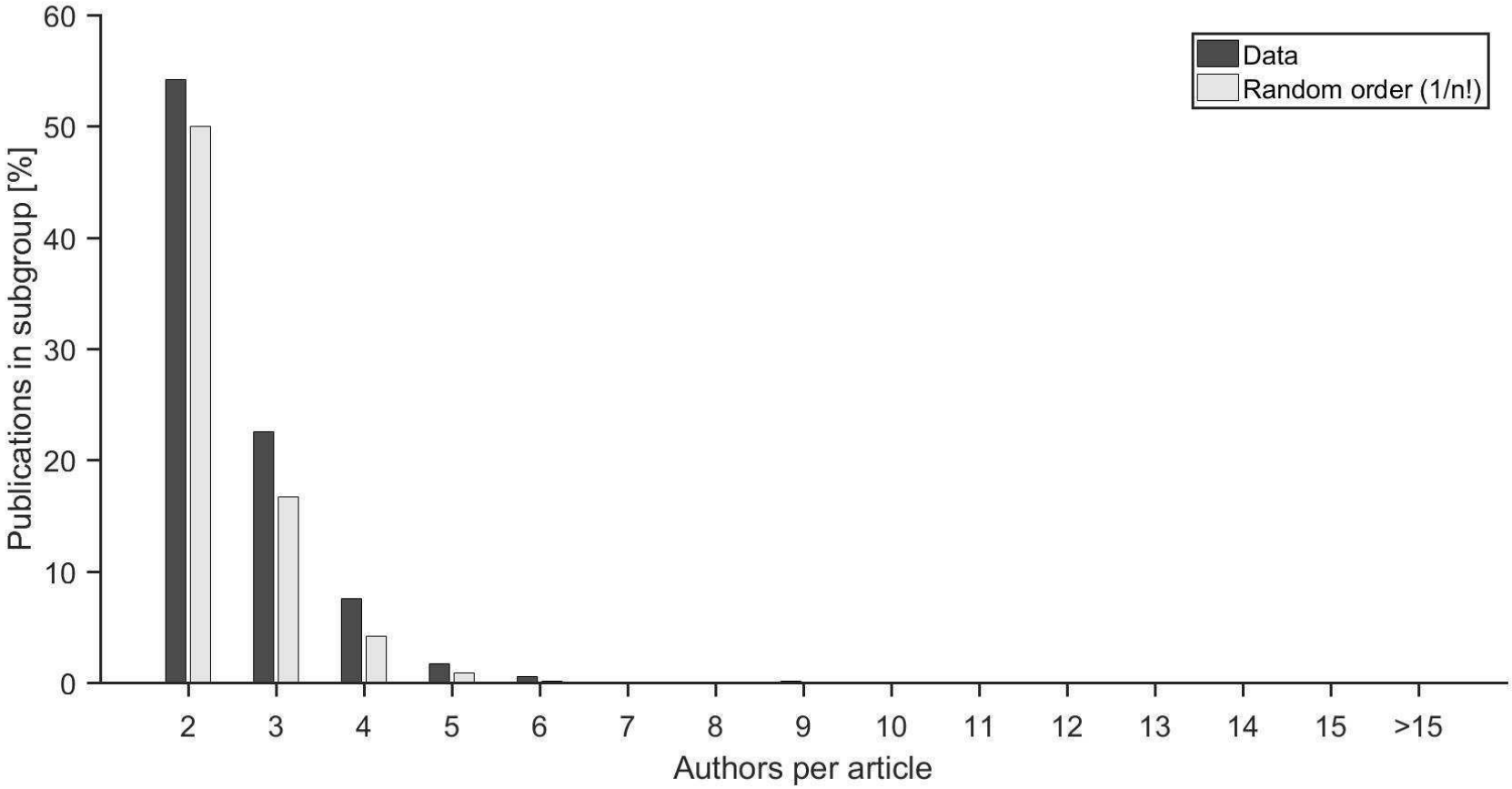
SFig 1: Gender Detection Output by Time. The ratios of detected male, female, unisex and undefined authorships ordered by publication year document a relatively small inter-annual variability.



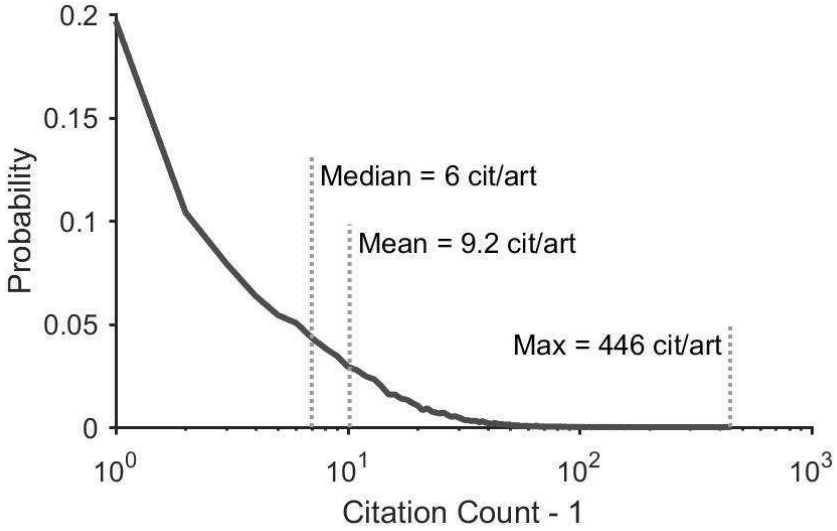
SFig 2: Quality of algorithmic gender detection by country. (**A**) An adaptive threshold country criterion θ for the inclusion of a country in the country-specific gender analysis was defined by a ROC-like curve incorporating both detection ratio and cumulative author count [1]. In this study, countries with a detection rate of at least θ = 0.793 male + female authors (i.e. 79.3% of all authorships) from N=77 countries were included in the country-specific analysis. Countries with a large amount of authors are indicated by country code. (**B**) The result of the algorithmic gender detection - classified as male/female, unisex or undefined - grouped by countries that are ordered in descending order by their publication count, documents a relative high frequency of male/female authors for most of the top 20 countries, with the exception of the Asian countries China (CN), South Korea (KR), and India (IN). The latter countries are characterized by a high frequency of unisex (CH, KR) or unknown names (IN) and are excluded (**X**) from analysis due to the threshold criterion θ (dotted line). AU=Australia, AT=Austria, BE=Belgium, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IL=Israel, IN=India, IT=Italy, JP=Japan, KR=South Korea, NL=Netherlands, SG=Singapore, SE=Sweden, TR=Turkey, US=United States.



SFig 3: Bibliometric overview. (A) The article count increases from 2,281 in 2008 to 2,750 in 2015; the average annual growth rate (AAGR) is 2.5%. (B) The number of authors per article increases from 5.3 authors/article in 2008 to 6.7 authors/article in 2017. (C) The percentage of international collaboration articles increases from 18.9% in 2008 to 25.6% in 2017 with an AAGR of 3.6%. (D) The fraction of articles grouped the gender of their key authors' documents a quantitative superiority of articles with male last authorships. (E) The fraction of articles is depicted by country (bar plot) and by continent (pie charts). Please note that the sum of percentages is greater than one due to international collaborations. AU=Australia, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IT=Italy, KR=South Korea, NL=Netherlands, SE=Sweden, US=United States.



SFig 4: Test for alphabetical ordering of the author list. The proportion of publications with an alphabetic ordered author list is depicted with respect to the authors per article (blue). The values correspond very closely to those obtained for randomly ordered author lists (yellow).



SFig 5: Probability density function of the citation rate. The semi-logarithmic plot of the citation count per article (=citation rate) exhibits an exponential-like decreasing probability density function with a mean citation rate of 9.2 citations/article.

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Primary Subject Heading:	Dermatology
Secondary Subject Heading:	Medical publishing and peer review
Keywords:	odds ratio, prestige, citations, productivity, career

Gender disparities in high-quality dermatology research - a descriptive bibliometric study on scientific authorships

Michael H. K. Bendels[1], Michelle C. Dietz[1], Dörthe Brüggmann[1], Gerhard M. Oremek[1], Norman Schöffel[1*], and David A. Groneberg[1*]

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List of Abbreviations

AAGR: Average Annual Growth Rate

FAOP: Proportion of Female Authorships

FAP: Female Authorship Ratio

PI: *Prestige Index*

Abstract

Objective: The present study aims to elucidate the state of gender equality in high-quality dermatological research by analyzing the representation of female authorships from January, 2008 to May, 2017.

Design: Retrospective, descriptive study.

Setting: 113,189 male and female authorships from 23,373 research articles published in twenty-three dermatological Q1 journals were analyzed with the aid of the Gendermetrics Platform.

Results: 43.0% of all authorships and 50.2% of the first-, 43.7% of the co- and 33.1% of the last-authorships are held by women. The corresponding female-to-male odds ratios are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The annual growth rates are 1.74% overall and 1.45% for first authorships, 1.53% for co-authorships, and 2.97% for last authorships. Women are slightly underrepresented at prestigious authorships compared to men (Prestige Index = -0.11). The underrepresentation remains stable in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals. Multi-author articles with male key authors are only slightly more frequently cited than those with female key authors. Women publish slightly fewer papers compared to men (47.2% women hold 43.0% of the authorships). At the level of individual journals, there is a high degree of uniformity in gender-specific authorship odds. By contrast, distinct differences at country level were revealed. The prognosis for the next decades forecasts a consecutive harmonization of authorship odds between the two genders.

Conclusions: In high-quality dermatological research, the integration of female scholars is advanced as compared to other medical disciplines. A gender gap consists mainly in the form of a career dichotomy, with many female early career researchers and few women in

academic leadership positions. However, this gender gap has been narrowed in the last decade and will likely be further reduced in the future.

Keywords: odds ratio; prestige; citations; productivity; career

Strengths and limitations of this study

- The Gendermetrics Platform is a well-established system to analyze gender disparities in science by considering the gender-specific distribution of first, co- and last authorships.
- The purely bibliometric and algorithmic approach allows analyses of large volumes of data standardized and independent of the examiner, and thus with a minimized interindividual variability.
- Our analysis is limited by the absence of information concerning equally distributed authorships, corresponding authors, as well as data providing information about the scholar's academic degree, their position, age, employment status and their participation on editorial boards.
- The investigation period is technically limited to articles that are published after 2006 due to the predominance of initials preventing a correct gender identification by first names in older articles.

Introduction

The past decades have seen an enormous increase in the number of women entering medicine[1]: While in 1969, 6.9% of the U.S. medical graduates were women, the percentage reached a value of 47.5% in 2014[2]. The enrollment in U.S. medical school in 2016 was almost evenly divided between women (49.8%) and men (50.2%)[3]. Despite this enormous increase of women entering the field of medicine, "across medicine and dermatology, this influx has not been accompanied by a parallel progress by female faculty with academic credentials or in leadership roles", as stated by an editorial of Alexa Kimball[4] and many articles have addressed different gender and generational aspects in academic dermatology in the past years [5-9]. In 2012, Sadeghpour et al. published results from a national survey on the role of gender in academic dermatology[1]. They assessed whether there is an association between gender and academic rank. They came to the conclusion that gender-based differences in academic dermatology, including career track, academic rank distribution, leadership, and career satisfaction, persist[1]. Of a total of 259 full-time US academic dermatologists (38.6% were female), they found that men held more senior positions even after adjustment for age and number of years since completion of residency[1]. Working hours did not differ significantly. While most men (90.3%) and women (82.8%) were satisfied with their career, women were 24.6% more likely than men to consider leaving academia[1]. In line with these findings, Shi et al. conducted in 2017 a cross-sectional observational study of dermatology departments and divisions in the U.S. revealing that women account for 47.9% of dermatology residency program directors (PD) but comprise only 23.5% of chairpersons/chiefs[10]. Another recent study investigates the influence of women in academic dermatology by assessing the number of women acting as editors-in-chief of prominent dermatology journals[11]. The study revealed that there have been 26 female editors and at least 128 male editors in the considered 25 dermatology journals and that

45.8% of journals have not yet had a female editor[11]. Moreover, the study clearly showed that in the last decades there has been an increase in the number of women holding these prestigious positions.

As stated previously, an indicator for the balance between integration of female and male dermatologists and scientists is the quantification of their scholastic activity as represented by “authorship” in scientific publications[12-15]. In general, authorships represent the currency system of research and academic community[16]. In original medical articles, the assignment of authorship follows, by convention, the rule that "the first author indicates the person whose work underlies the paper as a whole"[17], whereas the last authorship "indicates a person whose work or role made the study possible without necessarily doing the actual work" [17]. Thus, the assignment of authorships differs considerably from, for example, economics or mathematics, where authors are usually listed in alphabetical order [16]. One consequence is that an early-career researcher normally publishes as first or co-author, whereas a senior researcher prefers the last author position in original research articles[18,19]. A further consequence of this assignment rule is that the different types of authorships are associated with different prestige. Specifically, first and last authorships have a significantly higher reputation than co-authorships[18].

Based on these consideration, we here applied the recently established Gendermetrics Platform[20] to analyze the integration of women in high-quality dermatological research by assessing 113,189 male and female authorships from twenty-three dermatological Q1 journals.

Conceptually, we determined the proportion of female first, co- and last authorships and quantified the relative distribution of female authorships among the different authorships

compared to men by applying odds ratios. Moreover, we used the *Prestige Index* to analyze the distribution of prestigious authorships between the two genders. The analysis includes global status and temporal development, differences across countries and the role women tend to have in articles with many authors, e.g. collaboration on articles [14]. Moreover, a gender-specific analysis of scholarly productivity and citation rate was conducted. The study concludes with a ten-year forecast regarding the development of gender disparities in the field of high-quality dermatological research.

Methods

Data acquisition & integration

The data analysis was conducted using Gendermetrics.NET[20], a SQL-Server based Platform for analyzing bibliometric data with a special emphasis on gender aspects. Research articles from high impact dermatology journals listed in the Scimago Journal & Country Rank database (http://www.scimagojr.com/journalrank.php?category=2708) were acquired on May 15, 2017 from the Web of Science Core Collection (Thomson Reuters). The journals constitute the subset of dermatological Q1 journals in 2016 representing the top 25% of the corresponding impact factor distribution. The journals '*Fibrogenesis and Tissue Repair*', '*Infectious Diseases in Obstetrics and Gynecology*' and '*Dermatology and Therapy*' were not considered because there were not indexed in the Web of Science database. The journals *'Aids Research and Treatment*', '*BMC Dermatology*', '*Clinics in Dermatology*', '*Dermato-Endocrinology*' and '*HIV/AIDS-Research and Palliative Care*' were excluded from analysis due to a low number of articles (< 200 articles). Furthermore, the journals '*British Journal of Dermatology*' and *'Journal of the European Academy of Dermatology and Venereology*' had to be excluded from analysis due to the predominant usage of initials instead of full first names, which prevents the correct gender determination. In total, 23 of the 33 dermatological Q1-journals with 23,373 articles written by 74,354 authors remain for analysis.

Gender determination

The algorithmic gender determination operates on the basis of a data table containing the gender of 77,818 forenames (male, female or unisex), see Bendels et al.[20]. By applying the algorithm, 30,538 (= 41.1%) male authors, 27,261 (= 36.7%) female authors, 5,509 (= 7.4%) unisex authors and 11,046 (= 14.9%) undefined authors were determined with a relatively little inter-annual variability (supplementary Fig. 1). The Unisex and undefined authors and

their authorships were not taken into consideration (in total 27,182 authorships). As a result, 113,189 male and female authorships affiliated to institutions from 150 countries were analyzed. The research output of a country was thereby benchmarked by considering the authorships of the related institutions[14]. It is important to note, that the quality of gender detection depends on the authorships country as illustrated by supplementary Fig. 2. In order to ensure the validity of the *country-specific* analysis, we set a threshold criterion for the country-specific analysis (supplementary Fig. 2), as recently described in Bendels et al. [20]. In particular, only countries with a detection rate of at least 79.3% male or female authorships were considered. As a result, among the top 20 most productive countries, the Asian countries China, South Korea (with high rates of unisex names) and India (with many undefined names) were excluded. A bibliometric overview is given in supplementary Fig. 3.

Proportion of Female Authorships (FAP) & Female Authorship Odds Ratio (FAOR)

In this study, first-, co- and last-authorships were considered, whereby co-authorships encompasses all authorships between *one* first- and *one* last-authorship. Equally distributed authorships were not considered due to a lack of information. The ***proportion of female authorships*** (***FAP***) is defined as the quotient between the female authorship count and the total sum of male and female authorships. The FAP is presented as a percentage to improve the textual readability. The female to male odds ratios for first-, co- and last-authorships were determined (***female authorship odds ratio***, ***FAOR***) with the corresponding confidence intervals at a confidence level of 95%[14]. The FAOR measures the female odds of securing a particular authorship type compared to men. A FAOR of e.g. 2.0 or 0.5 means that women or men, respectively, have twice the odds of holding a particular authorship compared to respective other gender[14]. For a simplified representation, a triplet is used to indicate the sign of the *significant* female odds ratio excess to get a particular authorship. For example,

the FAOR-triplet **(-, =, +)** indicates that women have *significantly* lower odds ratios for first-, equal odds ratios for co- and significantly higher odds ratios for last-authorships compared to men[14]. In summary, the FAP measures the quantitative representation of female authorships, whereas the FAORs quantify the relative distribution of female authorships among the different authorships[14]. To increase the statistical significance, the FAP/FAOR-classification is only conducted for subjects (e.g. countries, journals) with at least 750 male or female authorships.

Prestige Index

The *Prestige Index* measures the female odds of holding prestigious authorships compared to men[14]. It is defined as the prestige-weighted average of the FAOR excess ε_t that is calculated over all authorship types t (i.e. for first, co- and last authorships), $\varepsilon_t = w_t\,(FAOR_t - 1)$, if $FAOR_t \geq 1$, otherwise $\varepsilon_t = w_t\,(1 - 1/FAOR_t)$ with the weighting factor w_t[14]. In medical science, the prestige of scholarships follows a ranked order with a higher reputation of first and last authorships and a lower reputation of co-authorships [18]. Specifically, a potentially alphabetical ordering of the author list was excluded by an additional test (supplementary Fig. 4). Therefore, co-authorships were weighted negatively ($w_{co} = -1$), whereas first and last authorships were weighted positively ($w_{first} = w_{last} = 1$)[14]. This definition implies that the *Prestige Index* is e.g. lowered by both higher odds for co-authorships and lower odds for first and last authorships. A value of 0 characterizes a balanced distribution of prestigious authorships between the two genders, whereas a value above (below) 0 indicates an excess (lack) of prestigious authorships held by women.

Analysis of data

Average annual growth rates (AAGR) were applied to characterize annual growth rates[14]. The AAGRs of both, FARs and number of authorships were used to make a linear prognosis of the

temporal development of FAP, FAOR and *Prestige Index* for the coming decade. The Pearson correlation was applied to evaluate the linear association between the FAP, the *Prestige Index* and the journals' mean impact factor. The latter was calculated over the years 2008 to 2016/2017. The null hypothesis, whether the *non-normally* distributed gendered citation rates (supplementary Fig. 5) stem from the same distribution, was tested by a Kruskal-Wallis-test and a post-hoc multi-comparison test. The significance threshold was set at .05.

Patient and Public Involvement statement

No patients were involved in the study.

Results

Female authorships on a global level

In a first step, we analyzed the representation of female authorships on a global level. The analysis reveals an underrepresentation of female authorships with a FAP of 43.0% (Fig. 1A, bottom), relatively more first-authorships (50.2%), an almost equal proportion of female co-authorships (43.7%) and a substantially less fraction of last-authorships (33.1%). The corresponding FAORs (Fig. 1A) are 1.41 (CI: 1.37-1.45) for first authorships, 1.07 (CI: 1.04-1.10) for co-authorships and 0.60 (CI: 0.58-0.62) for last authorships. The differences are statistically significant (P<.05) for all types of authorships between the two genders. Thus, the global FAOR-pattern is characterized by the FAOR-triplet (+, +, -), i.e. women have significant higher odds for first and co-authorships and significant lower odds for last-authorships. The *Prestige Index* is on average -0.11, indicating a minor lack of prestigious authorships held by women (Fig. 1A, bottom).

The FAP exhibits a relatively high increase over the evaluation period (39.5% in 2008, 46.1% in 2017, Fig. 1B) with an AAGR of 1.74%. The subanalysis reveals a disproportionally high annual growth for last authorships (2.97%) and disproportionally low values for co- (1.53%) and first authorships (1.45%). Overall, this led to more gender-neutrality in authorships odds during the recent years, as also indicated by the *Prestige Index* (-0.19 in 2008 and -0.11 in 2017).

Differences across countries

When we refined our analysis from global to country-specific level, we identified among the most productive countries a wide range of FAPs that extent from 66.7% in Finland to 25.3% in Japan (Table 1). Different FAOR-patterns were identified ranging from *unfavorable* with the FAOR-triplet (=, +, -) identified in Poland, Italy, and Spain to *favorable* with the FAOR-triplet (+, -, =) in Denmark, Finland and the Netherlands (Table 1). Israel provides gender-

neutrality with respect to all authorships (FAOR-triplet (=, =, =)). The majority of the countries exhibit FAOR-patterns that are characterized by lower female odds for last and higher female odds for first authorships compared to men. Remarkably, there is not a single country where women have currently higher odds for a last authorship compared to men.

When considering the distribution of prestigious authorships, we found countries with very high *Prestige Indices*, like Denmark (*Prestige Index* = 0.60), Finland (0.54), and the Netherlands (0.42). In these countries, women have higher odds to hold a prestigious authorship compared to men. By contrast, Italy (*Prestige Index* = -0.46), Spain (-0.50), Japan (-0.51) and Austria (-0.58) are characterized by a lack of prestigious authorships held by women. Remarkably, we found no significant correlation between the FAP of a country and its *Prestige Index* (r(18)=0.36, P>.05).

Differences across journals

At the level of individual journals, the FAP ranges from 53.4% in *Sexually Transmitted Diseases* to 32.9% in *Lasers in Surgery and Medicine* (Table 2). The predominant FAOR-pattern is characterized by the FAOR-triplet (+, =, -). Moreover, in almost all journals (with the exception of *Contact Dermatitis*) women have significant lower odds for last-authorships. Furthermore, in our analysis, there is no journal, where a) male scholars have significantly higher odds for first authorships compared to their female counterparts, and b) where women have higher odds to secure last authorships than men.

The *Prestige Index* value range is from -0.50 to 0.19 (Table 2): Best odds for women to secure prestigious authorships are given in *Contact Dermatitis* (*Prestige Index* = 0.19) and *Acta Dermato-Venereologica* (0.11), whereas *Dermatology* (-0.5) and *Mycoses* (-0.41) provide best odds for male scholars. We found no significant correlation between the a) FAP of the

journal and its Mean Impact Factor (r(21)=0.08, P>.05), b) the *Prestige Index* and the Mean Impact Factor (r(21)=0.37, P>.05), and c) the FAP and the *Prestige Index* (r(21)=0.08, P>.05).

Female authorships by authors per article

We also assess the role women tend to have in articles with many authors, e.g. collaborative articles. The FAP fluctuates between 40.9% (1-3 authors/article) and 43.7% (7-9 authors/article) and exhibits no significant correlation to the number of authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article) (Fig. 2). In addition, the FOAR for co-authorships shows no significant relationship to the author rate. As a consequence, the *Prestige Index* fluctuates between -0.02 (13-15 authors/article) and -0.21 (>15 authors/article). To summarize, FAP, FAORs and *Prestige Index* show no clear correlation to the number of authors per article.

Citation & Productivity Analysis

The analysis reveals that articles with male key authors are more frequently cited than articles with female authors (Fig. 3A). However, the differences are very low as articles with a male last or first author have average citation rates of 9.7 citations/article and 9.6 citations/article, respectively and articles with a female first or last author exhibit citation rates of 9.1 citations/article and 9.0 citations/article, respectively. Statistically significant differences in the distributions of citation rates were only found between articles with male last authors and all other article groups (Kruskal-Wallis-Test, P<.05). Articles with a female first or last authorship were on average below the mean citation rate of 9.2 citations/article.

The analysis of combined authorships shows that male-first/female-last and male-first/male-last articles have on average the highest citation rates with 10.1 citations/article and 9.9

citations/article, respectively, followed by female-first/male-last (9.5 citations/article) and female-first/female-last (8.5 citations/article) articles (Figure 3A, right). Single-authored articles have the lowest citation rates with slightly higher citation rates for male-authored articles (6.8 citations/article vs. 6.5 citations/articles).

The analysis further demonstrates that statistically the citation rate of an article gets higher the more authors are involved, e.g. articles with 1-3 authors are on average cited 7.8 times, whereas articles with more than 15 authors are cited 15.9 times on average (Fig. 3B). Furthermore, the revealed differences in the citation rates between articles with male or female key authors are not preserved when articles are grouped by the length of their author list, as shown by Fig. 3B. In this grouping scheme, articles with female last authors and more than 15 authors attract the highest citation rates of on average 18.6 citations per article.

Considering the gender-specific distribution of the article count per author, we found, that the subgroups 'author of 1 article' and 'author of 2 articles' are relatively dominated by women. In particular, 71.5% of the female authors, but only 68.1% of the male authors had published a single article in our data set (Fig. 3C). By contrast, all other subgroups with three or more articles per author show a relative overrepresentation of male authors. Particularly, the subgroup of most productive authors ('author of more than 10 articles') is considerably dominated by men (2.4% of the male authors vs. 1.2% of the female authors). This finding results in a slightly higher productivity of male authors, as 53.0% of male authors hold 57.0% of all authorships (Fig. 3C).

Discussion

Advanced integration of women

The field of high-quality dermatological research is characterized by a moderate underrepresentation of female authorships with an FAP of 43.0%. This value is considerably higher than the previously determined FAPs, which were found for the whole area of science (30%) [13], for six high-quality medical journals (34%)[21], and for similar studies from the research fields of epilepsy (39.4%)[14], schizophrenia (37.6%)[12], stroke research (36.3%, unpublished data), and lung cancer research (31.3%)[22], see Table 3.

Female scholars are inhomogeneously distributed across the different authorships: We found many female first authorships and a significantly lower proportion of female last authorships. Evidently, this finding illustrates the well-known, gender-specific career dichotomy as first- or co-authorships are usually held by early career researchers, whereas last authorships are regularly preserved for institutional heads or principal investigators [18]. Such a discrepancy in leadership positions has been described for the most scientific disciplines [13], including various medical research fields[1,12,14,23-26]. What are the reasons for such a striking career dichotomy between the two genders? Differences in career preferences between men and women are one reason that can be cited in this regard[27]. Specifically, it has been shown that men were more likely to occupy investigative career tracks (26.5% vs. 11.1%), whereas women predominantly occupied clinical educator tracks (81.5% vs. 50.0%) in U.S. dermatology [1]. Other reasons include altered life priorities like family planning[13], the lack of role models[26], an insufficient work-life balance[26], women's increased likelihood to occupy part-time positions[1], and the consistently high influx of female medical students and graduates[26].

Interestingly, low female odds for last-authorships are numerically compensated by high female odds for first-authorships. This constellation leads to an almost gender neutral distribution of prestigious authorships on the global level. This finding is important, since academic publishing at prestigious authorships is one of the core elements of career advancement in science[12,28-30]. However, the underrepresentation of last authorships potentially reduces the further career advancement of the female scientists[31], since last authorships are often taken as a major indicator of successful leadership, e.g. by committees making this a criterion in granting and hiring[18]. In line with this, a cross-sectional survey from 2009 revealed a clear gender difference in academic *senior* ranks of U.S. dermatologists, as it was reported that "women were predominantly at the assistant professor level (50.0%) compared with men (24.3%), whereas men were predominantly at the full professor level (47.4%) compared with women (14.9%)"[1]. Evidently, in dermatology, the proportion of female faculty members declined as academic rank increased.

Stable representation of women in multi-author articles results in almost gender-neutral citation rates

Remarkably, we found no significant relationship between the representation of female authorships and the number of authors per article. Specifically, the representation of female authorships remains also stable for articles with high numbers of authors (e.g. collaboration articles), which statistically attract the highest citation rates (Fig. 3B)[32]. This is an important result, since it provides a good explanation for the almost equal citation rates of articles that were grouped by the gender of their keys authors. This is particularly remarkable, since for all other disciplines we have examined so far, we find a) an accentuating underrepresentation of women at prestigious authorships with an increasing number of authors per article and b) significantly higher citation rates of articles with male key authors. Moreover, previous studies from various disciplines also reported about substantially higher

citation rates for articles with male key authors[13,29,31,33-35]. To summarize, well-balanced citation rates between the two genders suggest that the integration of women in dermatological science is well-advanced. Methodically, it is important to note that the determined citation rates describe essentially the situation from the early phase of investigation (2008-2010), since older articles have a stronger impact on the citation statistics than newer articles ("Cited Half-Life")[36].

Structural position affects productivity

The lower productivity of female scholars (47% female authors hold 43% of the authorships) is in line with reports from other scientific fields and medical disciplines[12-14,23-25,37]. Interestingly, we were able to reproduce the clear male overrepresentation at levels of higher productivity (Fig. 3C), as already shown for the fields of ecology and evolutionary biology[34], the medical research fields of schizophrenia[12] and epilepsy[14], and for the field of high-quality research from the areas life science, earth & environmental, multidisciplinary and chemistry[35]. It is reasonable to assume that the primary factors affecting women's productivity are not higher rejection rates as explicitly shown for the journals *Cortex*[38] and *Nature Neuroscience*[39], but rather, due to the position of women within the scientific system[28,35]. In practice, the mainly male senior scientists are often associated to more or less fruitful (citation) networks, whereas "women are more likely to work as adjuncts or at teaching-intensive institutions with limited resources" [28]. This assumption is confirmed by a previous study from Sadeghpour et al.[1] documenting no differences in the number of publications of full-time academic dermatologists after adjustment for academic rank. Moreover, it has been shown by Reed at al. [37] that women's publication rates start to increase later in their career.

Distinct regional differences

Apart from these global findings, distinct regional differences were found with best-balanced authorship odds between the two genders in Israel (FAOR-triplet (=, =, =), *Prestige Index* = -0.01). When taking the chance of holding a prestigious authorship as a general surrogate parameter for career advancement in science [14], Denmark, Finland, and the Netherlands provide the best conditions for female authors. By contrast, Italy, Spain, Japan, and Austria offer optimal conditions for men in dermatological research. This finding correlates quite well with the results of the Global Gender Gap Report 2016 as the countries Finland, the Netherlands and Denmark were ranked 2nd, 16th, and 19th, respectively, whereas the countries Spain, Italy, Austria, and Japan were ranked 29th, 50th, 52nd and 111th, respectively, out of a total of 144 countries in the world [40]. It is plausible to assume that these regional differences are not caused by discipline-specific characteristics, but rather, are primarily due to socio-cultural surroundings, as, for example, Japan is characterized by a strong sense of patriarchy and traditional gender roles in society[41]. This is all the more relevant, since similar constellations were found in most of our studies[12,14]. Overall, the given information supplies women operating in the field of dermatology with a solid basis for decision-making for professional reorientation or career planning.

As in all our previous studies, we did not find a significant correlation between the FAP of a country and the distribution of prestigious authorships between the two genders[12]. This means, countries with a high FAP can also provide disadvantageous career opportunities for women and vice versa. A valuable example is Italy with a high rate of FAP (54.2%) and a negative *Prestige Index* (-0.46). Interestingly, this finding is contrary to the socio-cultural theory of the critical mass[42], postulating a self-sustained harmonization of gender aspects

once the participation of women has exceeded a critical threshold value of about 30% to 35%.

Journals with a high degree of uniformity

At the level of individual journals, we reveal a striking uniformity of gender-specific authorship odds, as in 19 out of 23 journals women have significantly higher odds for first authorships and lower odds for last authorships. Evidently, the global gender-specific hierarchy of research groups is mapped to the related journals. This finding explains also the relatively small value range of the journals' Prestige Index compared to that of other countries (Δ*Prestige Index*: 0.69 vs. 1.18). Remarkably, we do not find a significant correlation between the impact of a journal (characterized by the SJRI) and the revealed Prestige Index measuring the distribution of prestigious authorships between the two genders. Interestingly, this finding is contrary to our recent study analyzing the female authorship odds in fifty-four of *highest-quality* research journals listed in the Nature Index, which covers the journal categories *Life Science*, *Multidisciplinary*, *Earth & Environmental* and *Chemistry*. In this study a clear negative correlation between the 5-year-impact factor of a journal and its Prestige Index ($r(52)=-0.63$, $P<.01$) was revealed[35]. In contrast to academic dermatology, in this cross-discipline group of highest-impact journals, the female underrepresentation is accentuated in highly competitive articles attracting the highest citation rates, namely, articles with many authors and articles that were published in highest-impact journals (Table 3). To conclude, uniformity of authorship odds as well as stable representation of women regardless of the journal impact speak for an advanced integration of women and against the predominance of "old boys' networks" in the field of high-quality dermatology research and its related journals[14].

Limitations of the study

Methodically, our purely bibliometric and algorithmic approach enables us to analyze large volumes of data standardized and independent of the examiner, and thus with a minimized interindividual variability. However, as already mentioned in Bendels et al. [14], it is limited by the absence of information concerning equally distributed authorships, corresponding authors, as well as data providing information about the scholar's academic degree, their position (e.g. Associate Professor vs. Full Professor)[1], age, employment status and their participation on editorial boards [26,43]. Questionnaires or the inspection of e.g. online profiles provide a better access to this specific data, as shown by other studies [24,26,43]. Furthermore, the investigation period is technically limited to articles that are published after 2006 due to the predominance of first names initials preventing a correct gender identification in older articles[20]. Another limitation of the gender determination by first names is the fact that we had to exclude some countries from the *country-specific* analysis due to a relative high fraction of unisex names (primarily the Asian countries China and South Korea participating at 5% and 4%, respectively, of the articles).

Conclusion & Outlook

In conclusion, a) the relatively high FAP, b) the almost gender-neutral citation rates, and c) the stable representation of female scholars in both articles with many authors as well as highest impact journals can be considered indicators for an advanced integration of women in high-quality dermatological research compared to other (medical) disciplines (Table 3). However, a considerable career dichotomy is still present, with many female researchers at the beginning of their career and few women in academic leadership positions. Since there is a clear time-dependence present in authorship hierarchy - current early career researchers may be future research leaders – it is plausible to prognosticate a considerable increase of women in academic leadership positions in the next decade. This trend will likely be intense

due to the high annual increase of female authorships (1.74%) with the highest rates for the last author position (2.97%), and the trend of more and more female physicians entering the field of medicine in many Western countries[2,44]. In line with this perspective, a linear prognosis of the temporal development of female authorships prognosticates not only an FAP of 54.3% for the year 2026, but also increasing female odds for last authorships and decreasing female odds for co-authorships (Fig. 4). This harmonization in authorship odds results in a Prestige Index that is forecast to become almost gender-neutral in 2026 (*Prestige Index* = -0.03). On this basis, we expect a deeper integration of female scientists with a growing number of women in academic leadership positions in the next decade. However, it should be critically mentioned that, contrary to this prediction, various studies recently report about a striking persistence of gender inequalities regarding academic leadership positions despite a considerable increase in female first authorships [24-26,45].

In view of this, the present analysis may define a starting point: Continuous monitoring over the next years will elucidate if female career dichotomy will break down, leading to a more balanced distribution of research leaders between both genders in dermatological research.

CONTRIBUTORSHIP STATEMENT

MB, NS and DG designed the study. MB and MD collected and performed the analysis. MB, MD, DB, GO, NS and DAG interpreted the result. MB wrote the first draft of manuscript. MB, MD, DB, GO, NS and DG contributed to and have approved the final manuscript.

DATA SHARING STATEMENT

No additional data available.

COMPLIANCE WITH ETHICAL STANDARDS

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Tables

Table 1: Country Classification. Countries are descendingly ordered by their *Prestige Index*.

The number of considered male and female authorships is given by #Authorships.

Country Name	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Denmark	43.4%	(+, -, =)	0.60	637	2,392
Finland	66.7%	(+, -, =)	0.54	177	787
Netherlands	44.8%	(+, -, =)	0.42	941	3,400
Brazil	56.1%	(+, -, -)	0.14	959	4,141
Turkey	45.2%	(+, =, =)	0.08	518	1,930
Sweden	53.7%	(+, =, -)	0.07	630	2,118
Israel	38.3%	(=, =, =)	-0.01	331	1,032
Canada	42.1%	(+, =, -)	-0.04	816	2,160
Germany	37.6%	(+, =, -)	-0.09	2,498	10,438
Australia	42.6%	(+, =, -)	-0.10	817	3,016
United States	42.9%	(+, +, -)	-0.14	8,391	33,510
Belgium	51.2%	(+, =, -)	-0.16	378	1,001
France	48.9%	(+, =, -)	-0.17	1,171	5,566
United Kingdom	45.8%	(+, +, -)	-0.18	1,751	4,825
Switzerland	34.3%	(+, =, -)	-0.26	560	1,659
Poland	54.2%	(=, +, -)	-0.39	257	967
Italy	54.2%	(=, +, -)	-0.46	1,269	6,455
Spain	48.8%	(=, +, -)	-0.50	711	3,073
Japan	25.3%	(+, +, -)	-0.51	1,564	8,126
Austria	38.6%	(+, +, -)	-0.58	475	1,760

Table 2: Journal Classification. Journals are descendingly ordered by their *Prestige Index*.

Journal Name	Mean Impact Factor 2008-2016	Female Authorship Ratio	FAOR-triplet	*Prestige Index*	#Articles	#Authorships
Contact Dermatitis	3.85	49.5%	(+, -, =)	0.19	721	3,623
Acta Dermato-Venereologica	3.27	47.4%	(+, =, -)	0.11	834	4,749
Sexually Transmitted Infections	2.88	50.1%	(+, =, -)	0.06	1,110	4,369
Wound Repair and Regeneration	2.80	38.1%	(+, =, -)	0.03	847	4,354
Journal of Dermatological Science	3.54	33.4%	(+, =, -)	0.03	727	3,763
Journal of the American Academy of Dermatology	4.83	44.9%	(+, =, -)	-0.01	2,103	11,338
Sexually Transmitted Diseases	2.78	53.4%	(+, =, -)	-0.05	1,370	7,500
Journal of Investigative Dermatology	6.26	42.1%	(+, =, -)	-0.06	2,392	16,865
Lasers in Medical Science	2.29	40.1%	(+, =, -)	-0.1	1,550	6,130
American Journal of Clinical Dermatology	2.16	47.5%	(+, =, -)	-0.13	263	981
Melanoma Research	2.29	44.6%	(+, =, -)	-0.14	616	3,845
Dermatologic Surgery	2.04	35.9%	(+, =, -)	-0.16	1,715	6,473
Archives of Dermatological Research	2.19	41.6%	(+, =, -)	-0.16	799	3,355
Lasers in Surgery and Medicine	2.67	32.9%	(+, =, -)	-0.17	938	4,161
Pigment Cell & Melanoma Research	4.91	42.9%	(+, =, -)	-0.18	510	3,199
Experimental Dermatology	3.45	41.9%	(+, +, -)	-0.19	1,644	8,732
International Wound Journal	1.99	37.1%	(=, +, -)	-0.21	891	3,877
JAMA Dermatology	5.46	47.2%	(+, +, -)	-0.27	491	3,163
Journal of Dermatological Treatment	1.65	45.1%	(+, +, -)	-0.3	655	2,590
Dermatologic Clinics	1.74	47.3%	(+, +, -)	-0.35	569	1,205
Clinics In Dermatology	2.40	43.6%	(=, +, -)	-0.39	743	1,732
Mycoses	1.81	47.0%	(=, +, -)	-0.41	974	3,710
Dermatology	2.06	41.7%	(+, +, -)	-0.5	911	3,475

Table 3: Synopsis of different subject areas. In high-quality dermatological research, the integration of female scholars is advanced as compared to other (medical) disciplines. However, in all subject areas, a considerable career dichotomy is still present, with many female researchers at the beginning of their career and few women in academic leadership positions. Please note that the *Nature Index* offers a database for the specific analysis of high impact scientific efforts from the journal categories of multidisciplinary, earth & environmental, life science and physics[46] (physics was excluded from analysis).

Subject Area	FAP	FAOR First	FAOR Co	FAOR Last	*Prestige Index*	Female representation at prestigious authorships in		Gender-specific differences in citation rates
						multi-author articles	highest impact journals	
Q1 Dermatology	43.0%	1.41	1.07	0.60	-0.11	Stable	Stable	minor
Epilepsy[14]	39.6%	1.25	1.17	0.57	-0.22	Decline	-	major
Schizophrenia[12]	37.6%	1.30	1.20	0.57	-0.22	Sharp Decline	-	major
Lung Cancer[22]	31.3%	1.22	1.19	0.59	-0.22	Sharp Decline	-	minor
Nature Index Journals[35]	29.8%	1.19	1.35	0.47	-0.42	Sharp Decline	Decline	major

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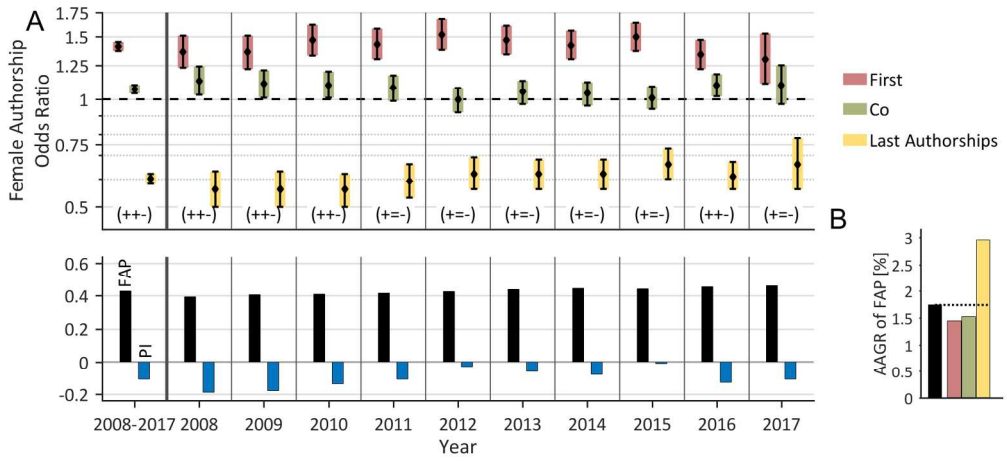
Figure Legends

Fig 1: Time trend of female authorships on the global level. (**A**) The relative frequency of female authorships (FAP, bottom), the pattern of FAORs (with FAOR-triplet, top) and its associated Prestige Index (PI) are depicted by year and averaged over time. The averaged FAOR distribution is characterized by the FAOR-pattern (+, +, -), i.e. women have significantly higher odds for first and co-authorships and significantly lower odds for last-authorships. The slightly negative PI indicates a lack of prestigious authorships held by women. (**B**) The FAP exhibits a relatively high increase as documented by its average annual growth rate (AAGR) of 1.74% per year with the highest rate for last authorships (2.97%). Overall, this led to more gender-neutrality in authorships odds during the recent years.

Fig 2: Female authorships by authors per article. Although the FAORs for first and last authorships have the tendency to slightly increase and decrease, respectively, with an increasing number of authors, this trend is reversed for higher author rates (>12 authors/article). FAP, FAORs and Prestige Index show no clear correlation to the number of authors per article.

Fig 3: Gender-specificity of citations & scholarly productivity. (**A**) The descendingly ordered citation rates show that articles with male key authorships are slightly more frequently cited than articles with female key authorships. The mean citation rate of 9.2 citations/article is depicted by a dotted line (Kruskal-Wallis test, (*): P<.05 (**): P<.01). (**B**) Average citation rates of ungrouped articles (bars) and articles that were grouped by the gender of their key authorships (lines), depicted as a function of the number of authors. Statistically, the citation rate of an article is higher the more authors are involved. The gender-specific differences in citation rates are not preserved across the different levels of author count. (**C**) Gender-specific distribution of the article count per author. Women dominate the sub-groups 'author has one or two article(s)'. All other sub-groups are characterized by a relatively over-representation of male authors. This finding correlates with the higher productivity of male authors, as 52.8% male authors are responsible for 57.0% of all authorships.

Fig 4: Linear projection of the development of female authorships on the global level. The prognosis for the next decades forecasts a further harmonization of authorship odds between the two genders with an almost gender-neutral distribution of prestigious authorships in 2026 (*Prestige Index* = -0.03). An FAP of 54.3% is prognosticated for the year 2026.



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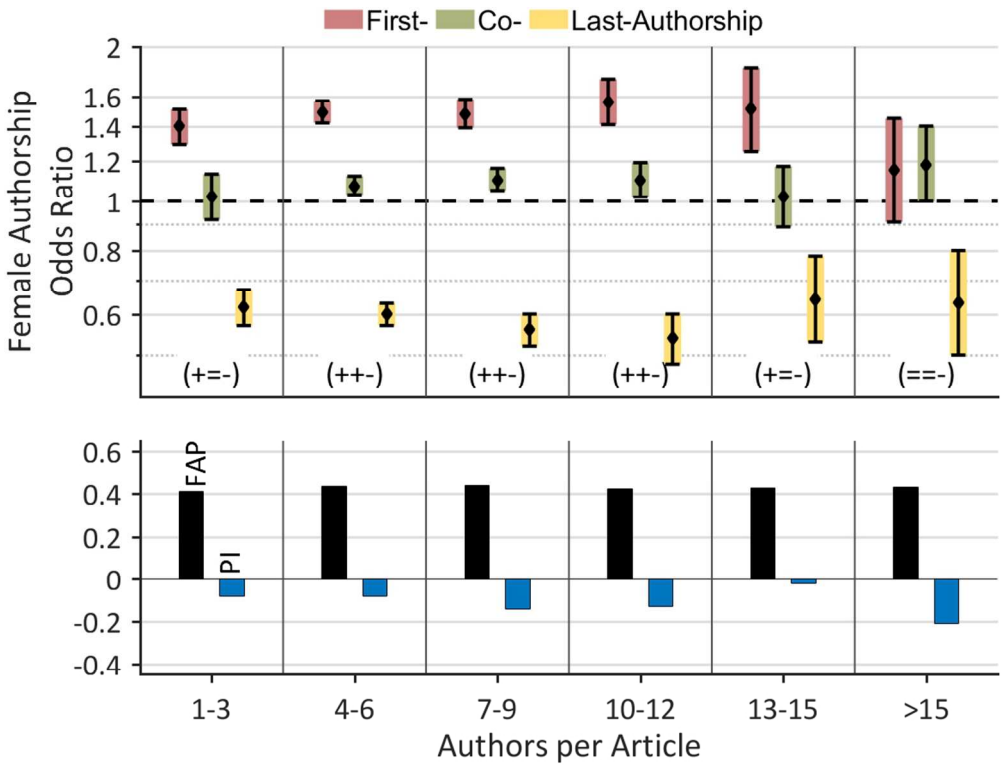

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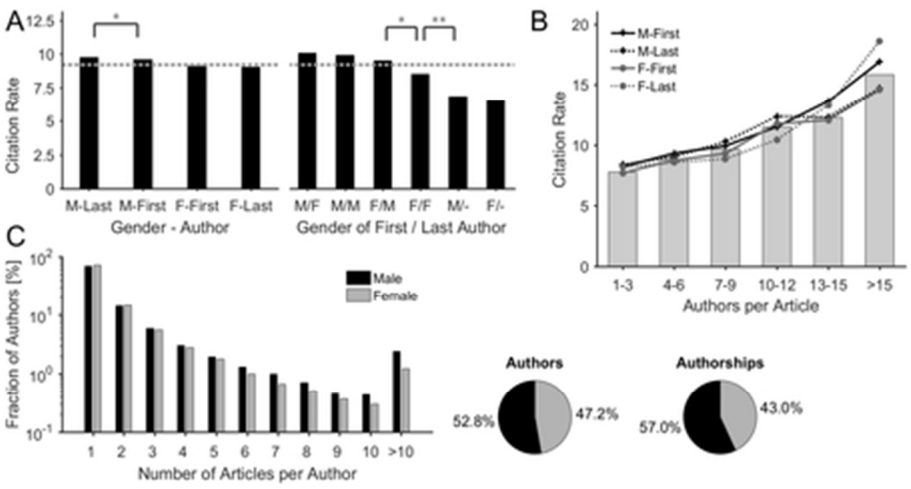

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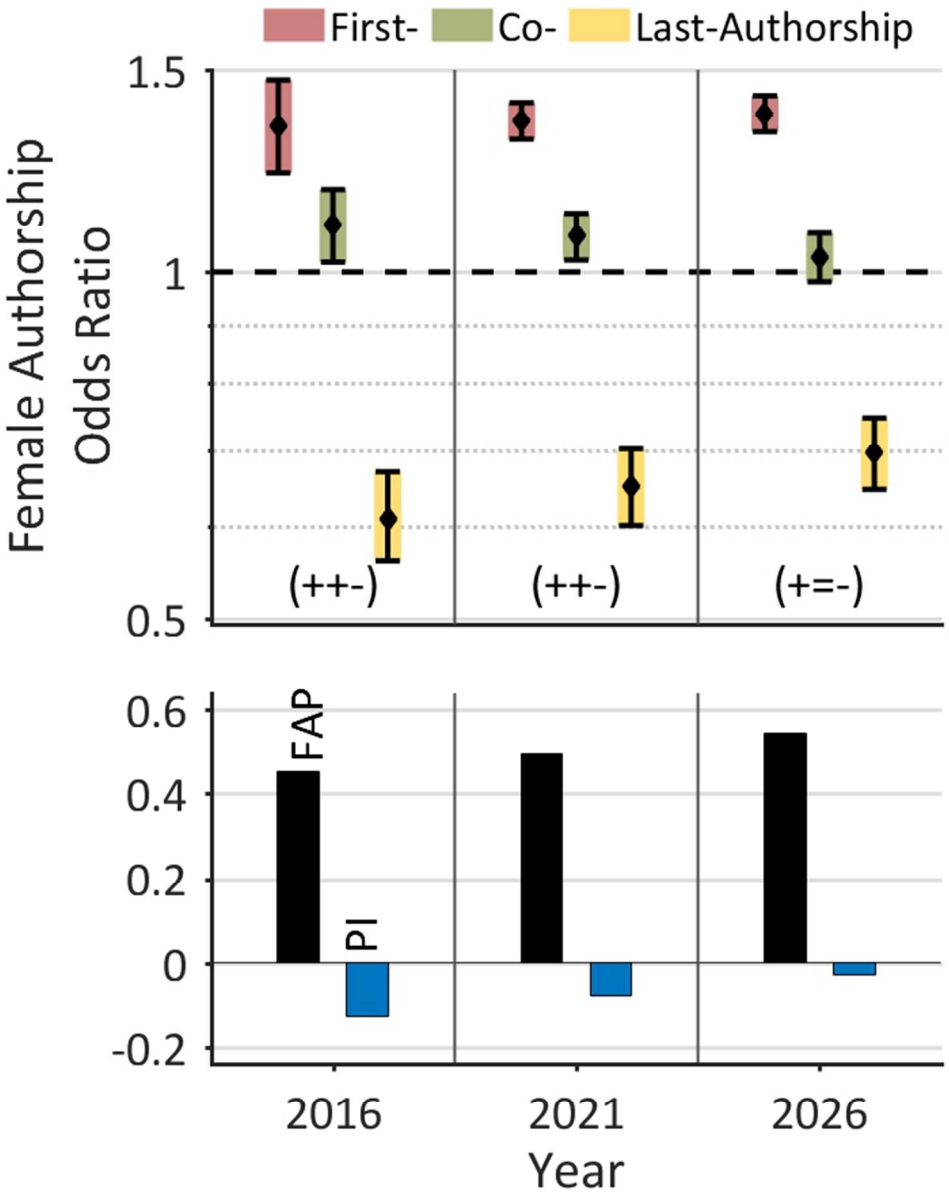

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Online Supplement

Gender disparities in high-quality dermatology research - a study on scientific authorships

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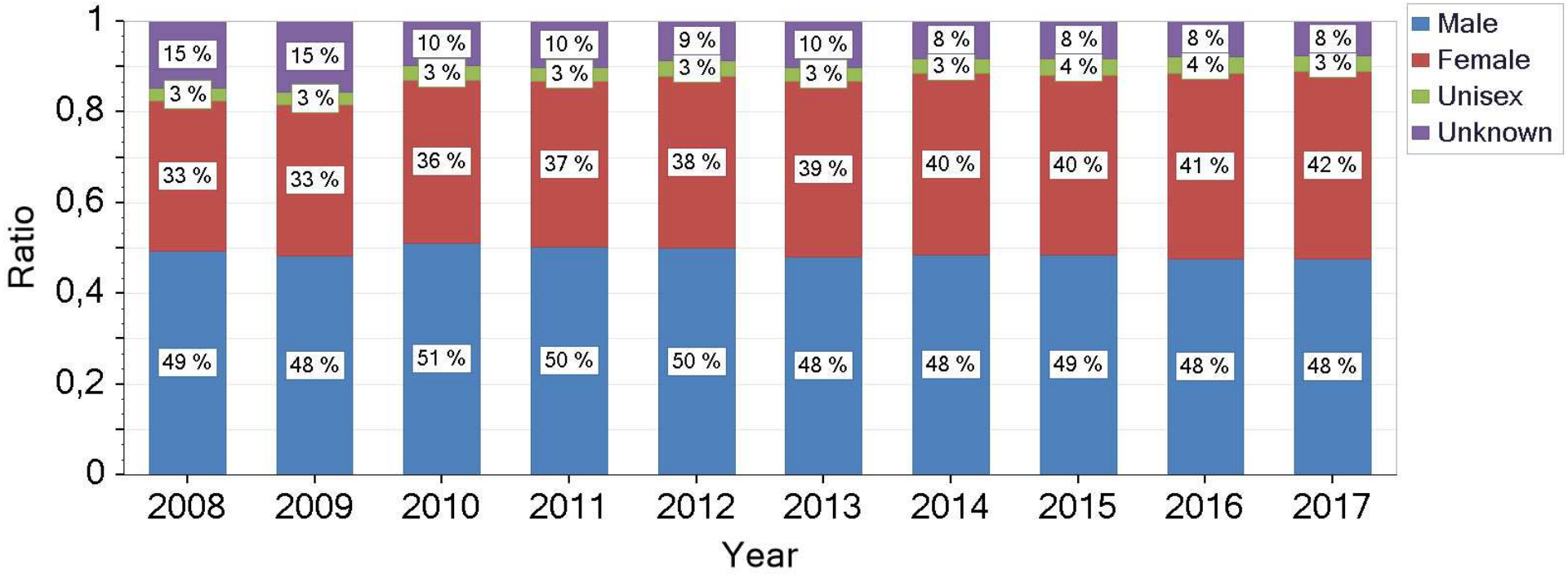
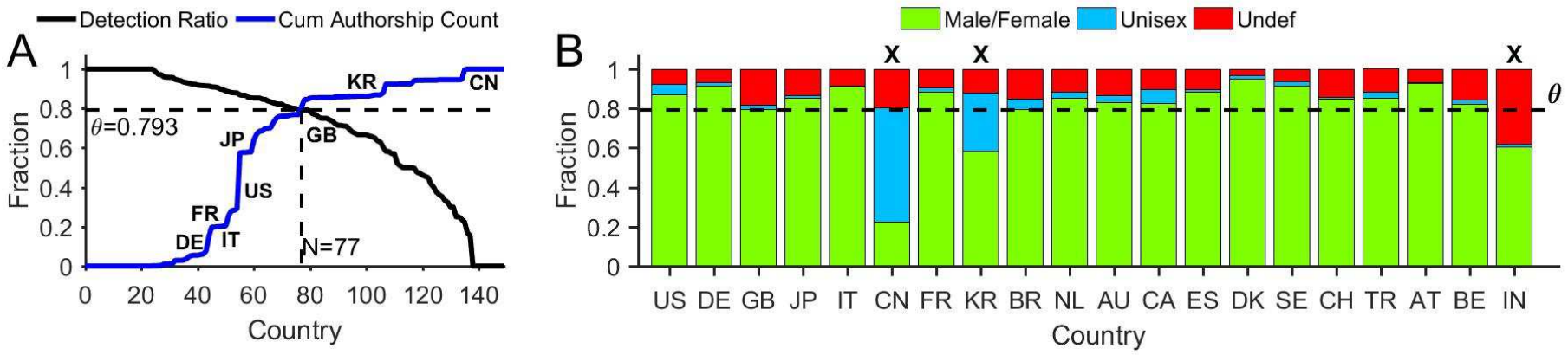
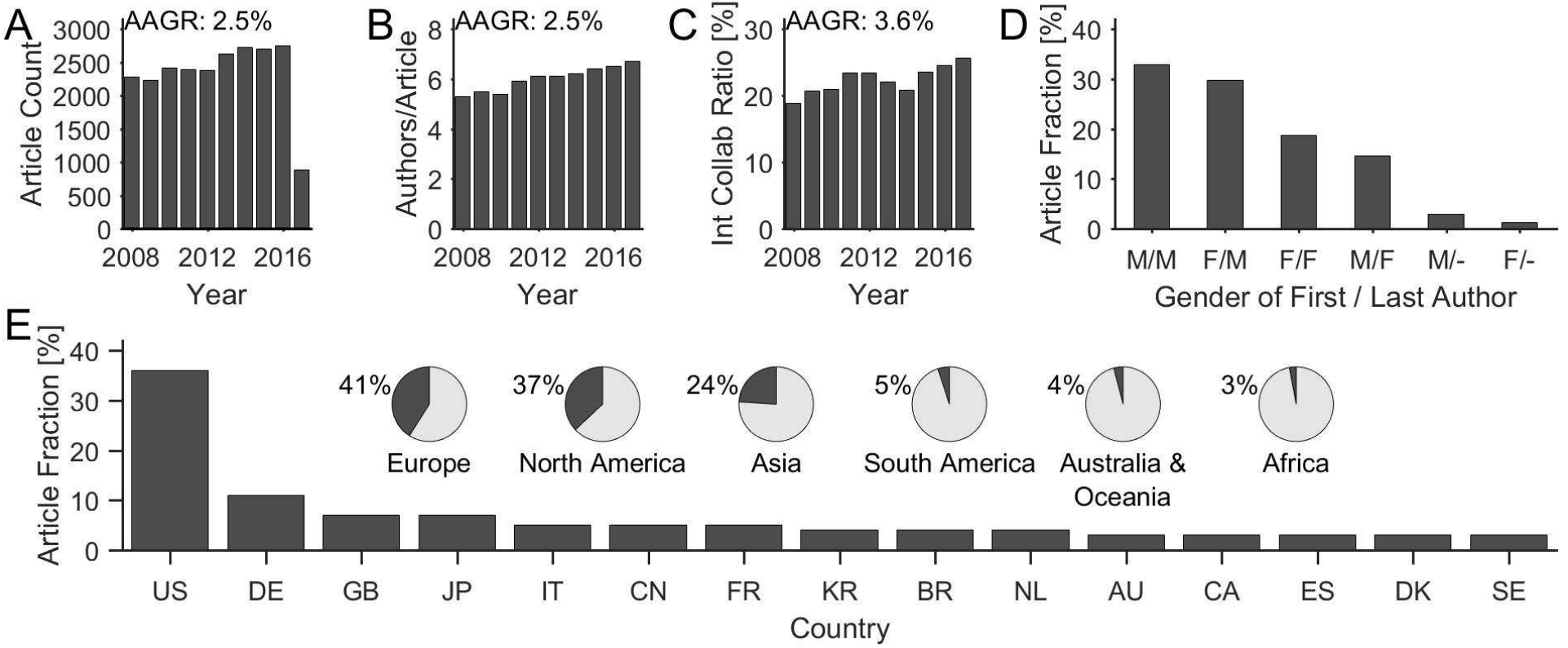


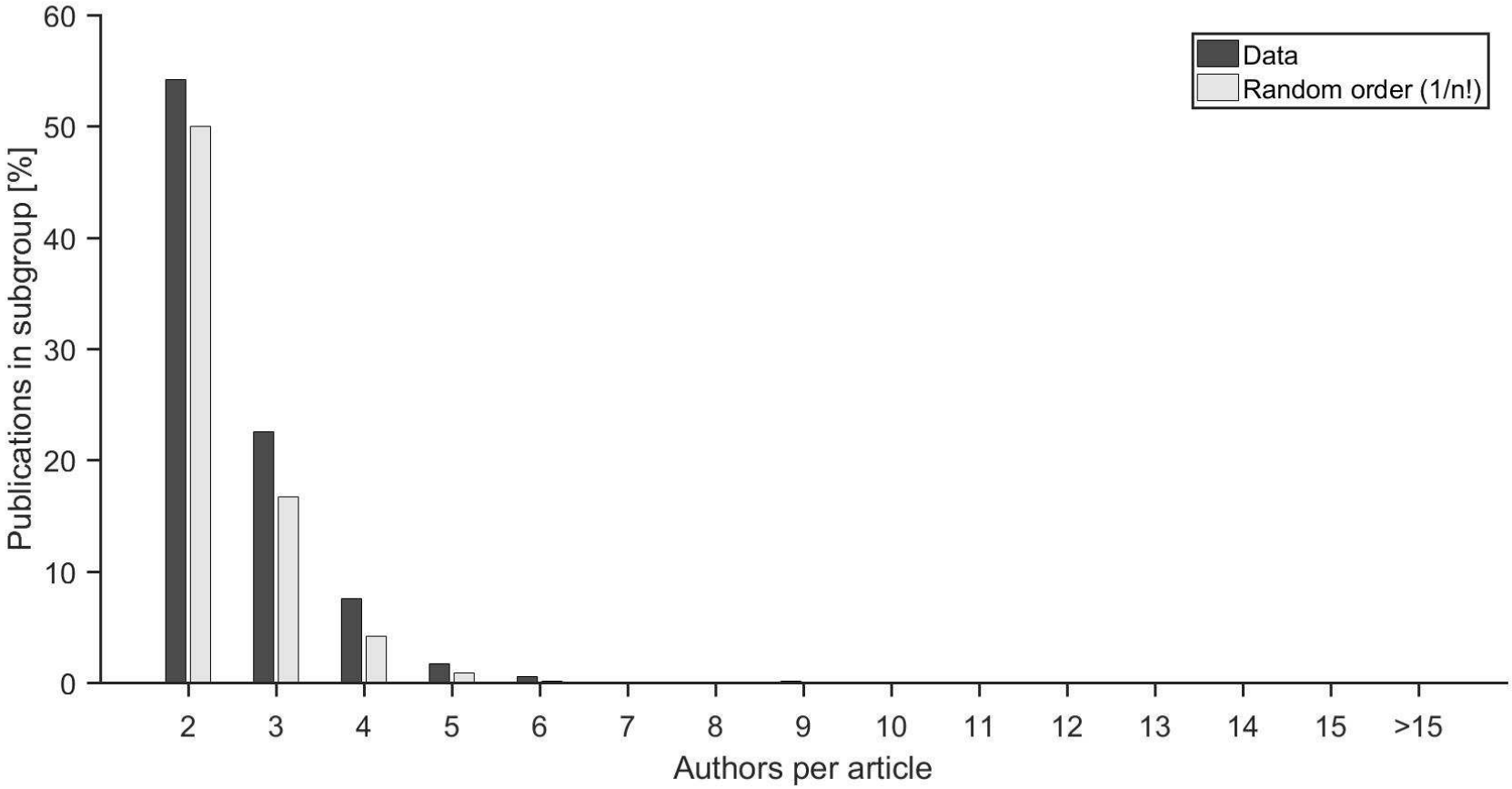
SFig 1: Gender Detection Output by Time. The ratios of detected male, female, unisex and undefined authorships ordered by publication year document a relatively small inter-annual variability.



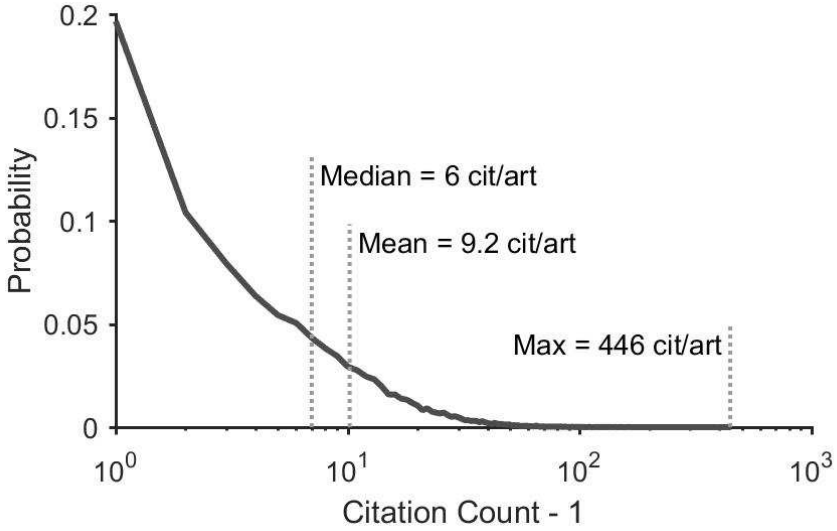
SFig 2: Quality of algorithmic gender detection by country. (**A**) An adaptive threshold country criterion θ for the inclusion of a country in the country-specific gender analysis was defined by a ROC-like curve incorporating both detection ratio and cumulative author count [1]. In this study, countries with a detection rate of at least θ = 0.793 male + female authors (i.e. 79.3% of all authorships) from N=77 countries were included in the country-specific analysis. Countries with a large amount of authors are indicated by country code. (**B**) The result of the algorithmic gender detection - classified as male/female, unisex or undefined - grouped by countries that are ordered in descending order by their publication count, documents a relative high frequency of male/female authors for most of the top 20 countries, with the exception of the Asian countries China (CN), South Korea (KR), and India (IN). The latter countries are characterized by a high frequency of unisex (CH, KR) or unknown names (IN) and are excluded (**X**) from analysis due to the threshold criterion θ (dotted line). AU=Australia, AT=Austria, BE=Belgium, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IL=Israel, IN=India, IT=Italy, JP=Japan, KR=South Korea, NL=Netherlands, SG=Singapore, SE=Sweden, TR=Turkey, US=United States.



SFig 3: Bibliometric overview. (A) The article count increases from 2,281 in 2008 to 2,750 in 2015; the average annual growth rate (AAGR) is 2.5%. (B) The number of authors per article increases from 5.3 authors/article in 2008 to 6.7 authors/article in 2017. (C) The percentage of international collaboration articles increases from 18.9% in 2008 to 25.6% in 2017 with an AAGR of 3.6%. (D) The fraction of articles grouped the gender of their key authors' documents a quantitative superiority of articles with male last authorships. (E) The fraction of articles is depicted by country (bar plot) and by continent (pie charts). Please note that the sum of percentages is greater than one due to international collaborations. AU=Australia, BR=Brazil, CA=Canada, CH=Switzerland, CN=China, DE=Germany, DK=Denmark, ES=Spain, FR=France, GB=United Kingdom, IT=Italy, KR=South Korea, NL=Netherlands, SE=Sweden, US=United States.



SFig 4: Test for alphabetical ordering of the author list. The proportion of publications with an alphabetic ordered author list is depicted with respect to the authors per article (blue). The values correspond very closely to those obtained for randomly ordered author lists (yellow).



SFig 5: Probability density function of the citation rate. The semi-logarithmic plot of the citation count per article (=citation rate) exhibits an exponential-like decreasing probability density function with a mean citation rate of 9.2 citations/article.

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