Sex Differences in Academic Rank, Scholarly Productivity, National Institutes of Health Funding, and Industry Ties Among Academic Cornea Specialists in the United States

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• PURPOSE: This study analyzed sex differences among cornea specialists with regards to academic rank, scholarly productivity, National Institutes of Health (NIH) funding, and industry partnerships.

• DESIGN: Cross-sectional study.

• METHODS: This was a study of faculty at 113 US academic programs. Sex, residency graduation year, and academic rank were collected from institutional websites between January and March 2019. H-indices and m-quotients were collected from the Scopus database. The NIH Research Portfolio Online Reporting Tool and Centers for Medicare and Medicaid Services databases were queried for data on NIH funding and industry partnerships.

• RESULTS: Of the 440 cornea specialists identified, 131 (29.8%) were female. The proportions of females and males at each academic rank (assistant 69.5% vs 41.8%; associate 17.6% vs 21.0%; full professor 13.0% vs 37.2%) were not significant after adjusting for career duration ($P = .083$, .459, and .113, respectively). Females had significantly lower median h-indices (4.0 [interquartile range {IQR} 7.0] vs 11.0 [IQR 17.0], $P < .001$) and shorter median career duration (12.0 [IQR 11.0] vs. 25.0 [IQR 20.0] years, $P < .001$) than males but similar median m-quotients (0.5 [IQR 0.8] vs 0.5 [IQR 0.8], $P = 1.00$). Sex differences in h-indices were not seen at each academic rank or career duration interval. Among NIH-funded investigators, the median grant funding was $1.6M (IQR $2.2M) for females and $1.2M (IQR $4.6M, $P = .853$) for males. Overall, 25.5% of females and 58.6% of males ($P = .600$) had industry partnerships.

• CONCLUSION: Sex differences within academic ranks and h-indices are likely due to a smaller proportion of females with advanced career duration. (Am J Ophthalmol 2021;222:285–291. © 2020 Elsevier Inc. All rights reserved.)

FEMALES COMPRISE A QUARTER (25.3%) OF ALL OPHthalmologists in the United States (US) and 29.6% of academic ophthalmology faculty.[1,2] Similar to other medical fields, the proportion of females in ophthalmology is expected to increase, as they currently make up half of all US medical graduates and 44.3% of ophthalmology residents.[1]

Despite the slow neutralization toward sex equity, previous studies have shown that female ophthalmologists continue to be under-represented on a national scale within leadership positions.[3,4] Our group previously found that the proportion of females on journal and society boards were similar to the proportion of females in ophthalmology, but that differences continue to exist in top positions such as journal editors-in-chief and society presidents.[4] Previous studies examining sex equity within academic institutions similarly found that females represent a small fraction (10.0%) of department chairs and that 13% of females compared with 34% of males achieve the rank of full professor.[5,6] Tuli and associates[7] found that the sex ratios at each academic rank have not changed significantly from 2003 to 2017.

One explanation for the differences above might be that they are related to academic productivity. In fact, using the h-index, Lopez and colleagues[6] previously concluded that females have lower scholarly productivity during earlier stages of their careers, thus impeding academic advancement. With regard to National Institutes of Health (NIH) funding among ophthalmologists, a study by Svider and colleagues[8] found that female principal investigators (PIs) were less likely to receive grants in their early careers and had lower award amounts compared with their male colleagues.[8] Reddy and associates[9] also found that female ophthalmologists establish fewer industry partnerships, which provides individuals with another source of income and collaboration.[10]

Cornea represents the second largest subspecialty among academic ophthalmologists at 16%, second only to vitreoretinal disease.[2] Females represent roughly 26% of this

Accepted for publication Sep 8, 2020.

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0002-9394/$36.00
https://doi.org/10.1016/j.ajo.2020.09.011

subspecialty.[11] Although previous studies have compared the academic productivity of cornea specialists with other subspecialties, the studies were limited in that none investigated sex differences within the field.[2] The purpose of this study is to investigate sex differences among academic cornea specialists in terms of academic rank, scholarly productivity, NIH funding, and industry partnerships.

METHODS

THIS CROSS-SECTIONAL STUDY RECEIVED A NONHUMAN research notification by the Penn State College of Medicine Institutional Review Board; therefore, informed consent was not required. All data were collected and managed using Research Electronic Data Capture (REDCap) by Penn State University.[12]

A search of all ophthalmology residency training programs participating in the 2019 San Francisco match yielded a total of 114 programs. Official institutional websites were accessed between January and March 2019 to obtain a list of all the cornea faculty at each academic institution. One program was excluded because of the lack of a faculty roster on the institutional website and because this information was not attainable through direct email communication. Therefore, 113 US academic ophthalmology programs were included for analysis.

Using official institutional websites and search engines, information was gathered on each cornea specialist regarding sex, year of residency graduation, and academic rank. The sex of each individual faculty was obtained using photograph identification, pronouns, physician profiles, and other supporting online search tools. Career duration of each individual faculty was calculated based on the number of years between their residency graduation year and the year 2019, which was the year of this study's data acquisition. Residency, instead of fellowship, graduation year was used because of greater accessibility of these data.

The Scopus database was used to determine each faculty member's total number of publications, the total number of publications that cited the author's papers, and h-index. Attempts were made to determine any alternative names that faculty members may have had via online searches of curricula vitae and Scopus website profiles to capture publications under previously used last names. The h-index, a measure of the scholarly productivity and impact of an author, is calculated based on the highest number of publications an author has received with at least the same number of citations.[13] Each faculty member's m-quotient, which adjusts for varying career lengths, was calculated by dividing the h-index by the author's career duration.[13]

The NIH Research Portfolio Online Reporting Tool Expenditures and Results (RePORTER, available at https://report.nih.gov) was queried using all faculty names (including alternative names when available) to gather data on research funding totals and the number of projects funded for each PI. This database captures NIH funding from the years 1985 to present. Available data for each faculty member for all available years was included for analysis.

The Centers for Medicare and Medicaid Services Open Payments database was queried for payments to cornea specialists by biomedical companies in 2019.[14] Data were collected on industry payments for research, consulting, honoraria, royalties and licenses, faculty and speaker positions for continuing education programs, and "services other consulting," which is typically defined as serving as a speaker at an event other than a continuing education program.

• **STATISTICAL ANALYSIS:** A binomial logistic regression model was used to compare academic ranks as binary response variables in terms of percentages between sexes while adjusting for career duration. Wilcoxon rank sum tests and medians were used to compare career duration, which was a continuous variable with a skewed distribution, between sexes at each academic rank. Additional Wilcoxon rank sum tests were conducted to compare academic productivity metrics, including the medians of the h-index and m-quotient, between sexes. The same comparison was performed at each decade interval of career duration (0-9, 10-19, 20-29, and ≥30 years) and at each academic rank (assistant, associate, and full professorship). Interquartile ranges (IQRs) were calculated for all median data. Quantile regression models adjusted for career duration were created to compare the median total number of publications, citations, h-indices, m-quotients, and NIH funding between sexes. Wilcoxon rank sum tests were conducted to compare overall median industry payments by sex. $P < .05$ was considered statistically significant, and all analyses were performed using SAS software (version 9.4; SAS Institute, Cary, North Carolina, USA).

RESULTS

• **DEMOGRAPHICS:** There were 488 academic cornea specialists identified across 113 institutional websites. Ophthalmologists with insufficient online information to complete all biographic data collection (n = 44) or faculty listed as part time (n = 4) were excluded from the analysis (17 [35.4%] were female and 31 [64.6%] were male), yielding a total sample of 440 cornea faculty. Of the 440, 131 (29.8%) were female and 309 (70.2%) were male. In addition to holding an MD or a DO, similar proportions of females and males held additional PhD (13 [9.9%] vs 22 [7.1%], $P = .205$), MS (9 [6.9%] vs 11 [3.6%], $P = .260$), MPH (3 [2.3%] vs 8 [2.6%], $P = .696$), and other degrees (4 [3.1%] vs 12 [3.9%], $P = .795$).

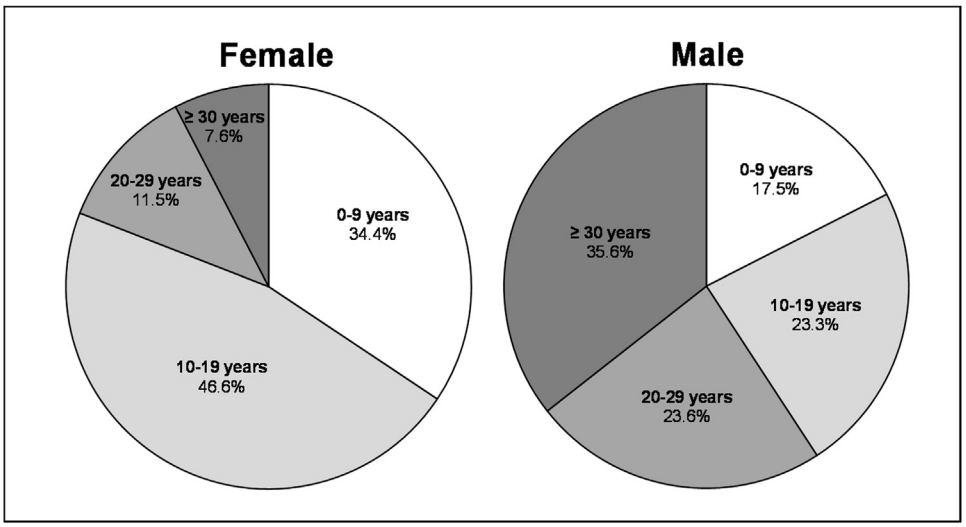

FIGURE 1. Career duration distribution of cornea specialists by sex. Career duration intervals calculated based on the number of years since residency graduation.

TABLE. Academic Cornea Specialists Based on Sex and Academic Rank

Academic Rank	Female	Male	*P* Value
Assistant professor			
Percentage (n/N)	69.5 (91/131)	41.8 (129/309)	.083[a]
Median career duration (years) (IQR)	10.0 (11.0)	13.0 (19.0)	.013[b]
Associate professor			
Percentage (n/N)	17.6 (23/131)	21.0 (65/309)	.459[a]
Median career duration (years) (IQR)	16.0 (5.0)	21.5 (18.0)	.003[b]
Full professor			
Percentage (n/N)	13.0 (17/131)	37.2 (115/309)	.113[a]
Median career duration (years) (IQR)	21.0 (11.0)	32.0 (14.0)	<.001[b]
Overall			
Percentage (n/N)	29.8 (131)	70.2 (309)	
Median career duration (years) (IQR)	12.0 (11.0)	25.0 (20.0)	<.001[b]

IQR = interquartile range.
[a]*P* value from binomial logistic regression model adjusted for career duration.
[b]*P* value from Wilcoxon rank sum test with significant results ($P < .05$).

• SEX DIFFERENCES WITHIN ACADEMIC INSTITUTIONS: The career duration of females and males are summarized in Figure 1. When analyzing academic rank without adjusting for career duration, a significantly larger proportion of females (69.5% [91/131]) compared with males (41.8% [129/309]) were assistant professors ($P < .001$) and a significantly smaller proportion of females (13.0% [17/131]) compared with males (37.2% [115/309]) were full professors ($P < .001$). However, when career duration was included as a covariate, no significant difference was found between proportions of females and males at each academic rank (Table). Female cornea specialists had a significantly shorter median career duration compared with their male colleagues. When evaluated by academic rank, females had significantly shorter median career durations than males at all 3 ranks (assistant, associate, and full professor).

Cornea specialists comprised 15.0% (17/113) of all residency program directors, of whom 4.4% (5/113) were female and 10.6% (12/113) were male ($P = .438$). Cornea specialists also represented 30.1% of all department chairs (34/113), of whom 4.4% (5/113) were females compared with 25.7% (29/113) males ($P = .546$). The median career duration of female cornea specialists who were department chairs was shorter than their male counterparts, although this finding was not statistically significant (23.0 vs 31.0 years, $P = .224$).

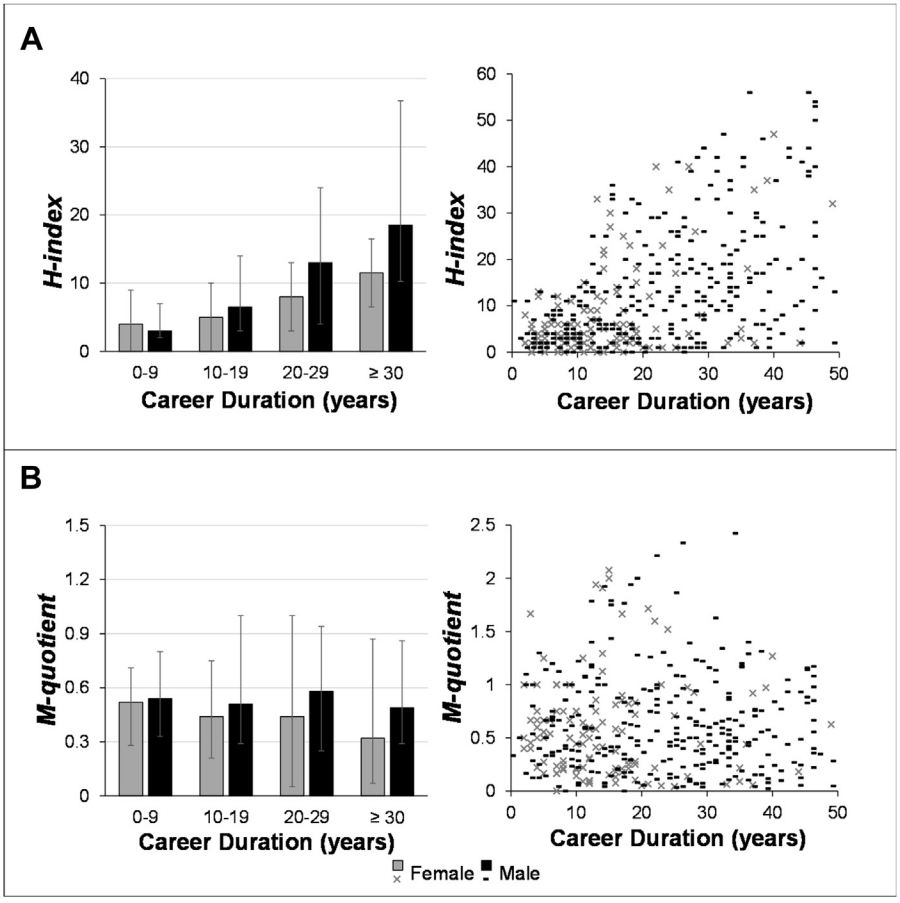

FIGURE 2. Bibliometrics for academic cornea specialists by their career duration and sex. A. H-indices by career duration. B. M-quotients by career duration. Median values with error bars representing interquartile ranges shown on bar graphs (left). Scatter plots showing absolute indices for each individual cornea specialist (right). No significant difference between sexes was found at each career duration ($P > .05$).

• **SEX DIFFERENCES IN BIBLIOMETRICS:** Bibliometric differences were observed when comparing female with male cornea specialists. Females had a lower median number of publications (9 [IQR 26]) compared with males (24 [IQR 65], $P = .392$) and lower total number of citations (108 [IQR 382] vs 412 [IQR 1376], $P = .512$), although these findings were not statistically significant in quantile regression models adjusted for career duration. In addition, when looking at citations per year, females had a similar median number of publications per year compared with males (1.1 [IQR 2.6] vs 1.4 [IQR 2.9], $P = .250$) and similar median citations per year (11.4 [IQR 34.8] vs 20.2 [IQR 51.7], $P = .324$).

Females had a lower median h-index compared with males (4.0 [IQR 7.0] vs 11.0 [IQR 17.0], $P < .001$), but no significant difference was found in median m-quotients between sexes (0.5 [IQR 0.8] vs 0.5 [IQR 0.8], $P = 1.00$). When analyzed by academic rank or career duration interval, the h-indices and m-quotients were equivalent for females and males, as shown in Figures 2 and 3. H-indices and m-quotients of each individual female or male academic cornea specialist, plotted against the number of years in practice, are shown in scatter plots (Figure 2, right).

• **SEX DIFFERENCES IN NIH FUNDING:** Of the 440 academic cornea specialists, 81 were identified as PIs receiving NIH grants. More than 15% (15.3% [20/131]) of females received NIH grants compared with 19.7% (61/309) of males ($P = .289$). The overall median grant awarded to females was $1.6M (IQR $2.2M) compared with $1.2M (IQR $4.6M) awarded to males ($P = .853$). Females had a similar median number of NIH projects compared with males (2.0 [IQR 1.5] vs 2.0 [IQR 2.0], $P = 1.000$). When analyzed by academic rank, females had an overall median grant of $1.0M (IQR $1.1M) compared with males with $2.0M (IQR $6.9M) at assistant ($P = .698$), $2.6M (IQR $2.4M) vs $2.5M (IQR $5.3M) at associate ($P = .885$), and $2.6M (IQR $5.4M) vs $1.0M (IQR $4.6M) at full professor ($P = .969$).

• **SEX DIFFERENCES IN INDUSTRY PARTNERSHIPS IN 2019:** Of the total sample, 84.1% (370/440) of academic

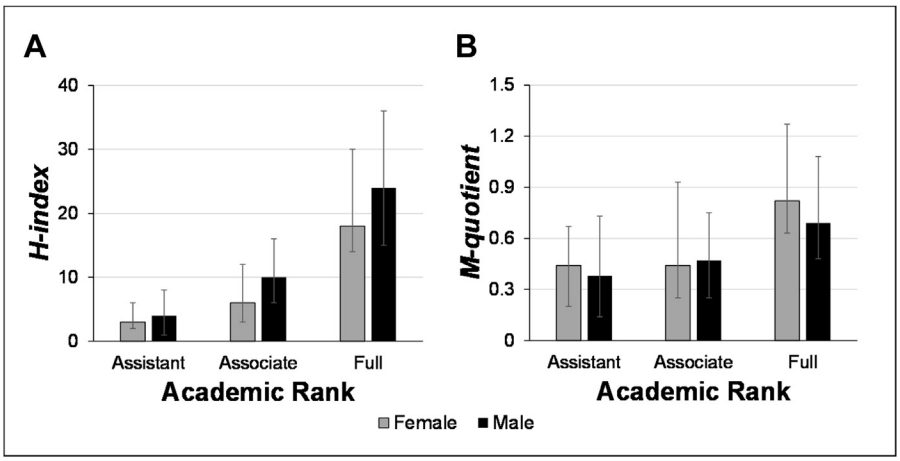

FIGURE 3. Bibliometrics for academic cornea specialists by their academic rank and sex. A. Median h-indices. B. Median m-quotients. Error bars represent interquartile ranges. No significant difference between sexes was found at each academic rank ($P > .05$).

cornea specialists received ≥1 industry payment(s) in 2019. More than a quarter (25.5% [112/131]) of females received industry payments compared with 58.6% (258/309) of males ($P = .600$). Females who received industry payments had a shorter career duration than their male counterparts (12.0 vs 22.5 years). Among those who had industry ties, overall median payments to women were $315 (IQR $2430) vs $442 (IQR $1927) to males ($P = .756$). Females represented 33.3% (2/6) of academic cornea specialists who received open payments for research with a median payment of $1420 (IQR $0) vs $1977 (IQR $1066) to males. Females represented 36.7% (33/90) of specialists who were industry consultants with a median consulting payment of $4550 (IQR $17,363) vs. $3475 (IQR $13,500) to males. Females represented 34.8% (8/23) of specialists who received industry honoraria with a median payment of $3100 (IQR $4253) vs $1600 (IQR $8250) to males. Only 2 specialists, of whom both were male, received payment for royalties and licenses with a median payment of $7907 (IQR $4665). Females represented 30.4% (7/23) of whom received payment for faculty and speaking positions with a median payment of $9500 (IQR $8925) vs $3050 (IQR $1763) to males. Females represented 27.9% of whom received payments for services other than consulting with a median payment of $6150 (IQR $14,503) vs $6988 (IQR $14,153) to males.

DISCUSSION

PREVIOUS STUDIES HAVE SHOWN THAT FEMALE FACULTY are disproportionately under-represented in leadership positions within ophthalmology.[2,5,6,15] Consistent with this, we also found a disproportionately high number of males holding the rank of full professor and a disproportionately high number of females holding the rank of assistant professor.[6] Furthermore, the proportion of cornea-specialized department chairs that were female (~15%) was lower than the proportion of cornea-specialized males (~30%). We hypothesize that these observed discrepancies in rank and leadership are simply related to the lower proportion of females in the field with advanced career durations. It is worth noting that the proportion of cornea-specialized residency program directors (~29%) that are female is approximately equal to the proportion of cornea-specialized females (~30%) overall. This is likely related to the fact that the residency program director position is more accessible to those with shorter career duration. As an increasing number of females join ophthalmology and the cornea subspecialty, the gaps seen at senior academic ranks are likely to diminish.

Interestingly, this study found that among cornea specialists, female assistant, associate, and full professors had a significantly shorter median career duration than males. One might conclude from this that females may be achieving academic promotion more quickly than males. However, this conclusion is premature and cannot be definitively drawn from the present study because information regarding time to promotion was not available. Future longitudinal studies that look specifically at time to promotion could investigate this observation.

Gender disparities at senior academic ranks should also be evaluated within the context of scholarly productivity. The h-index serves as a popular tool to evaluate an individual's publication output and citation impact.[13] A study by Thiessen and associates[2] reported that the h-index increases with each successive academic rank and noted a significantly lower h-index in female vs male ophthalmologists. This study confirms these two findings by Thiessen and associates[2] but goes a step further by also evaluating the h-index by career duration interval. The results suggest that the h-index might be best interpreted in the context of career duration (a continuous variable) vs academic rank (a

categorical variable). Simply stating that female cornea specialists' median h-index is lower than that of males overlooks the fact that more than a third of males have had ≥30 years to accumulate publications and citations on those publications, vs <10% of females. Thus, adjusting the h-index for career duration or using the m-quotient may serve as a sex-neutral measure of academic productivity in a field where females and males currently have differing career durations. Furthermore, median h-indices and m-quotients at each academic rank and career stage from this study could be used by academic departments and individual faculty as a benchmark tool for evaluating readiness for advancement in rank.

Although the h-index is a widely used parameter for measuring scholarly productivity, it is not without limitations and controversy. The h-index does not account for the extent of an author's contribution in a multiauthor publication because it neglects to include the order in which an author is enumerated in an article (ie, first, middle, or last author).[16] Future studies could further investigate academic productivity using modified h-indices that take into account authorship position.

The NIH is the largest supporter of biomedical research in the United States, and receiving NIH funding has been shown to be associated with higher scholarly productivity.[17,18] Previous studies by Svider and colleagues[8] concluded that female ophthalmologists receive lower NIH awards than their male counterparts. However, the current study showed that cornea specialists do not follow the same trends as the entire field of ophthalmology because there was no difference in the median amount of NIH awards provided to females and males among cornea specialists. This is an especially impressive statistic, given that most female cornea specialists are in the early stage of their careers (Figure 1).

Industry partnerships, although controversial, can provide ophthalmologists with another source of income, and collaboration and may be thought of as another measure of professional achievement.[10] A previous study reported under-representation of female ophthalmologists in industry partnerships.[9] Although no statistical significance was found, our study similarly found that only a quarter of females had industry partnerships compared with more than half of males. This difference may be related to the shorter career duration of females—simply put, the average male has been in the field longer and therefore has had additional time to form these industry partnerships. Nevertheless, our results show that industry is actively engaging with young female cornea specialists.

The results of this study are limited by the study design, which relied upon information that was publicly available on the internet. The accuracy of this study's data is dependent upon the available information provided on official department websites and online search engines, Scopus, NIH RePORTER, and Centers for Medicare and Medicaid Services Open Payments databases. Sex was assigned through the evaluation of photographs, pronouns, and names; it is possible that the assigned binary sex categories do not align with how an individual self-reports their sex.[19] Furthermore, 11 individuals with alternative names were found, of whom 2 (18.2%) were female and 9 (81.1%) were male. It is possible that some alternative names were not identified, limiting the accuracy of searches in Scopus, NIH RePORTER, and Centers for Medicare and Medicaid Services Open Payments. Alternative names—maiden names in particular—were challenging to find and might have skewed the productivity analysis, making women's productivity appear lower than their true value. Another limitation in this study is the use of graduation year from residency instead of fellowship in determining career duration. Residency graduation information was more readily and uniformly available; therefore, for consistency, it was used for both sexes. In addition, there may be differences by sex in career gaps, which could theoretically disproportionately affect women of childbearing age who may have to take maternity leave or longer periods of time away from clinical and academic responsibilities. Information on career gaps were not accessible for this study. Part-time appointment status is not commonly stated on institutional websites and this study's data might have unintentionally included part-time faculty. The Scopus database has inherent limitations as the results include only PubMed indexed articles, which may also result in incomplete picture of author productivity.[20] The NIH RePORTER database is limited in that it only captures NIH grants dating back to 1985 and thus it is possible that some NIH grants were not identified. The omission of funding before 1985 may disproportionately under-report NIH awards among the older individuals, especially males. Last, although this study highlights sex differences among cornea specialists, we cannot infer causality between sex and any of the outcome measures reported upon.

In conclusion, we found that the sex differences seen in senior academic ranks and in scholarly productivity are likely related to differences in career duration between the sexes; therefore, career duration should be considered when evaluating academic productivity. As time passes, more females will enter advanced stages of their careers and inequities seen between sexes may diminish. Further work is needed to investigate why females have shorter career durations at each academic rank compared with their male counterparts. While the present study provides insight into sex differences, it does not begin to touch upon the politically charged (and harder to research) topic of sex discrimination.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

MCKENZEE CHIAM: WRITING - ORIGINAL DRAFT, INVESTIgation, Visualization. **Mona L. Camacci:** Project

administration, Conceptualization, Methodology, Writing - original draft. **Erik B. Lehman:** Formal analysis. **Michael C. Chen:** Writing - review & editing. **Gargi K. Vora:** Writing - review & editing. **Seth M. Pantanelli:** Supervision, Writing - review & editing, Conceptualization, Methodology.

ALL AUTHORS HAVE COMPLETED AND SUBMITTED THE ICMJE FORM FOR DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST. Funding/Support: Supported by the National Center for Advancing Translational Sciences grants UL1 TR002014 and UL1 TR00045. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health, Bethesda, Maryland, USA. Financial Disclosures: Seth M. Pantanelli serves in the role of consultant, advisory board member, and medical monitor for Carl Zeiss Meditec. He also serves in the role of consultant to Bausch & Lomb. These relationships are not relevant to the present work. The following authors have no financial disclosures: Mckenzee Chiam, Mona L. Camacci, Erik B. Lehman, Michael C. Chen, and Gargi K. Vora. All authors attest that they meet the current ICMJE criteria for authorship.

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