NIH funding longevity by gender

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Women have achieved parity with men among biomedical science degree holders but remain underrepresented in academic positions. The National Institutes of Health (NIH)—the world's largest public funder of biomedical research—receives less than one-third of its new grant applications from women. Correspondingly, women compose less than one-third of NIH research grantees, even though they are as successful as men in obtaining first-time grants. Our study examined women's and men's NIH funding trajectories over time (n = 34,770), exploring whether women remain funded at the same rate as men after receiving their first major research grants. A survival analysis demonstrated a slightly lower funding longevity for women. We next examined gender differences in application, review, and funding outcomes. Women individually held fewer grants, submitted fewer applications, and were less successful in renewing grants—factors that could lead to gender differences in funding longevity. Finally, two adjusted survival models that account for initial investigator characteristics or subsequent application behavior showed no gender differences, suggesting that the small observed longevity differences are affected by both sets of factors. Overall, given men's and women's generally comparable funding longevities, the data contradict the common assumption that women experience accelerated attrition compared with men across all career stages. Women's likelihood of sustaining NIH funding may be better than commonly perceived. This suggests a need to explore women's underrepresentation among initial NIH grantees, as well as their lower rates of new and renewal application submissions.

NIH funding | gender disparities | National Institutes of Health | biomedical workforce | academia

Women have achieved parity with men among biomedical science doctoral degree holders (1), yet at subsequent career stages, they continue to be less well represented (2, 3). For example, in the field of biology, women earned 53% of the PhDs awarded in 2015 (4), but in the same year composed 48% of postdocs, 44% of assistant professors, and 35% of the professoriate with PhDs in biology (5). Even when accounting for the interval between earning a PhD and becoming an assistant professor, women are underrepresented among assistant professors. For example, women earned 49% of PhDs in biological sciences in 2005 and 52% in 2010 (4), yet composed 44% of assistant professors with biology PhDs in 2015 (5). Similar discrepancies between PhD holders and faculty representation persist in academic medicine (6). In addition, interest in faculty positions varies by gender across successive career stages; women pursuing biomedical science PhDs, as well as female postdocs at the National Institutes of Health (NIH), report less interest than men in becoming principal investigators (7, 8).

For several decades, researchers have used images like "leaky pipelines" (9) and "ladders" (10) to describe women's greater likelihood than men's of leaving the sciences over successive academic stages. These models, however, may not hold once women have become independent academic investigators (hereinafter referred to as "investigators"). Some researchers have explored whether women and men leave academic positions at equal rates (11), but no similar analysis has explored women's and men's success in maintaining major grants—a key indicator of an investigator's continued involvement in research and a material constraint on an investigator's ability to conduct experiments.

The NIH is the world's largest public funder of biomedical research (12), supporting major lines of health-advancing research through the administration of multiple grant types, including Research Project Grants (RPGs) such as the R01. Scientists depend on such grants to conduct research, sustain their laboratories (13), and qualify for tenure (14). Strikingly, women submit less than one-third of NIH research grant applications (15) and compose less than one-third of grantees (16–18), even though they are as successful as men in obtaining first-time grants (17). Given this large gender gap in grantees, we explored whether this disparity is exacerbated over the course of investigators' careers after their first major NIH awards.

In our analyses, we examined NIH grant support as a proxy for an investigator's career success. We analyzed NIH funding trajectories over time, comparing whether women who "make it" (i.e., receive a first major research project grant) in the early stage of their careers continue to stay funded at the same rates as men. We explored women's and men's funding trajectories from 1991 to 2015, using NIH grant records for investigators who received a first major NIH RPG between 1991 and 2010. We then explored investigators' funding amounts and stability, and considered factors that might affect funding longevity, such as investigators' application behaviors, grant review outcomes, and personal and institutional characteristics.

Significance

Diversity of the biomedical workforce is essential to the scientific enterprise, yet women remain underrepresented in academic positions in biomedical sciences and compose less than one-third of National Institutes of Health (NIH) research grantees. We explored NIH grant support as a proxy for participation in academic research. We found that women had similar funding longevity as men after they received their first major NIH grants, contradicting the common assumption that across all career stages, women experience accelerated attrition compared with men. Despite longevity similarities, women composed only 31% of grantees in our analysis. This discrepancy in grantee demographics suggests that efforts may be best directed toward encouraging women to enter academia and supporting their continued grant submissions.

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Results

Funding Longevity. To examine men's and women's funding trajectories over time, we obtained NIH grant records from the IMPACII database, an internal NIH administrative grants database. We focused specifically on major RPGs, a subset of NIH grants, such as R01, U01, and P01 grants, that fund major lines of health-advancing research. We tracked the RPG application and funding history of the 34,770 investigators who received a first major NIH RPG between 1991 and 2010 and also reported their gender to NIH (98.5% reported). Using this set of grantees, we conducted a survival analysis in which leaving the NIH funding pool was the event of interest. We considered investigators to be active within the NIH funding pool from the year in which they first held funding on any major RPG through the last year in which they held funding on a major RPG. Exit was defined by a gap in funding of 3 or more years after the most recent award. We tracked investigators' funding histories from 1991 to 2015.

Fig. 1 displays a nonparametric Kaplan–Meier estimate of the funding survival curve by gender (Fig. 1*A*). We performed significance testing using the nonparametric Mantel–Haenszel (MH) and Gehan–Wilcoxon (GW) tests. As illustrated, men's (n = 24,110) and women's (n = 10,660) funding trajectories were similar but not identical [MH: $\chi^2(1) = 15.5$, $P < 0.001$; GW: $\chi^2(1) = 10.2$, $P = 0.001$]. Men had a slight survival advantage over women, a difference of 3.5 percentage points at the end of the 25-y analysis period. This small gender difference in funding longevity runs contrary to the traditional "leaky pipeline" view noted above. Rather, after obtaining a first major RPG, women and men sustained funding at more similar rates than might be expected. We found that rather than leaving the NIH funding pool at much greater rates than men, women were much more dramatically underrepresented to begin with among first-time RPG holders, composing only 30.66% of investigators in the analysis.

To account for the growing competitiveness of obtaining NIH funding (19), and to evaluate changes in gender retention over time, we examined separate 5-y cohorts (Fig. 1*B*) based on the year in which investigators received their first major RPG. Considering the survival curves by cohort, the first notable points of funding loss generally occurred around 5 y after the first RPG—about the time that a typical NIH RPG ends, and a critical juncture for early career investigators (20). In the earliest two cohorts, women left the funding pool at slightly higher rates than men [1991–1995: women, n = 2,192; men, n = 5,539; MH, $\chi^2(1) = 6.6$, $P = 0.01$; GW, $\chi^2(1) = 3.9$, $P = 0.05$; 1996–2000: women, n = 2,436; men, n = 5,876; MH, $\chi^2(1) = 4.6$, $P = 0.03$; GW, $\chi^2(1) = 4.0$, $P = 0.05$] (Fig. 2 *A* and *B*). In the two later cohorts, we found no reliable longevity difference between men and women ($P > 0.14$ for all) (Fig. 2 *C* and *D*). Follow-up analyses indicate that cohort-specific effects are sensitive to changes to the final funding gap length used to define exit, while the survival difference across all investigators is robust. When extending the gap to five or more unfunded years, cohort effects became nonsignificant ($P \geq 0.04$ for all; *SI Appendix*) but whole-sample effects persisted [5 y: MH: $\chi^2(1) = 9.1$, $P < 0.01$; GW: $\chi^2(1) = 5.8$, $P = 0.02$].

Funding Characteristics. Finding only small longevity differences between men and women, we investigated whether women and men could differ in other funding characteristics, such as funding amounts or stability. First, to explore funding amount, we computed the average number of NIH research projects investigators held per year (total projects held divided by the span of years funded). We also calculated the average overall RPG funding that investigators held per year (total funding awarded divided by the span of years funded), adjusting for inflation using the Biomedical Research and Development Price Index (21). Unless noted otherwise, we used the Wilcoxon rank-sum test (two-tailed) to compare distributions for the gender comparisons. Small but reliable gender differences emerged on both funding measures (*SI Appendix*, Fig. S1). Specifically, women held fewer projects on average each year than men (1.17 vs. 1.24; W = 136,646,273; $P < 0.001$), a difference found across all cohorts ($P < 0.005$ for all; *SI Appendix*, Fig. S1*A*). Women also held less overall funding on average per year compared with men ($316,628 vs. $343,496; W = 133,016,978, $P < 0.001$). This difference held for the first three cohorts ($P < 0.002$ for all), but not for the most recent one (W = 10,950,491, $P = 0.36$; *SI Appendix*, Fig. S1*B*). This effect likely was not due to the average funding amount per project; women also did not hold significantly less funding per project than men ($269,527 vs. $282,337; W = 128,055,744, $P = 0.60$).

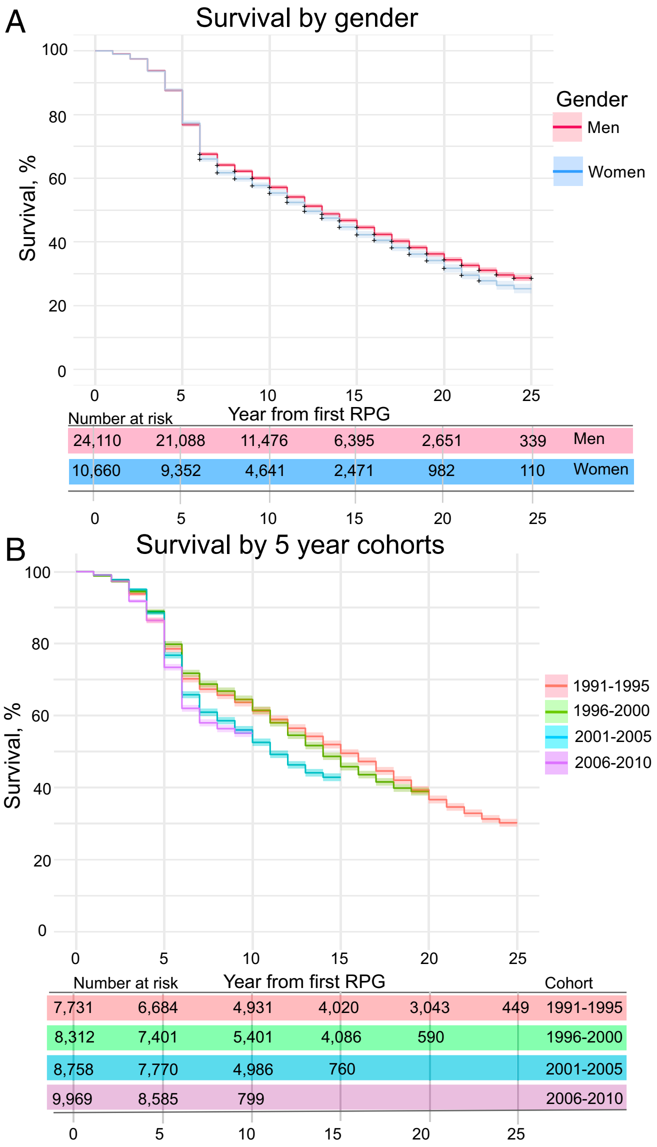

Fig. 1. Kaplan–Meier survival plot of investigators' sustained NIH RPG funding. The number of individuals at risk are listed below the plot, and 95% CIs are shown (Greenwood's formula). (*A*) Men remained in the funding pool at slightly higher rates than women [women, n = 10,660; men, n = 24,110; MH: $\chi^2(1) = 15.5$, $P < 0.001$; GW: $\chi^2(1) = 10.2$, $P = 0.001$]. (*B*) Funding longevity by cohort, based on the year of first major RPG award. Recently funded investigators exited the NIH funding pool more quickly than earliest-funded investigators [1991–1995, n = 7,731; 1996–2000, n = 8,312; 2001–2005, n = 8,758; 2006–2010, n = 9,969; MH: $\chi^2(3) = 223$, $P < 0.001$; GW: $\chi^2(3) = 217$, $P < 0.001$].

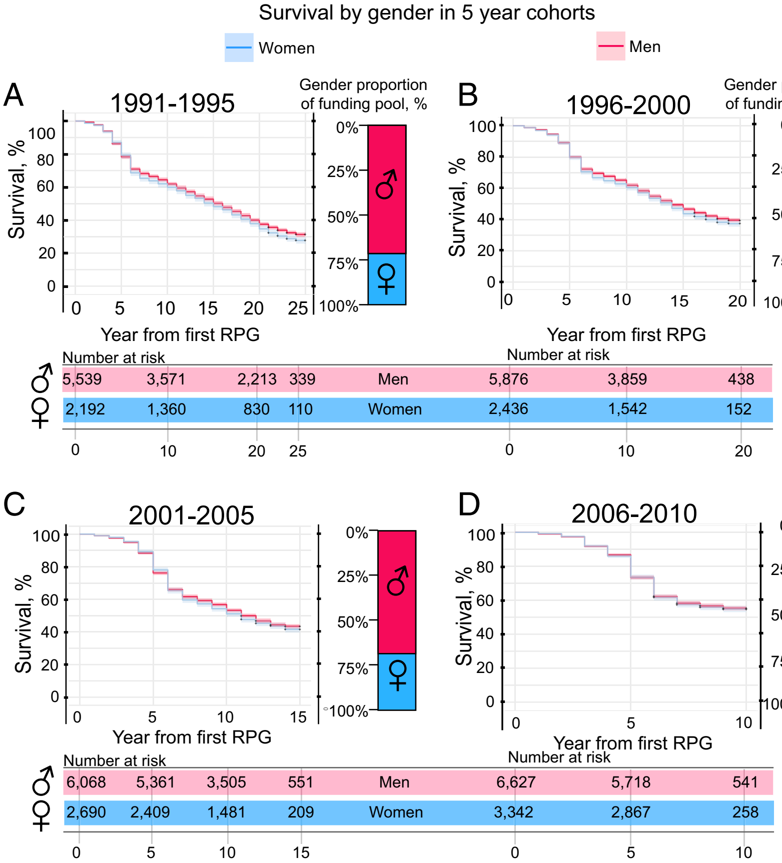

Fig. 2. Kaplan–Meier survival curves, by gender, for each cohort. The numbers of individuals at risk are below the plots, and the percentages of women and men initially funded are to the right; 95% CIs are shown (Greenwood's formula). Results are shown by cohort based on the year of first RPG. (*A*) In 1991–1995, women (28.35% of the cohort) left the funding pool at a slightly higher rate than men [women, n = 2,192; men, n = 5,539; MH: $\chi^2(1) = 6.6$, $P = 0.01$; GW: $\chi^2(1) = 3.9$, $P = 0.05$]. (*B*) In 1996–2000, women (29.31% of the cohort) left the funding pool at slightly higher rates than men [women, n = 2,436; men, n = 5,876; MH: $\chi^2(1) = 4.6$, $P = 0.03$; GW: $\chi^2(1) = 4.0$, $P = 0.05$]. (*C*) In 2001–2005, women (30.71%) and men showed no statistically significant survival difference [women, $n = 2,690$; men, $n = 6,068$; MH: $\chi^2(1) = 2.1$, $P = 0.14$; GW: $\chi^2(1) = 1.1$, $P = 0.31$]. (*D*) In 2006–2010, women (33.52%) and men showed no statistically significant survival difference [women, $n = 3,342$; men, $n = 6,627$; MH: $\chi^2(1) = 0.2$, $P = 0.68$; GW: $\chi^2(1) = 0.1$, $P = 0.74$].

Along with exploring funding amounts, we also aimed to characterize men's and women's funding stability. For example, did women have more gaps in funding than men? To address this question, we computed the span of years for which each investigator was funded (distance between the first year and last year of RPG funding) and the total number of distinct years for which each investigator was funded (to exclude unfunded years within investigators' careers). We then calculated the percentage of years in which investigators held funding (funded years divided by span). On average, women held RPG funding for shorter time spans than men (10.08 y vs. 10.56 y; $W = 133,563,024$, $P < 0.001$), although this difference was significant only for the 1996–2000 cohort ($W = 7,387,058$, $P = 0.02$; *SI Appendix*, Fig. S2*A*). Women also held funding for fewer total years compared with men (mean, 9.28 y vs. 9.77 y; $W = 134,003,822$, $P < 0.001$), a difference significant for the 1991–1995 cohort ($W = 6,256,887$, $P = 0.04$) and the 1996–2000 cohort ($W = 7,478,524$, $P = 0.001$) (*SI Appendix*, Fig. S2*B*). Women held RPG funding for 94.45% of the years, comparable to the 94.62% in men ($W = 128,264,309$, $P = 0.72$; *SI Appendix*, Fig. S2*C*). Therefore, we conclude that women did not have larger gaps in funding than men. Rather, the earlier-funded cohorts showed small gender differences in span and number of funded years, corresponding to the small gender differences seen in funding longevity. Overall, these analyses indicate that the largest gender difference in funding amount and stability is in the number of RPGs women hold.

Understanding Longevity Differences. Although the observed gender differences in funding longevity were small, in an effort to understand the cause of these differences, we next examined whether there were gender differences in application and review behavior, or in any other investigator characteristics that could contribute to funding longevity. First, exploring NIH administrative data, we considered three factors that might influence funding disparities: application volume, success on application, and review scores.

Application and review. We first considered application and review metrics for new project applications (Fig. 3). For application volume, we calculated the average number of new project applications per year that each investigator submitted after the year of her or his first major RPG and compared these averages between genders. Consistent with related reports (17, 22, 23), women submitted slightly fewer new applications per year than men (mean, 0.38 vs. 0.45; $W = 137,514,629$, $P < 0.001$); this difference held across all cohorts (Fig. 3*A*). We then measured success on application by calculating, for each investigator, the percentage of new project applications reaching review (after the year of the first major RPG award) that were awarded (i.e., funding rate). Consistent with related reports (17, 22, 24, 25), we found no overall difference in men's and women's funding rates

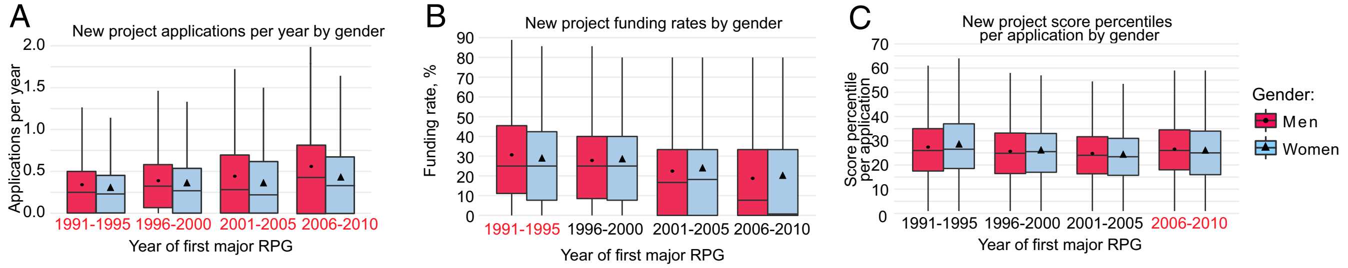

Fig. 3. Boxplots of new project application volume, funding rates, and score percentiles, by gender and cohort. Markers indicate means; bars indicate medians. Red cohort labels indicate statistically significant gender differences ($P \leq 0.05$, Wilcoxon rank-sum test, two-tailed). Outliers are not shown. (*A*) Women submitted slightly fewer new applications per year than men overall and within each cohort (1991–1995: women, $n = 2{,}192$; men, $n = 5{,}539$; $W = 6{,}383{,}318$, $P < 0.001$; 1996–2000: women, $n = 2{,}436$; men, $n = 5{,}876$; $W = 7{,}802{,}511$, $P < 0.001$; 2001–2005: women, $n = 2{,}690$; men, $n = 6{,}068$; $W = 8{,}868{,}382$, $P < 0.001$; 2006–2010: women, $n = 3{,}342$ men, $n = 6{,}627$; $W = 11{,}865{,}699$, $P < 0.001$). (*B*) While average funding rates were no different between the genders overall, women had a slightly lower funding rate in the 1991–1995 cohort (women, $n = 1{,}551$; men, $n = 4{,}032$; $W = 3{,}235{,}387$, $P = 0.04$). (*C*) While women and men's average score percentiles were not statistically different overall, in the 2006–2010 cohort, women scored slightly better on average than men (women, $n = 1{,}501$; men, $n = 3{,}175$; $W = 2{,}487{,}779$, $P = 0.02$).

(mean, 24.67% for both; women, $n = 7{,}540$; men, $n = 17{,}773$; $W = 67{,}687{,}328$, $P = 0.19$), although women in the 1991–1995 cohort had a slightly lower funding rate than men (28.68% vs. 30.65%; women, $n = 1{,}551$; men, $n = 4{,}032$; $W = 3{,}235{,}387$, $P = 0.04$; Fig. 3*B*). Finally, we calculated each investigator's average new application score (excluding the year of first major RPG; not all reviewed applications are scored). Here we used NIH-defined "score percentiles" (lower percentile indicates better scores). Although women scored slightly better on average than men in the most recent cohort (25.56 vs. 26.48; women, $n = 1{,}501$ men, $n = 3{,}175$; $W = 2{,}487{,}779$, $P = 0.01$; Fig. 3*C*), the average score percentiles were not overall statistically different (25.77 vs. 26.00; women, $n = 4{,}421$; men, $n = 10{,}611$; $W = 23{,}671{,}657$, $P = 0.37$). In summary, for new project applications, the main gender difference in application and review was that women submitted fewer applications per year, which may have contributed to women holding fewer projects than men.

Competitive renewal applications (Fig. 4) refer to the opportunity to renew a project at the end of an award period to continue a line of research. First, for submission rate, we calculated the number of projects that an investigator held that were sufficiently mature to be eligible for renewal and calculated the percentage of these projects that investigators attempted to renew. We then compared these percentages between genders. Consistent with related findings (17, 22, 23), women on average submitted 42.45% of their eligible projects for renewal, compared with 45.44% for men (women, $n = 9{,}766$; men, $n = 22{,}567$; $W = 114{,}500{,}128$, $P < 0.001$). This difference held across all cohorts (Fig. 4*A*), meaning that women were less likely to try to renew existing projects. Also consistent with previous findings (17, 22, 24, 25), women had a 35.98% funding rate for project renewals—lower than the 39.28% rate for men (women, $n = 5{,}074$; men, $n = 12{,}931$; $W = 34{,}579{,}705$, $P < 0.001$). This was true for all but the most recent cohort (Fig. 4*B*). Women also scored less well on review, with score percentiles averaging 23.76, compared with 23.00 in men (women, $n = 2{,}594$; men, $n = 6{,}820$; $W = 8{,}520{,}363$, $P = 0.01$). This difference was not significant within any cohort, although it was found numerically across all cohorts (Fig. 4*C*). Importantly, these renewal discrepancies—differences also noted in other analyses (17, 22, 23)—may have contributed to the aforementioned gender gap in funding longevity at about the 5- to 6-y mark. RPGs tend to be funded for 4 or 5 y (26), with funding ending in years 5 and 6, respectively, if an investigator does not renew the RPG. If women apply to renew less often than men, and are also less successful when they do apply, we would expect to find corresponding differences in NIH funding longevity.

Investigator characteristics. We next considered gender differences in investigator characteristics potentially related to longevity: age at first award, degree type, first RPG type, first year of NIH funding, and characteristics of institutional affiliation at the time of first RPG (Carnegie classification, representing the level of research activity at the investigator's institution, and relative level of NIH funding received by the institution). Gender differences across

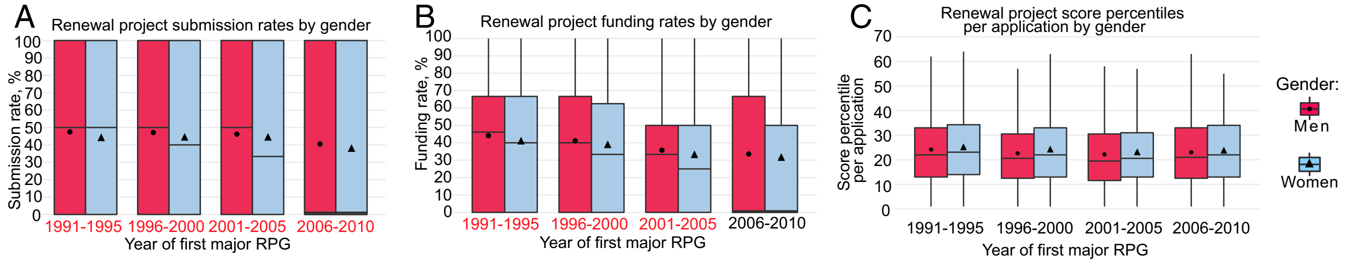

Fig. 4. Boxplots of renewal project submission rates, funding rates, and score percentiles, by gender and cohort. Markers indicate means; bars indicate medians. Red cohort labels indicate statistically significant gender differences ($P \leq 0.05$, Wilcoxon rank-sum test, two-tailed). Outliers are not shown. (*A*) Women on average submitted a lower proportion of their eligible projects for renewal than men, overall and within each cohort (1991–1995: women, $n = 2{,}157$; men, $n = 5{,}461$; $W = 6{,}113{,}935$, $P = 0.007$; 1996–2000: women, $n = 2{,}395$; men, $n = 5{,}776$; $W = 7{,}233{,}755$, $P < 0.001$; 2001–2005: women, $n = 2{,}642$; men, $n = 5{,}965$; $W = 8{,}115{,}178$, $P = 0.02$; 2006–2010: women, $n = 2{,}572$; men, $n = 5{,}365$; $W = 7{,}124{,}838$, $P = 0.007$). (*B*) The women's funding rate for project renewals was significantly lower than the men's overall and for the first three cohorts (1991–1995: women, $n = 1{,}322$; men, $n = 3{,}581$; $W = 2{,}513{,}130$, $P < 0.001$; 1996–2000: women, $n = 1{,}380$; men, $n = 3{,}684$; $W = 2{,}668{,}360$, $P = 0.005$; 2001–2005: women, $n = 1{,}355$; men, $n = 3{,}329$; $W = 2{,}365{,}518$, $P = 0.006$). (*C*) Women also scored less well on review overall, but this difference was not significant within any cohort.

these variables are presented in *SI Appendix*, Table S1. The two factors that emerged with the most notable (SMD > 0.1) and statistically significant differences across genders were degree type and first year funded. For degree type, 73.7% of the women held PhDs, 14.3% held MDs, and only 9.1% held MD/PhDs, compared with 63.6%, 19.2%, and 15.4% respectively, for men [$\chi^2(2) = 485.92$, $P < 0.001$]. Women's underrepresentation among MD/PhDs is most notable, as MD/PhDs show greater funding longevity than PhDs or MDs [PhDs, $n = 23{,}193$; MDs, $n = 6{,}157$; MD/PhDs, $n = 4{,}677$; MH: $\chi^2(2) = 178.0$, $P < 0.001$; GW: $\chi^2(2) = 186.0$, $P < 0.001$]. Considering women's and men's first year funded, men were more evenly distributed across cohorts than women (*SI Appendix*, Table S1), with roughly one-quarter (23.0%–27.5%) of men in each of the four cohorts. In contrast, women were more concentrated in the most recently funded cohort (31.4%) and least concentrated in the first funded cohort [20.6%; $\chi^2(3) = 64.98$, $P < 0.001$]. Women's greater relative presence in later-funded cohorts is notable, as NIH funding has become more competitive in recent years (19). Overall, such investigator differences highlight that men and women were not identical when "coming into" the funding pool. To adjust for these differences and to understand their contributions to survival, we performed three additional analyses.

Additional modeling: Covariate importance. First, to examine funding longevity differences between men and women matched on the characteristics with which they "enter" the NIH funding pool, we reexamined survival differences when matching men to women on the investigator characteristics described above (propensity score matching; *SI Appendix*). Comparing women and matched men, we found that survival differences no longer existed between genders [*SI Appendix*, Fig. S3*A*; women, $n = 10{,}212$; men, $n = 10{,}212$; MH, $\chi^2(1) = 0.2$, $P = 0.63$; GW, $\chi^2(1) = 0.1$, $P = 0.82$]. This suggests the importance of investigator characteristics as contributors to survival.

Next, to examine the relative impacts of gender, investigator characteristics, application behavior, and funding amount on survival, we used a random survival forest algorithm (27, 28) to fit the survival data nonparametrically. We included the following variables in our model: gender, the six described investigator characteristics, new application submissions per year, renewal submission rate, and average funding held per year. Using a model with 1,000 trees resulted in a Harrell's concordance index > 0.82. The standard metrics, variable importance (VIMP) and minimal depth (MD) (29), indicated that gender ($n = 31{,}987$; VIMP < 0.001, MD = 6.28) was by far the least useful variable in predicting survival time (*SI Appendix*, Fig. S4). The most predictive variables were renewal submission rate (VIMP = 0.10, MD = 0.88), new applications per year (VIMP = 0.08, MD = 1.45), and funding per year (VIMP = 0.04, MD = 1.22), with investigator characteristics all ranking lower. This suggests that application rates—investigators' rates of attempting to renew projects and apply for new ones—are most predictive of an investigator's survival. Thus, based on the importance of grant resubmission, we matched men and women on renewal rate and first year of funding and found no survival difference between the genders [women, $n = 9{,}395$; matched men, $n = 9{,}395$; MH: $\chi^2(1) = 0.3$, $P = 0.60$; GW: $\chi^2(1) = 1.6$, $P = 0.20$; *SI Appendix*, Fig. S3*B*]. Both matched sets were also investigated for gender differences in other reported outcomes (*SI Appendix*, Table S2 and *SI Appendix*) to understand how these factors affect funding outcomes more broadly. Taken together, all these additional analyses suggest that such characteristics as degree and time first funded matter, but that applications—especially grant renewals—have the greatest impact on funding longevity.

Discussion

Overall, we found only small differences in NIH funding longevity between genders. Considered along with another recent survival analysis demonstrating equal job retention among male and female science professors (11), we believe that the traditional notion of constant attrition fails to capture the overall research success of women in academia. Importantly, however, our data point toward several gender-related findings, which in turn suggest areas for future study and intervention.

Women's initial underrepresentation in the NIH RPG pool is striking and overwhelms all other gender differences that we report. Specifically, women composed just 31% of investigators in our analysis. Putting this finding into context, our group of investigators would have earned doctoral degrees from roughly 1979 to 1999 (*SI Appendix*), when women composed 33–53% (overall, 45%) of PhDs (30) in key biomedical research fields (31), including biology, psychology, and medical fields. Thus, women were underrepresented among initial NIH grantees at the time. Women continue to remain underrepresented among biomedical science professors and RPG holders (32), but not among biomedical science PhDs (3). These gaps highlight the need to retain women when transitioning into postdocs and the professoriate, and to explore gender differences in RPG applications among early career investigators. While our data cannot address the many social factors that influence women's career trajectories (7, 8, 33–35) and application patterns, our findings highlight the importance of early career transitions in reaching parity among grant holders.

Although the most dramatic gender differences occur before women hold their first RPGs, smaller gender differences also exist within the time frame that we explored. Importantly, women were less likely to attempt to renew grants and less successful in RPG renewal. We also found that renewal submission rate was the factor most predictive of sustained funding for either gender, and that gender differences in survival disappear when genders were matched on renewal submission rate and first year of funding. These findings highlight the importance of supporting women at the time of first RPG renewal—a juncture critical for both genders (Fig. 1*A*). Women's larger drop-off in NIH funding at first renewal could reflect career changes, differing grant application strategies, or other factors; future work looking beyond administrative data may address why women in academia might not be reapplying (or applying) for RPGs at the same rates as men, and how this pattern could be changed. In addition, further investigation into why women receive less favorable reviews than men for renewal applications is underway.

Beyond observed gender differences in application behavior, we also find that women and men in our investigator pool were not matched on all initial characteristics—most notably degree and first year of funding. Many small differences in both investigator characteristics and application behavior likely combine to result in small survival differences. As we have noted, these small gender differences in funding longevity are minor relative to the initial gaps in representation.

A final point to consider, based on these data, is the traditional and long-standing narrative communicated to women regarding their potential future success in academia. Based on the known drop-offs in participation observed between the graduate, postdoctoral, and professorial career stages, one might predict drop-offs of equal magnitude to occur over the rest of women's careers. This analysis demonstrates, however, that women who obtain funding do stay in the workforce and do write successful RPG applications. Thus, the data tell two very important stories. The first story, a positive one, is that women who have "made it" in science are having careers of comparable length to men and are sustaining funding to support these careers. Women should be made aware of these results, particularly as they might expect worse odds (relative to men) than they actually face when pursuing academic careers. The second—and equally important—story is that broad gender differences remain, and that thoughtful intervention during key transitions such as those described could help reduce these differences.

Methods

Data Sources. The NIH receives tens of thousands of applications for RPGs every fiscal year, and stores all RPG application data in its Information for Management, Planning, Analysis, and Coordination (IMPACII) database. Each application has an activity code associated with it (e.g., R01, P01, U01). The NIH uses activity codes to differentiate the wide variety of research-related programs that it supports. Major RPGs consist of all activity codes considered by the NIH to represent both major research projects (MRGs) and RPGs. The major RPG activity codes are DP1, DP2, DP3, DP4, DP5, P01, P42, PN1, R01, R22, R23, R29, R33, R35, R37, R50, R61, RC1, RC2, RC3, RC4, RF1, RL1, RL2, RM1, U01, U19, U34, UA5, UC1, UC2, UC4, UC7, UF1, UG3, UH2, UH3, UM1, and UM2.

Survival Analyses. The survival analysis was performed using the *survival* (36) and *randomForestSRC* (28) packages in R. All principal investigators (PIs) who successfully competed for their first major research project grant between 1991 and 2010 were included. The analysis was done over the period 1991–2015, considering all RPGs in which an investigator was designated as a PI or multi-PI. The event of interest was leaving the NIH funding pool. Given that investigators can have gaps in their funding (i.e., be unfunded for a period of time but later receive another grant), we considered investigators active up until the last year in which they were funded. To account for potential reentry at the end of the analysis, a funding gap length cutoff was used to determine the exit that balanced the likelihood of reentry with minimal censoring of data (*SI Appendix*). Here investigators were considered out of the funding pool if their last year of funding was followed by at least 3 y of no active support. Since the raw data consisted of all records through 2017, PIs whose last year of funding was 2015 were right-censored; it was not possible to determine when they left the NIH funding pool. Approximately 45% of the PIs in our study were right-censored. The nonparametric Kaplan–Meier estimate of the survival function was used to produce the survival curves. Greenwood's formula was used to produce the 95% confidence intervals around these survival curves. The MH and GW tests were used to compare Kaplan–Meier survival curves. Robustness of the findings was tested using different gap length cutoffs for exit (*SI Appendix*). The nonparametric Random Survival Forest algorithm (28) was used to estimate the impact of covariates, such as gender, on the survival time of PIs via the standard metrics of VIMP and MD (29). Harrell's concordance index was used to evaluate the accuracy of the algorithm in predicting survival time (29). Propensity score nearest-neighbor matching was performed using the MatchIt package in R (37). Men were first matched to women on age at first award, degree type, first RPG type, first year of NIH funding, Carnegie Classification of first institution, and NIH funding for first institution. In a second analysis, men were matched to women on renewal submission rate and first year of funding.

Data Availability. Public NIH grant records may be downloaded from the NIH RePORTER website (https://projectreporter.nih.gov/). Under the Freedom of Information Act (FOIA), 5 U.S.C. 552, individuals may submit a formal request to obtain information on funded biomedical research grants not publicly available. Inquiries may be directed to the FOIA Coordinator in the Office of Extramural Research at OERFOIA@mail.nih.gov.

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