Sex Differences in Application, Success, and Funding Rates for NIH Extramural Programs

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Abstract

Purpose
The authors provide an analysis of sex differences in National Institutes of Health (NIH) award programs to inform potential initiatives for promoting diversity in the research workforce.

Method
In 2010, the authors retrieved data for NIH extramural grants in the electronic Research Administration Information for Management, Planning, and Coordination II database and used statistical analysis to determine any sex differences in securing NIH funding, as well as subsequent success of researchers who had already received independent NIH support.

Results
Success and funding rates for men and women were not significantly different in most award programs. Furthermore, in programs where participation was lower for women than men, the disparity was primarily related to a lower percentage of women applicants compared with men, rather than decreased success rates or funding rates. However, for subsequent grants, both application and funding rates were generally higher for men than for women.

Conclusions
Cross-sectional analysis showed that women and men were generally equally successful at all career stages, but longitudinal analysis showed that men with previous experience as NIH grantees had higher application and funding rates than women at similar career points. On average, although women received larger R01 awards than men, men had more R01 awards than women at all points in their careers. Therefore, while greater participation of women in NIH programs is under way, further action will be required to eradicate remaining sex differences.

The career progression of women and men in academic science and engineering has been catalogued for decades[1,2]; more recently, the 2007 report from the National Academies, *Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering*,[3] elevated the issue of women's participation in research on a national scale. One of its recommendations to federal agencies was to "collect, store, and publish composite information on demographics, field, award type and budget request, review score, and funding outcome" for applications. The National Institutes of Health (NIH) has disseminated this kind of information since the early 1990s[4–6] and has provided more reports and analyses in recent years.[7–10]

Despite these publicly available resources, a detailed analysis of the participation of women and men along a typical "career ladder" of NIH extramural funding has not been performed. We therefore undertook the current study to provide a refined analysis and obtain a clearer picture of the participation of women and men in NIH extramural programs. We also included longitudinal data analyses on early career NIH investigators, studying their success in obtaining subsequent NIH awards to identify any sex differences in sustained NIH funding.

Method

Before conducting our analyses, we selected 17 activity codes[17] (plus trainees supported by T32 awards) that are representative of a career pathway from predoctoral trainees and fellows to institutional awards received by senior, established investigators. Eight of these (plus T32 trainees) were identified as early career stage awards, which we further divided into three categories: fellows and trainees, transition, and mentored faculty. The earliest career stage was the fellows and trainees category, which included predoctoral support through the T32 training program, as well as through F30 and F31 fellowship awards. T32 trainees receive indirect NIH support in that the T32 award is made to the institution to fund trainees. In contrast, the F30 and F31 awards are made directly to the MD/PhD or PhD students, respectively. This category also included postdoctoral support through the T32 training program and the F32 fellowship awards. The second early career stage was the transitional period, which NIH supports via the K22 and K99/R00 awards; both of these award programs provide two-phased support, with an initial mentored phase followed by an independent research phase. The mentored faculty stage was the third early career stage category, and we included K01, K08, and K23 awards in this category. All three of the latter award programs are used to support junior faculty members who are able to devote at least 75% of their effort to a mentored research experience. K01 awards are restricted to investigators with research

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or health-professional doctoral degrees; K08 awards are restricted to clinician researchers, and K23 awards are restricted to patient-oriented researchers with health-professional doctoral degrees.

Because the R01, R03, and R21 awards are not limited to a particular career stage, we considered them the independent stage. Applications for all three award programs are usually investigator initiated, although they can also be in response to a particular funding opportunity announcement. Whereas the R01 award is the "gold standard" of research awards and provides up to five years of funding, the R03 and R21 award programs both supply two years of funding for smaller research projects. We included only one award program (K24) that is specific for midcareer investigators and provides clinician (patient-oriented) researchers with protected time for mentoring early career investigators.

Finally, the most senior career stage was composed of the P50, U54, T32, P01, and P30 award programs. Both the P50 and U54 activity codes support research specialized centers; the P50 is a grant mechanism, whereas the U54 is a cooperative agreement. As mentioned previously, the T32 program provides institutional awards; the recipient is required to be an established researcher in the basic, behavioral, and/or clinical sciences. The P01 award generally provides support for integrated, multiproject research projects and involves the organized efforts of relatively large groups, whereas the P30 award supports shared resources and facilities for a multidisciplinary approach to a common research problem.

The activity codes we selected represent a majority (77%) of the NIH's competing research and training awards funded in 2008. We retrieved and analyzed data from the NIH electronic Research Administration (eRA) database, Information for Management, Planning, Analysis, and Coordination using SAS 9.2 software (SAS Inc., Cary, North Carolina). All data were retrieved on January 13, 2010, and reported for the specified fiscal years (October 1 to September 30). Data for sex and age of the applicants and awardees were self-reported in their eRA Commons profiles[11]; counts change over time as individuals edit their profiles. Data for sex and age of T32 trainees were submitted by T32 principal investigators (PIs) through the "Statement of Appointment"[12]; we retrieved these on July 14, 2010. We performed cross-sectional analyses for fiscal year 2008, which is the most recent year of complete data that avoids the distortions caused by additional applications and awards associated with the American Recovery and Reinvestment Act.[13]

R01 investigators were considered first-time investigators when they applied for a competing R01-equivalent award without previous significant NIH competing research grant support.[14] Experienced investigators were defined as those who were not first-time investigators.

Where possible, we considered both *application-based* and *person-based* metrics because they may display different trends (note that one person may submit multiple R01 applications, for example). We defined success rates (*application-based*) by the percentage of reviewed grant applications for competing awards that received funding in a fiscal year,[15] and funding rates (*person-based*) by the percentage of applicants who received competitive funding in a fiscal year.[16] For *application-based* data calculations (number of applications and awards, success rates, direct costs requested and received), we excluded applications from multiple PIs because of mixed combinations; these represented less than 6% of all independent research applications and awards. For *person-based* data calculations (number and age of applicants and awardees, funding rates), we included investigators submitting applications with either single or multiple PIs. In all analyses, we excluded investigators with unknown sex. In *applicant-based* analyses, we also excluded investigators with uncoded or unreliable ages, which were defined as ages other than 15 to 65 for T32 trainees, fellowship applicants, and fellowship awardees, and other than 20 to 90 in all other cases.

We identified several transition points for longitudinal analysis: transition to R01 award from career development or small research awards, and transition from first to subsequent R01 award. To examine transition of early career investigators, we only included investigators who did not have an R01 award before the first year of the study. We defined cumulative application rates by the percentage of awardees (of the initial award) who submitted at least one application for a subsequent R01 award during the indicated multiyear period. Cumulative funding rates were defined by the percentage of applicants who received at least one award during the indicated multiyear period. Because of the importance of the R01 program, we also analyzed various subgroups, which included application type and experience level of the investigator.

We used the binomial test to determine whether the percentage of women or men applicants and awardees was significantly different from 50%, and the Pearson chi-square test to assess sex differences in application, success, and funding rates. Because age and direct costs were not distributed normally, the two-sample Kolmogorov–Smirnov test was used to compare distributions between sexes for these variables. To analyze investigators' requests and eliminate contributions of indirect costs (which are dependent on rates negotiated for each institution), we compared the average direct costs requested and received for each program. We used logistic regression, controlling for investigator experience level, to assess the sex effect on cumulative R01 application and success rates. For further investigation into established investigators, we examined the R37 MERIT Award, which provides long-term grant support to investigators whose research competence and productivity are distinctly superior and who are highly likely to continue to perform in an outstanding manner. Investigators do not apply for a MERIT Award; instead, program staff or members of national advisory councils and boards identify candidates during the course of review of competing R01 grant applications. In all cases, we considered P values $<.05$ statistically significant.

The NIH institutional review board determined that federal regulations for the protection of human subjects did not apply to our study.

Results

The percentage of records with valid data was as follows: 89% and 91% for

applicants and awardees on *person-level* data, respectively, and 92% and 95% for applications and awards on *application-level* data, respectively, for analyses of activity code by age, sex, experience level, or application type (see Chart 1 and Table 1). For analyses of awardees' application and funding rates for subsequent R01 awards by sex or by initial award, 95% of records included valid data (see Table 2). For analyses of awardees' application and funding rates for subsequent R01 awards by experience level, sex, or human subjects inclusion, 92% of records included valid data (see Table 3). For analyses of investigators with multiple R01 awards by sex or by age, 99% of records included valid data (see Figures 1 and 2). Chart 1 displays sex differences for the activity codes we analyzed; it includes both person-level and application-level data. The R01 program represented 44% of the extramural research and training budget[18] and 38% of the awards[19] in 2008; analyses of various R01 subgroups (by experience level of investigator and type of application) are shown in Table 1.

Participation and success

Percent representation, funding rates, and success rates. Within the three early career award categories (fellows and trainees, transition, mentored faculty), three programs had more female applicants than male (F31, K01, and K23), two programs had no statistically significant differences from 50% (F30, F32), and the remaining three programs (plus T32 trainees) had more male than female applicants (K99, K22, K08, and T32 trainees). In contrast, all the programs classified as midcareer, independent research, and senior career had significantly more male than female applicants. We also compared funding rates and success rates and found that only two programs had statistically significant differences between men and women: F31 and R01. For the F31 program, women had higher funding rates and success rates; in the R01 program, women and men had success rates that were not statistically different, but women had a lower funding rate that was statistically significant.

Further analysis of the R01 program data showed that funding and success rates for first-time applicants were comparable for men and women, but experienced male applicants had higher funding and success rates than experienced females (Table 1). Furthermore, for experienced investigators, success and funding rates were nearly equal for new applications (women were within one percentage point of men for both measures), but men were three to four percentage points more successful than women on renewal applications, when measured either by success rates or funding rates (Table 1). Therefore, the only R01 subgroup in which men outperformed women with statistical significance was experienced investigators competing for renewal awards.

Average ages of participants. We found a small but statistically significant difference in the ages of applicants in the R21 program, and applicants and awardees in the R01 program, with males older in all three cases (Chart 1). In our more detailed analysis of R01 awards (Table 1), we found that age differences were not statistically significant for first-time applicants and awardees, but, for experienced applicants and awardees, males were older than females by about two years ($P < .0001$).

Average direct costs requested and received. NIH data have shown that average R01 total costs for awards to women have been higher than R01 total costs for awards to men since 1993.[20] However, other NIH data showed that average total costs for men were higher than for women, when considering all research project grants together, as well as when considering other broad categories of related activity codes as one unit (i.e., career, small business, research centers).[7] When we compared the average direct costs requested and received for each program, most award programs showed no statistically significant differences (Chart 1). For the R21 program, in which research is exploratory and often higher risk, the direct costs received by R21 male awardees were higher than those received by female awardees, despite their requests not being statistically different. In contrast, in the R01 program, female awardees requested and received significantly more than male awardees ($P < .0001$), a difference that persisted in all further comparison groups for R01 awards (see Table 2).

R01 transition points

Transition from career development or small research to R01 awards. The long history of the K08 program demonstrates that about three-quarters of the recipients who received a subsequent R01 within 20 years did so within 8 years.[21] Therefore, we used an 8-year period to compare the subsequent R01 receipt for K awardees from 1999 to 2000 (Table 2). For the K01 award program, which supports a mix of basic biomedical, behavioral, or clinical researchers, female and male recipients were similarly likely to apply for R01 awards, and female applicants had a higher cumulative funding rate (although the difference was not statistically significant). For the K08 and K23 programs, which primarily support clinician scientists and patient-oriented researchers (i.e., primarily MDs), the subsequent R01 application and funding rates for males were higher than for females (although only one of the four comparisons was statistically different; see Table 2).

We also examined the R01 eight-year cumulative application and funding rates of investigators who received R03 and R21 awards in 1999–2000 (Table 2). For female R03 awardees, the cumulative R01 application rate was lower than for males ($P < .0001$), but the cumulative funding rate was similar. For the R21 awardees, although neither result was statistically significant, women had a higher cumulative application rate and a lower cumulative funding rate.

Retention and renewal of R01 awards. Success rates for new R01 awards over the past decade have been almost identical between the sexes, but women consistently have been less successful at receiving competing renewal R01-equivalent awards.[22] Therefore, we examined the application and funding rates of R01 awardees when transitioning from new to renewal R01 awards (Table 3). Males supported by R01 awards between 1999 and 2004 had higher cumulative application ($P < .0001$) and funding rates on renewals than females.

Because awardees for research involving human subjects are less likely to apply for renewal awards (data not shown), we segregated R01 awardees of new applications by whether or not they proposed human subjects research (Table 3). Within applications that proposed

Chart 1

Person-Level and Application-Level Data for Selected 2008 Competing National Institutes of Health (NIH) Applications and Awards, by Activity Code (Award Mechanism) and Sex, in Order of Increasing Average Age Within Each Career Stage (Early–Independent–Mid–Senior)

Category and activity code			Sex	Person-level data: Applicants No. (%)*	Applicants Age†,‡	Awardees No. (%)*	Awardees Age†,‡	Funding rate (%)§	Application-level data; excludes applications with multiple primary investigators: Applications, no. (%)	Awards, no. (%)	Success rate (%)§	Direct costs of awards¶,‡ Requested†	Direct costs of awards¶,‡ Received†
Early (fellows and trainees)	Predoctoral trainees (T32)**		F	Applicant data are institutional		777 (55)††	27	n/a	Trainees do not apply for NIH awards			n/a	
			M			639 (45)††	27						
	Predoctoral fellowships	F30	F	101 (45)	27	51 (49)	27	50	104 (45)	53 (50)	51	Not shown (costs are fixed)	
			M	123 (55)	28	52 (50)	27	43	128 (55)	54 (50)	42		
	Predoctoral fellowships	F31	F	809 (61)††	29	309 (65)††	29	39††	855 (62)	330 (67)	39††	Not shown (costs are fixed)	
			M	516 (39)††	29	161 (34)††	29	31††	534 (38)	166 (33)	31††		
	Postdoctoral fellowships	F32	F	898 (47)	32	276 (47)	32	31	938 (47)	286 (47)	30	Not shown (costs are fixed)	
			M	996 (52)	32	308 (52)	32	31	1,044 (53)	325 (53)	31		
	Postdoctoral trainees (T32)**		F	Applicant data are institutional		535 (55)††	33	n/a	Trainees do not apply for NIH awards			n/a	
			M			435 (45)††	33						
Early (transition)	Career	K99	F	279 (38)††	35	70 (42)	34	25	301 (40)	73 (43)	24	$91,869	$96,815
			M	437 (61)††	35	94 (57)	34	22	450 (60)	97 (57)	22	$93,679	$92,549
	Career	K22	F	35 (35)††	39	6 (30)	37	17	38 (35)	8 (35)	21	$158,954	$160,703
			M	65 (65)††	38	14 (70)	38	22	70 (65)	15 (65)	21	$145,865	$154,076
Early (mentored faculty)	Career	K23	F	290 (55)††	38	115 (56)	38	40	309 (56)	119 (55)	39	$142,722	$143,914
			M	232 (44)††	38	89 (43)	38	39	247 (44)	97 (45)	39	$148,990	$149,273
	Career	K08	F	151 (31)††	38	64 (30)††	38	42	158 (31)	71 (32)	45	$132,000	$130,101
			M	325 (68)††	38	143 (69)††	38	45	346 (69)	152 (68)	44	$135,490	$136,253
	Career	K01	F	226 (55)††	39	92 (57)	38	40	251 (57)	102 (58)	41	$127,330	$128,365
			M	181 (44)††	39	69 (42)	38	38	191 (43)	73 (42)	38	$123,837	$125,447
Independent research	Research project	R03	F	1,173 (43)††	45	301 (47)	44	27	1,254 (43)	320 (46)	26	$76,463	$72,772
			M	1,500 (56)††	45	333 (52)	45	24	1,662 (57)	373 (54)	22	$75,908	$73,842
	Research project	R21	F	2,892 (32)††	47††	501 (34)††	46	19	3,194 (32)	570 (34)	18	$219,490	$204,122††
			M	5,892 (67)††	48††	952 (65)††	47	19	6,686 (68)	1,109 (66)	17	$219,851	$205,642††
	Research project	R01	F	5,590 (27)††	48††	1,218 (27)††	48††	26††	6,454 (27)	1,461 (26)	23	$451,156††	$394,750††
			M	14,566 (72)††	49††	3,257 (72)††	50††	28††	17,724 (73)	4,161 (74)	23	$439,400††	$384,482††
Mid	Career	K24	F	25 (27)††	50	15 (31)††	51	58	29 (30)	15 (31)	52	$156,756	$157,574
			M	65 (72)††	48	32 (68)††	48	49	68 (70)	34 (69)	50	$161,705	$159,203
Senior (director)	Research center	P50	F	21 (13)††	53	8 (13)††	55	38	23 (14)	8 (13)	35	$1,856,334	$1,554,883
			M	137 (86)††	54	52 (86)††	54	38	146 (86)	54 (87)	37	$2,200,784	$1,880,032
	Research center	U54	F	37 (25)††	56	15 (28)††	56	42	34 (26)	16 (33)	47	$1,653,720	$1,345,789
			M	108 (74)††	56	38 (71)††	54	36	96 (74)	33 (67)	34	$3,421,380	$2,694,409
	Training	T32	F	134 (18)††	55	68 (19)††	54	51	155 (19)	77 (20)	50	$364,077	$276,602
			M	602 (81)††	56	286 (80)††	57	48	644 (81)	313 (80)	49	$387,802	$295,084
	Program project	P01	F	75 (19)††	56	25 (17)††	56	34	82 (19)	29 (19)	35	$1,862,298	$1,541,436
			M	316 (80)††	57	120 (82)††	57	38	341 (81)	125 (81)	37	$1,854,577	$1,637,295
	Research center	P30	F	20 (14)††	57	12 (17)††	59	60	21 (14)	13 (18)	62	$1,693,537	$1,457,231
			M	121 (85)††	59	56 (82)††	60	46	129 (86)	61 (82)	47	$2,047,296	$1,536,126

* Binomial test was used to determine whether the percentage of women or men in the applicant or awardee pool was different from 50%.
† Distribution comparisons between males and females were performed with the two-sample Kolmogorov–Smirnov test.
‡ Values shown are averages.
§ Pearson chi-square test was used to assess sex differences.
¶ Applications with incomplete values for direct costs were excluded from cost calculations.
** Only full-time trainees appointed to FY2008 competing awards were included; trainees are not NIH awardees because the trainees are selected by the institution.
†† $P < .05$.

Table 1

Person-Level and Application-Level Data for National Institutes of Health (NIH) R01 2008 Competing Applications and Awards, by Sex, Applicant Experience Level (First-Time or Experienced), and Application Type*

			Person-level data					Application-level data; excludes applications with multiple primary investigators				
			Applicants[†]		Awardees[†]						Direct costs of awards[‡,§]	
Applicant experience level	Competing application type	Sex	No. (%)[¶]	Age[†,§]	No. (%)[¶]	Age[†,§]	Funding rate (%) **	Application, No. (%)	Awards, No. (%)	Success rate (%)**	Requested[†]	Received[†]
First-time	All competing types: 1, 2, 3, 9	F	1,924 (33)[††]	44	474 (36)[††]	43	27	1,962 (32)	481 (34)	25	$422,191[††]	$372,536[††]
		M	3,914 (67)[††]	44	842 (64)[††]	43	27	4,091 (68)	945 (66)	23	$393,323[††]	$344,449[††]
Experienced	All competing types: 1, 2, 3, 9	F	3,666 (26)[††]	50[††]	744 (24)[††]	51[††]	27[††]	4,492 (25)	980 (23)	22[††]	$465,373	$405,653[††]
		M	10,652 (74)[††]	52[††]	2,415 (76)[††]	53[††]	31[††]	13,633 (75)	3,216 (77)	24[††]	$452,942	$396,246[††]
	New only (Type 1)	F	2,503 (26)[††]	50[††]	376 (24)[††]	50[††]	24	2,989 (25)	492 (24)	17	$480,651[††]	$415,876[††]
		M	7,075 (74)[††]	52[††]	1,162 (76)[††]	52[††]	25	8,947 (75)	1,582 (76)	18	$459,222[††]	$399,780[††]
	Renewal only (Type 2)	F	1,128 (24)[††]	52[††]	355 (22)[††]	52[††]	37[††]	1,463 (24)	472 (23)	32	$450,031	$395,346
		M	3,510 (76)[††]	54[††]	1,225 (78)[††]	54[††]	41[††]	4,579 (76)	1,586 (77)	35	$446,878	$392,824

* As defined by the OER Glossary,[16] where "all competing types" includes new (Type 1), renewal (Type 2), supplemental support (Type 3), and change of NIH awarding institute or division in a competing continuation (Type 9). First-time investigators are those applying for a competing R01-equivalent award without previous significant NIH competing research grant support. Experienced investigators are those who are not first-time investigators.

† Distribution comparisons between males and females were performed with the two-sample Kolmogorov–Smirnov test.

‡ Applications with incomplete values for direct costs were excluded from cost calculations.

§ Values shown are averages.

¶ Binomial test was used to determine whether the percentage of women or men in the applicant or awardee pool was different from 50%.

** Pearson chi-square test was used to assess sex differences.

†† $P < .05$.

human subjects research, cumulative application rates were lower for women than men ($P < .0001$), but funding rates were not significantly different. Within applications that did not propose research on human subjects, women had higher cumulative application rates but lower funding rates. Whether or not human subjects were proposed in the application, the pattern did not vary appreciably between first-time and experienced investigators. Finally, we noted that 49% (2,549/5,209) of female R01 awardees and 35% (5,580/16,002) of male awardees proposed human subjects research ($P < .0001$), a pattern that persisted when matched on experience level.

Senior investigators and investigators with multiple awards

Of all investigators with R01 awards in 2008, 75% (15,678/20,796) held only one award; the remainder held two or more concurrent awards. Thirty percent of investigators with one R01 award were female (4,666/15,678), but the percentage of female investigators decreased with each additional concurrent R01 award to a low of 13% female (25/191) for investigators holding four or more concurrent awards (Figure 1, $P < .0001$). Investigators who held more than one concurrent award were older than those who held only one award, and the average age increased with each additional concurrent R01 award held (except for women with four or more awards). On average, females reached all of these milestones (in terms of multiple awards) at younger ages. For example, females were 0.5 years younger than their male counterparts at the receipt of three R01 awards and 2.7 years younger at the receipt of four or more R01 awards. We also examined the average number of R01 awards for each age between 30 and 65, and we found that men had more concurrent awards than women in every age cohort (Figure 2) and that the percentage of males holding more than one R01 award was higher than the percentage of females at every age (except for investigators aged 36 years old; data not shown). When we restricted the analysis to new R01 awards, the results were similar (data not shown). Combined, these data indicate that the preponderance of multiple concurrent awards to men cannot be explained solely by age differences.

Table 2

Application and Funding Rates for 1999–2000 Awardees of Competitive National Institutes of Health (NIH) K01, K08, K23, R03, or R21 Awards, as the Awardees Applied for Subsequent R01 Awards Over the Ensuing Eight Years, by Sex

Award type	Sex	No. (%) initial 1999–2000 awardees*	Cumulative (to 2008) application rate for subsequent R01 award†	Cumulative (to 2008) funding rate for subsequent R01 award†
K01	F	106 (48)	70	58
	M	116 (52)	71	49
K08	F	137 (29)	64‡	55
	M	331 (71)	74‡	59
K23	F	114 (45)	69	51
	M	142 (55)	73	60
R03	F	373 (47)	67‡	50
	M	429 (53)	78‡	52
R21	F	126 (27)	84	57
	M	339 (73)	79	64

* Investigators who received R01 award(s) before the K01, K08, K23, R03, or R21 award (respectively) were excluded.
† Sex differences in application and funding rates were determined with the Pearson chi-square test.
‡ $P < .05$.

For R37 MERIT Awards in 2008, the selection rate for females was half that of males (2.0% [24/1,218] versus 4.1% [132/3,257]; $P = .02$), and the awardees were older (by about seven years) and more often male than the pool of eligible candidates (R01 awardees). Although it is possible that the selection of older, more established investigators led to the preferred selection of males (who are enriched in older pools), further investigation of impact/priority scores and other selection factors could help determine other reasons for this phenomenon. In this context, it is important to note that advisory council and board membership is regulated by the Federal Advisory Committee Act, and the NIH ensures broad participation,[23] determined by several metrics, including the percentage of women.

Discussion and Conclusions

Women and men are equally successful in most award programs, but men are more successful once becoming NIH investigators

In our cross-sectional analyses of most award programs in 2008, there were no significant differences in men's and women's success rates or funding rates. Age differences within a total population often obscure differences in cross-sectional analyses, making conclusions less generalizable. However, for our cross-sectional studies, we stratified the population by activity code, which allowed us to target specific career phases and age cohorts, eliminating this disadvantage. The only activity code for which women were not equally or more successful than men was the all-important R01 program, which, unlike most other activity codes, is not targeted to a particular career stage. For the R01 program overall, success rates were comparable between the sexes, but women had a lower funding rate than men. Further stratification by experience level (another proxy for age cohorts) revealed that the lower funding rate was driven by the subgroup of experienced R01 applicants submitting renewal applications. In the other classes of R01 applications we examined (first-time applicants and experienced applicants submitting new applications), there were no statistically significant differences between the sexes.

Longitudinal analysis of career development and small research awards for investigators in transition to R01 awards, and investigators transitioning from new to renewal R01 awards, revealed that men were generally more likely to apply and be funded than women, whether their initial award was career development, small or exploratory research, or R01. Therefore, our findings for the longitudinal analysis of the R01 program (Table 3; showing that experienced men are more likely to apply for renewal awards than women) were supported by the results of our cross-sectional analysis of all programs.

Women are more likely than men to perform human subjects research

Our longitudinal analysis of the R01 program shows a different pattern whether the research involves human subjects or not. Women seemed to be less successful compared with men when not proposing human subjects (despite a higher application rate, they had a lower funding rate), and equally or more successful than men when proposing human subjects (despite a lower application rate, they had a cumulative funding rate that was not statistically different than men). Interestingly, of all R01 awardees, the females were almost evenly distributed by whether they proposed human subjects research, whereas almost two-thirds of the males did not propose human subjects research. Further investigation could determine the reason for the propensity for women to propose human subjects research.

Direct costs received do not differ by sex, with two exceptions

Overall, direct costs that were requested and received by female awardees were not statistically different than direct costs requested and received by male awardees. The statistically significant greater direct costs received by men in the R21 program, despite their direct cost requests not being significantly higher, could potentially indicate bias[24] against females performing costly "high-risk" research or could be the function of something more benign such as the particular fields of science that are represented by the institutes and centers that distribute R21 awards. In contrast, the higher direct costs received by female R01 awardees compared with males seem to be a function of higher direct costs requested, because both men and women receive the same percentage of their requests.

Age and career stage affect the participation and success of women

We noticed an inverse correlation between age and the participation/success of women in NIH award programs in three ways. First, the percentage of female

Table 3

Application and Funding Rates for 1999–2004 Awardees of Competitive New National Institutes of Health (NIH) R01 Unsolicited Awards, as the Awardees Applied for Subsequent Competing Renewal R01 Awards Through 2008, by Experience Level at Time of Original Award, Sex, and Inclusion of Human Subjects in the Research

Inclusion of human subjects	Experience level of awardee*	Sex	No. (%) of initial awardees of new R01 unsolicited applications	% Cumulative (to 2008) *application* rate for subsequent competing R01 renewal award†	% Cumulative (to 2008) *funding* rate for subsequent competing R01 renewal award†
Yes and No (combined)	Combined	F	5,209 (25)	45‡	45‡
		M	16,002 (75)	49‡	49‡
	First-time	F	2,317 (30)	49‡	42‡
		M	5,498 (70)	55‡	47‡
	Experienced	F	2,892 (22)	42‡	49
		M	10,504 (78)	46‡	50
Yes	Combined	F	2,549 (31)	34‡	45
		M	5,580 (69)	40‡	46
	First-time	F	1,129 (38)	35‡	40
		M	1,861 (62)	44‡	43
	Experienced	F	1,420 (28)	33‡	49
		M	3,719 (72)	38‡	48
No	Combined	F	2,660 (20)	56‡	46‡
		M	10,422 (80)	54‡	50‡
	First-time	F	1,188 (25)	63	44‡
		M	3,637 (75)	60	48‡
	Experienced	F	1,472 (18)	50	48
		M	6,785 (82)	50	51

* First-time investigators are those applying for a competing R01-equivalent award without previous significant NIH competing research grant support. Experienced investigators are those who are not first-time investigators. "Combined" indicates both first-time and experienced investigators.

† The indicated *P* values refer to the effect of sex on application and funding rate as determined with logistic regression tests.

‡ $P < .05$.

applicants and awardees decreased for award mechanisms with higher average ages. Second, the R01 participation and success rates of experienced women investigators were lower than for first-time women investigators. Finally, investigators of multiple concurrent R01 awards (and those who received R37 awards) were older and more often male than investigators with one award (or R01 awardees, who are the "applicants" for R37 awards), consistent with national data that show much smaller proportions of women among older cohorts, and fewer females in senior positions.[25,26]

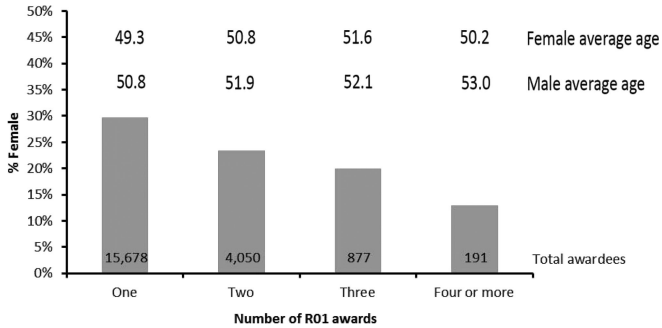

Figure 1 Participation of women, by number of concurrent R01 awards. The percentage of female investigators is shown for the indicated number of concurrent R01 awards in 2008. The total awards in each cohort are indicated, as well as the average ages of females and males in each cohort.

Caveats

We offer two main caveats with our conclusions that are relevant for future studies. First, we did not examine application scores, which, although not immune from bias,[24] reflect scientific and technical merit; further studies could investigate whether differences in scores correlated with differences in success rates for women and men. This kind of analysis could help separate the contribution of review and selection of applications for funding within the observations we have reported. Second, we did not include variables such as degree type, field of research, academic rank of applicants, or institutional rank in our analyses. We and others at the NIH are continuing to study these issues.

Summary

In this study, we examined a majority (77%) of the NIH competing research

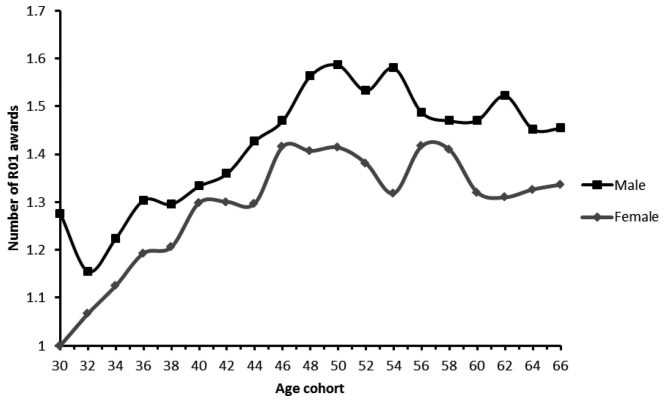

Figure 2 Number of concurrent R01 awards in 2008, by age cohort. The average number of concurrent R01 awards in 2008 is shown in two-year increments for ages 30 to 66.

and training awards funded in 2008, and we found that women generally performed just as well as men. Furthermore, women were equally or more successful than men in the R01 program, both as first-time investigators and as experienced investigators submitting new applications. However, men were more successful than women in the R01 program as experienced investigators submitting renewal applications, a finding which was supported by our longitudinal analyses of NIH awardees' subsequent performance, where application and funding rates were generally lower for women than for men. A variety of factors, including family circumstances,[27] self-confidence,[28] and other barriers resulting from gender stereotypes,[29] have been proposed as reasons why application rates may be lower for women than for men (and seem to be consistent between countries). The reasons for lower funding rates are also unknown and could include unconscious biases in review or selection, especially if men with enhanced social networks tend to receive more favorable treatment from peers who are part of their network.[3,24] The NIH is currently supporting extramural research to investigate causal factors and the efficacy of interventions with regard to the career patterns of women in biomedical and behavioral science and engineering,[30] and we eagerly anticipate results.

We hope that the balance between men and women that exists for current early career researchers persists as this cohort moves through their careers. However, it is not enough to simply wait for the situation to improve. The NIH, as the steward of biomedical and behavioral research for the nation, is committed to ensuring that opportunities for receiving extramural funding are available and awarded to a diverse pool of highly trained scientists. To this end, through the Working Group on Women in Biomedical Careers,[31] the NIH is addressing the new points highlighted in this study—particularly the sex differences in sustaining NIH funding beyond the first career development or small research award, or the first R01.

Finally, the NIH has already undertaken many initiatives to provide opportunities for women and men to succeed. Examples include establishing and promoting the Reentry[32] and Diversity[33] Supplements, allowing multiple PIs on research grant applications,[34] allowing for part-time effort on K awards,[35] establishing policies to promote the success of new and early stage investigators[36] (including a process to request extensions to the early stage investigator period[37]), extending the parental leave policy for the Kirschstein–NRSA awards,[38] and other initiatives of the NIH Working Group on Women in Biomedical Careers. Our analysis makes clear that we are progressing toward the full participation of women in NIH programs but that further actions will be required to eradicate remaining sex differences. The development of new initiatives, as well as furthering current programs, will be integral in ensuring that resources are available to enable talented scientists to achieve meaningful and successful research careers and to improve the health of our nation.

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