

Sex Differences in Attainment of Independent Funding by Career Development Awardees

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Background: Concerns have been raised about the career pipeline in academic medicine, including whether women with a demonstrated commitment to research succeed at the same rate as male colleagues.

Objective: To determine the subsequent academic success of recipients of National Institutes of Health (NIH) career development awards.

Setting: United States.

Participants: 2784 of 2799 (99.5%) recipients of K08 and K23 awards for whom sex could be ascertained from the NIH Computer Retrieval of Information on Scientific Projects database and other publicly available sources.

Measurements: Actuarial rates at which recipients of K08 and K23 awards from 1997 to 2003 went on to receive R01 awards. Sex-specific rates of R01 award attainment were calculated by using the Kaplan–Meier method, and sex differences were assessed by using a Cox proportional hazards model.

Results: Overall, 31.4% of the 1919 K08 awardees and 43.7% of the 865 K23 awardees were female ($P < 0.001$). Women were less likely than men to receive an R01 award ($P < 0.001$). The actuarial rate of R01 award attainment at 5 years was 22.7% overall, 18.8% among women, and 24.8% among men. At 10 years, the rate was 42.5% overall, 36.2% among women, and 45.6% among men. Sex persisted as an independent significant predictor of R01 award attainment (hazard ratio, 0.79 [95% CI, 0.68 to 0.92]; $P = 0.002$) in multivariate analysis controlling for K award type, year of award, funding institute, institution, and specialty.

Limitation: Whether the lower rate of R01 award achievement among women is due to lower rates of application or lower rates of success in application could not be determined.

Conclusion: Only a minority of K awardees studied achieved R01 award funding during the period assessed, and a significant sex disparity was evident.

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Although women are now entering the medical profession at rates that mirror their representation in the general population, they remain in the minority in the senior echelons of academic medicine. In 2007, women constituted 49% of the medical student body but only 33% of medical faculty, 17% of full professors, and 12% of department chairs at U.S. medical schools (1). To some extent, the low proportion of women in the senior ranks of academic medicine is the outcome of a metaphoric slow pipeline. Given the long interval from medical school graduation to achievement of senior faculty positions, persons in these senior positions attended medical school at a time when women were underrepresented. By this reasoning, it will take more time before parity can reasonably be expected. However, a slow pipeline alone seems insufficient to explain the current numbers, considering that 24% of medical school enrollees in 1975—more than 30 years ago—were women, and leakage from the pipeline becomes an additional concern. Previous studies that

sought to investigate this leakage problem (2–4) have been stymied by the possibility that women may be more likely to prefer teaching or clinical activity over research (5). Consequently, these studies could not address definitively whether women with a demonstrated commitment to research succeed at the same rate as their male colleagues.

The highly select cadre of physician-scientists who receive career development awards from the National Institutes of Health (NIH) are a particularly informative group for understanding the career trajectory of female faculty. In particular, it is useful to consider recipients of the NIH K08 and K23 awards, which are intended to support the career development of researchers who hold clinical doctorates. These awards are highly competitive grants made to young physicians with a strong interest in and demonstrated aptitude for building research careers. The awards are designed to support protected time for awardees to participate in an “intensive, supervised, research career development experience” under the guidance of an experienced mentor (6). Recipients of these awards are generally expected to progress to independent research careers. A key indicator of such independence is subsequent attainment of an R01 award from the NIH.

We sought to examine the rates at which men and women with K08 and K23 awards have gone on to achieve R01 grants, to offer specific evidence to inform the debate over the nature of the “pipeline problem” in academic medicine.

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Print

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Appendix

Appendix Figures

Conversion of graphics into slides

METHODS

Study Population and Determination of R01 Award Attainment

We identified recipients of new K08, K23, and R01 awards by using the NIH's online database, Computer Retrieval of Information on Scientific Projects (CRISP) (7, 8), for 1997 to 2003 (K08 awards), 1999 to 2003 (K23 awards; the K23 program did not begin until 1999), and 1997 to 2007 (R01 awards). Using Microsoft Excel 2002 (Microsoft, Redmond, Washington), we developed an automated algorithm to search for the full (first and last) name of each K08 and K23 recipient among a list of first and last names of R01 award recipients and the years in which a match appeared. We verified matches on the basis of other information in the CRISP database, including e-mail address, middle name or initial, institution, and department or subject area (as determined from the grant abstracts). If the data for these attributes were missing, we searched the Internet for institutional Web pages and curriculum vitae to provide additional information about recipient identities.

Determination of Recipient Characteristics

Two independent reviewers attributed sex for the K08 and K23 recipients on the basis of commonly accepted sex identity for first names (and middle names where available). In no cases did one reviewer believe a name to be female and the other believe the name to be male. For all recipients with first names for which either reviewer deemed sex to be potentially ambiguous, we determined sex by checking the project abstracts provided in CRISP for use of sex-specific pronouns or by searching the Internet to locate institutional Web pages with pictures of the recipient, use of sex-specific pronouns, or an explicit statement of sex.

We extracted information on each recipient's institution and department at the time of K award from CRISP. For the purposes of analysis, we grouped institutions listed in CRISP so that all hospitals affiliated with a single university were considered to be a single institution. We then grouped institutions into 4 tiers, which contained approximately equal numbers of K awardees, on the basis of total NIH funding received by each institution in 2000 as listed in the NIH's Research Portfolio Online Reporting Tool (9). We also reviewed recipients' departmental names and grouped them into 6 specialty categories: medical specialties (internal medicine and its subspecialties, as well as neurology); surgical specialties (general surgery and surgical subspecialties); clinical specialties for women, children, and families (family medicine, obstetrics and gynecology, pediatrics, and their subspecialties); hospital-based specialties (such as radiology, anesthesiology, and pathology); basic sciences; and missing (no department listed in CRISP).

We also used CRISP to determine the NIH funding institute that granted the K award. For analysis, we grouped funding institutes into 3 tiers of funding activity,

on the basis of total dollar amount of R01 awards granted in 2000 (10).

Female Surname Change

To account for female surname change due to marriage or divorce, we further scrutinized all female K08 and K23 recipients whose names did not appear on the lists of R01 award recipients. We considered all female K08 and K23 recipients who had a first name that matched 1 or more R01 award recipients' first names and did not appear as having received an R01 award. We first searched for each woman's name in the online directory of the institution listed in her grant application or by navigating from the institution's main Web page to a departmental personnel listing. If her name appeared in either the directory or departmental listing with the same e-mail address, we considered this to be sufficient confirmation that she continued to use the surname listed on her K award. If her full name did not appear, we used Google and PubMed to search the Internet for evidence of a new institutional affiliation or name change. The **Appendix** and **Appendix Figures 1 and 2** (available at www.annals.org) contain detailed information regarding our search criteria and methods. In all cases in which we found evidence for a name change, we searched the CRISP database for R01 awards under this new name and all potential last name combinations.

When we could confirm neither continued use of the same name nor a name change with these approaches, we identified all R01 award recipients with the same first name in the last year of the person's K award or later and, where feasible, confirmed that each of these persons were not the same person as the K award recipient. We considered the following to be sufficient confirmation of separate identities: a CRISP record that showed the R01 award recipient had received an NIH grant under that full name before the date when the K awardee with the same first name had received her K award or its continuation, a PubMed record that showed the R01 award recipient had published under that name before or during the years that the K awardee had received her K award, evidence that the R01 and K awardees were engaged in entirely unrelated areas of research, an institutional Web page for the R01 award recipient that detailed training and employment history which precluded previous affiliation with the K awardee's institution, or evidence that the R01 award recipient did not hold a known degree of the K awardee. As an additional check, we identified all R01 award recipients with hyphenated surnames and searched the K award recipient lists for both surnames.

Using the described methods, we confirmed that 17.4% of the women who did not receive R01 awards under the names listed on their K awards could not have received an R01 award because their first names did not appear on the list of R01 award recipients from 1997 to 2007, and that 74.7% of those women were still using the same name. We confirmed that an additional 5.2% had

not received R01 awards after checking all R01 award recipients with the same first name in the years 1997 to 2007. We found that 13 women (1.8% of women not receiving R01 awards) had changed their names; this represents 2.3% of the women confirmed either to be still using the same names or to have changed their names (of note, none of these had received an R01 award under the new name). Given the low rate of name changes observed, we assumed that the remaining 1.0% whose current name we could not identify had not received an R01 award under a new name.

Statistical Analysis

We analyzed the tabulated data by using SAS statistical software, version 9.1 (SAS Institute, Cary, North Carolina). We used the Kaplan–Meier product-limit method to construct estimates of the probability of the receipt of R01 awards for the period after K award receipt, by sex and K award type. We considered recipients to be “at risk” for receiving an R01 award through the 2007 award cycle. We made no attempt to adjust for rare competing events, such as death of the K award recipient. For K08 or K23 award recipients who received multiple R01 awards, we used the year in which they received their first R01 award as the date of the event for analysis. We used the log-rank test statistic to assess differences in attainment of R01 awards between male and female K award recipients. We then constructed a multivariate Cox proportional hazards model to determine whether sex was an independent significant correlate of R01 award attainment after controlling for type of K award (K08 or K23), year of K award, institution, specialty, and funding institute (grouped as described), including time dependency terms where significant. We also performed a sensitivity analysis in which we analyzed the subset of persons whom we could arrange in male–female pairs matched for K award type, K award year, funding institute tier, and institution tier. For all statistical tests, we considered *P* values of 0.05 or less to be statistically significant.

Finally, to account for the potential effect of including non-MDs who received K awards, we conducted an addi-

tional sensitivity analysis after excluding NIH institutes for which a substantial proportion of K awardees would be expected to hold non-MD degrees. Because sufficient data on K awardees’ degrees were unavailable for our sample, we designed this sensitivity analysis after considering the distribution of degrees among 2007 K08 and K23 awardees (for whom we could determine degrees for all but 1 of the 408 recipients by searching the Internet). The frequency of non-MD recipients of K awards in 2007 was low: Of the 407 K awardees whose degree was known, 328 (80.3%) held MD degrees. Among the non-MDs, 56 (13.7%) held nonnursing PhDs alone (most frequently in psychology), 5 held dental degrees, 6 held optometry degrees, 5 held doctorates in nursing, 5 held veterinary degrees, and 1 held a doctorate in pharmacy. The National Institute of Mental Health, National Institute on Aging, National Institute on Drug Abuse, National Eye Institute, National Institute of Dental and Craniofacial Research, National Institute on Deafness and Other Communication Disorders, National Institute of Nursing Research, National Institute on Alcohol Abuse and Alcoholism, and National Center for Complementary and Alternative Medicine each granted more than 20% of their K awards in 2007 to non-MDs. For the remaining 12 institutes (National Cancer Institute; National Center for Research Resources; National Heart, Lung, and Blood Institute; National Institute of Allergy and Infectious Diseases; National Institute of Arthritis and Musculoskeletal and Skin Diseases; National Institute of Biomedical Imaging and Bioengineering; Eunice Kennedy Shriver National Institute of Child Health and Human Development; National Institute of Diabetes and Digestive and Kidney Diseases; National Institute of Environmental Health Sciences; National Institute of General Medical Sciences; National Institute of Neurological Disorders and Stroke; and Agency for Healthcare Research and Quality), the overall proportion of non-MDs was only 7.7%. Therefore, we repeated our analyses after excluding the high non-MD funding institutes to assess whether our finding of sex differences persisted.

Table 1. Number of K08 and K23 Awards Granted, by Sex and Subsequent R01 Award Receipt

Year	K08 Award				K23 Award			
	Men		Women		Men		Women	
	Recipients, <i>n</i>	Received an R01 Award, %	Recipients, <i>n</i>	Received an R01 Award, %	Recipients, <i>n</i>	Received an R01 Award, %	Recipients, <i>n</i>	Received an R01 Award, %
1997	203	45.3	100	41.0	–	–	–	–
1998	205	47.8	102	39.2	–	–	–	–
1999	180	41.1	67	32.8	51	39.2	34	38.2
2000	175	38.3	82	29.3	101	38.6	92	29.4
2001	164	31.1	74	23.0	110	31.8	73	21.9
2002	192	25.5	95	10.5	110	18.2	85	25.9
2003	198	11.1	82	11.0	115	18.3	94	5.3
Total	1317	34.4	602	27.1	487	27.7	378	22.0

Table 2. Sex of K08 and K23 Award Recipients, by Academic Institution, Funding Institute, and Department Type

Characteristic	Recipients, n	Women, %	Chi-Square P Value
Institution tier*			<0.001
1	708	30.4	
2	709	33.2	
3	704	37.9	
4	663	39.7	
Funding institute tier†			<0.001
1	791	28.3	
2	1222	36.3	
3	771	40.6	
Specialty group			<0.001
Medical	902	31.9	
Surgical	149	14.8	
Families, women, or children	279	46.6	
Hospital-based	467	34.1	
Basic sciences	176	47.2	
Unknown or missing	811	36.7	

* Ranked by NIH funding. Tier 1 includes institutions ranked 1–3 (Harvard University, University of Washington, and Johns Hopkins University). Tier 2 includes those ranked 4–12 (University of Pennsylvania; University of California, San Francisco; Washington University in St. Louis; University of Michigan; University of California, Los Angeles; Yale University; Columbia University; University of Pittsburgh; and Stanford University). Tier 3 includes those ranked 13–37 (Case Western Reserve University; University of North Carolina; Duke University; University of California, San Diego; University of Minnesota; Baylor College of Medicine; University of Wisconsin; University of Alabama; University of Colorado; Emory University; Scripps Research Institute; Yeshiva University; University of Southern California; Boston University; Cornell University; Vanderbilt University; University of Texas Southwestern Medical Center; Northwestern University; University of Iowa; University of Chicago; Oregon Health & Science University; Mount Sinai School of Medicine; New York University; and University of Rochester). Tier 4 includes those ranked 38 or lower (<\$100 million in total funding). † Ranked by monetary amount of R01 awards granted. Tier 1 includes the National Institute of General Medical Sciences; National Heart, Lung, and Blood Institute; and National Cancer Institute. Tier 2 includes the National Institute of Neurological Disorders and Stroke, National Institute of Allergy and Infectious Diseases, National Institute of Diabetes and Digestive and Kidney Diseases, and National Institute of Mental Health. Tier 3 includes the remaining K-awarding institutes.

Role of the Funding Source

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RESULTS

We identified 2799 recipients of K08 and K23 awards and ascertained sex for 2784 recipients (99.5%), which constitute our analyzed sample. We excluded 1 person from the time-to-event analyses of R01 award attainment because he received his R01 award in the year before his K award, leaving a sample of 2783 recipients for those analyses.

Women constituted a lower proportion of K08 awardees than K23 awardees in the years studied ($P < 0.001$); 31.4% of the 1919 K08 awardees and 43.7% of the 865

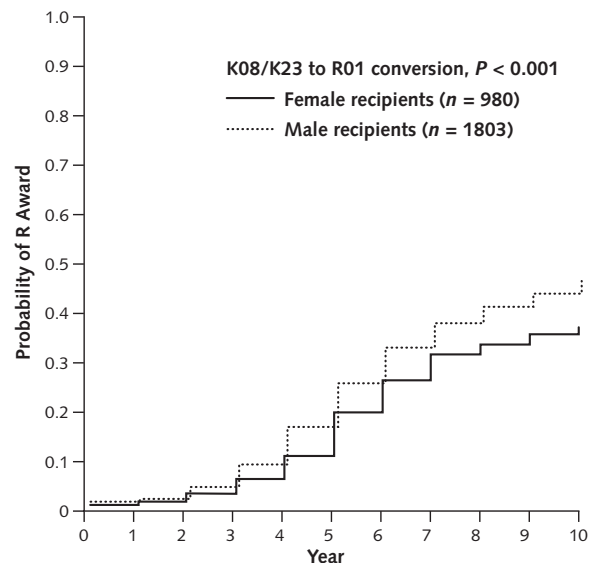
K23 awardees were female. The percentage of K08 recipients who were female remained stable from 1997 to 2003 ($P = 0.57$), as did the percentage of K23 recipients who were female from 1999 to 2003 ($P = 0.84$). From the year of K award receipt through 2007, 836 (29.9%) of all K awardees studied had received R01 awards. Table 1 shows the absolute numbers of K award recipients 1997 to 2003, by sex and subsequent attainment of an R01 grant.

As shown in Table 2, K awardees from the funding institutes that awarded the highest amount of R01 funding were more likely to be male, as were those from the institutions that received the highest levels of NIH funding. We also found significant differences in sex distribution of K awardees by specialty.

Among those who received R01 awards during the study period, the median time to attainment of a K awardee's first R01 award was 5 years, defined as the year of K award receipt subtracted from the year of R01 award receipt. The Figure shows the actuarial rates (product-limit estimates) of first R01 award attainment in the study population, by sex. The actuarial rate of R01 award attainment at 5 years was 22.7% overall, 18.8% among women, and 24.8% among men. At 10 years, the rate was 42.5% overall, 36.2% among women, and 45.6% among men.

As shown in Table 3, in a multivariate Cox proportional hazards model that was stratified by K award type and included sex, institution group, specialty group, and funding institute as independent variables, sex was an independent, significant predictor of R01 award attainment

Figure. Actuarial rates of R01 attainment by the K awardees studied, by sex.



At risk, n

Men	1803	1791	1780	1735	1651	1247	882	605	391	233	116
Women	980	979	972	955	929	718	501	346	198	126	60

Table 3. Cox Proportional Hazards Model of R01 Award Attainment

Effect	K08 Award		K23 Award		Combined*	
	Hazard Ratio (95% CI)	P Value	Hazard Ratio (95% CI)	P Value	Hazard Ratio (95% CI)	P Value
Main						
Sex						
Male	1.00		1.00		1.00	
Female	0.79 (0.66–0.95)	0.013	0.75 (0.57–0.99)	0.046	0.79 (0.68–0.92)	0.002
Institution tier						
1	1.20 (0.94–1.55)	0.150	1.36 (0.89–2.06)	0.152	1.23 (0.99–1.52)	0.063
2	1.39 (1.09–1.77)	0.007	1.48 (0.98–2.22)	0.060	1.41 (1.15–1.74)	0.001
3	1.25 (0.97–1.60)	0.086	1.37 (0.91–2.07)	0.132	1.27 (1.03–1.58)	0.026
4	1.00		1.00		1.00	
Specialty						
Medical	1.00		1.00		1.00	
Surgical	2.25 (0.90–5.63)	0.082	0.76 (0.05–12.75)	0.85	1.96 (0.83–4.62)	0.123
Families, women, or children	1.09 (0.46–2.62)	0.84	0.42 (0.06–3.04)	0.39	0.92 (0.42–2.02)	0.83
Hospital-based	2.88 (1.52–5.45)	0.001	1.12 (0.39–3.23)	0.84	2.36 (1.38–4.04)	0.002
Basic science	0.30 (0.09–0.93)	0.037	1.34 (0.14–12.64)	0.80	0.39 (0.14–1.09)	0.072
Unknown or missing	1.39 (0.79–2.45)	0.258	1.00 (0.37–2.70)	1.00	1.32 (0.81–2.15)	0.27
Funding institute tier						
1	1.08 (0.86–1.36)	0.51	0.91 (0.62–1.34)	0.65	1.07 (0.88–1.29)	0.51
2	1.00 (0.80–1.24)	0.97	1.14 (0.84–1.54)	0.41	1.04 (0.87–1.24)	0.67
3	1.00		1.00		1.00	
Year of K award†	0.83 (0.72–0.94)	0.004	0.90 (0.63–1.29)	0.57	0.84 (0.74–0.95)	0.005
Time-dependent‡						
Year of K award by time†	1.03 (1.00–1.07)	0.034	1.02 (0.94–1.12)	0.60	1.03 (1.00–1.06)	0.032
Hospital-based specialty by time	0.80 (0.70–0.91)	0.001	1.03 (0.82–1.30)	0.77	0.85 (0.76–0.95)	0.004

* We stratified baseline hazard by type of K award.

† One-year increase.

‡ We retained time-dependent effects in the combined model and reported them when significant. For consistency, we retained and reported the same effects for the K award-specific models. The time-dependent estimate for year of K award (combined model) suggests that the decrease in the likelihood of attaining an R01 award by the later year of K award attainment diminishes with increasing follow-up time. The time-dependent estimate for hospital-based specialty (combined model) suggests that compared with a medical specialty, the greater likelihood of attaining an R01 award diminishes with increased follow-up time.

(hazard ratio [HR], 0.79 [95% CI, 0.68 to 0.92], $P = 0.002$). A sensitivity analysis performed on a subset of male–female pairs matched on the basis of K award type, K award year, funding institute tier, and institution tier ($n = 1576$) yielded similar results (HR, 0.81 [CI, 0.67 to 0.99]; $P = 0.04$). In a second sensitivity analysis, performed after we limited the population to the 2126 K awardees who held awards from the 12 institutes from which most K awardees were expected to hold MD degrees, sex remained an independent significant correlate of R01 award attainment (HR, 0.76 [95% CI, 0.63 to 0.91]; $P = 0.003$).

DISCUSSION

Our study has 2 main findings. First, fewer than one quarter of K award recipients received R01 funding within 5 years, and fewer than half of those with a decade of follow-up had done so within 10 years. This is a concerning low observed rate of attaining R01 funding, given the high aptitude of these promising young investigators, their commitment toward research careers, and the substantial resources invested by society in supporting their success. Second, and even more concerning, we discovered a significant sex difference: Women were significantly less likely than men to achieve an R01 award. Our findings indicate

a leakage problem in the early pipeline of academic medicine, even among those who clearly desire research careers, and that this problem is more pronounced for women than for men.

The NIH has reported (11) that in the broader population of applicants, women and men have similar success rates in their applications for new R01 grants. However, a recent analysis of NIH data (12) suggests that success rates differ modestly—but significantly—among male and female MDs who apply for R01 grants. We cannot determine whether female K awardees were less likely to succeed in the grant review process. Female K awardees may have been less likely to apply for R01 awards in the first place. For example, our findings are consistent with a scenario in which 80% of female K awardees applied for R01 awards, 100% of male K awardees did so, and the rate of R01 funding did not differ by sex for those who applied. In such a case, our level of concern depends on whether all K awardees had such high potential that they should have reached the point of applying during the follow-up time studied, and whether disproportionately fewer female K awardees applied because they were more likely than male K awardees to choose equally rewarding non-R01 award career trajectories, such as leadership positions or other research endeavors.

It is possible that the observed disparity is rooted to some extent in “sex differences in career and life goals” (13). Some researchers have shown that sex differences in aspirations among medical faculty are minimal (14), but others have suggested that women physicians may be less likely to value leadership and scholarship than men (15). Some experts speculate that women may tend to define success in particular ways (16) or have different career priorities from men, with women preferring patient care or teaching over research or favoring a different balance between work and other activities (such as caring for family). No study can completely control for the effects of potential systematic differences in such preferences, but by focusing on a group of highly accomplished researchers, we aimed to reduce the effects of such differences in our study. Therefore, we believe that it is also important to consider the possibility that female K award recipients might be receiving less support to progress toward independent research careers.

One contributing factor may be that women’s K awards are on average smaller than those of their male peers, and thus women may be at a disadvantage from the outset. Throughout the past 15 years, female grant recipients have received on average approximately 80 cents for each dollar received by male grant recipients (11, 17)—the average of career awards to women in 2007 was \$145 795, whereas the average of career awards to men in 2007 was \$165 081 (11). Of note, the inverse trend is apparent in recent R01 funding—the average of R01 grants to women in 2007 was \$371 142, compared with \$360 291 for men (11). Thus, focusing attention on the causes of leakage in the early pipeline seems appropriate.

K awards are designed to provide both protected time and mentoring to support the research career development of recipients. However, qualitative evidence collected by the NIH (18) suggests that the financial support offered by K awards may sometimes be insufficient to protect three quarters of the recipient’s working time, as these awards are generally intended to do. Some recipients may face pressure to allocate substantial time to clinical activities. To the extent that women receive smaller awards, protecting time for research may be particularly problematic for them.

The sex disparities in our findings may in turn reflect a woman’s increased vulnerability to encroachment on protected research time. Beyond the fact that women seem to receive smaller awards than men, several other hypotheses are also important to consider. As reported by the National Academies of Science, “A substantial body of evidence establishes that most people—men and women—hold implicit [sex] biases” (19). To the extent that subconscious biases lead us to consider women as team players rather than leaders, pressure to contribute to the clinical workload of a department may be focused disproportionately on women. And, to the extent that women may be less successful in negotiations with their department chairs (20), they may be less able to obtain adequate protected working

time to accomplish their research goals. Finally, because women face biological constraints of fertility and challenging societal expectations regarding the distribution of domestic responsibilities, they may also be less able to compensate for inadequate protected research time by performing their research work on nights and weekends. Further research is needed to determine whether these hypotheses are true. If so, interventions should be considered to ensure the success of a greater proportion of all K awardees, and women in particular, such as increasing the amount of funding support per K award in conjunction with increased monitoring of institutional expectations regarding the nonresearch duties of K award recipients.

The quality of the mentoring relationships of K award recipients also merits further investigation and targeted support. Mentoring is essential to the success of junior investigators in general and may be particularly important for female junior investigators (21–24). Mentoring has long been heralded as a mechanism by which to combat sex disparities in the professions. Some studies have suggested that the quality of mentoring received by women may be inferior to that received by men (15, 25), but others have found no differences (26, 27). K awards require recipients to receive designated mentorship. The low rate of R01 award attainment demonstrated in our study raises important concerns about the quality of mentoring within the K award program and whether mentors are prepared to deal with the special challenges female award recipients face.

Our study has limitations. First, receipt of an R01 award is not the only measure of success for K award recipients. Some K award recipients may build successful independent research careers with the support of private foundation grants or industry, serve as principal investigators of projects supported by other types of NIH awards, or move rapidly to administrative or other leadership positions in their institutions. However, because the R01 award is the most common grant awarded by the NIH, receipt of one seems to be an important milestone in a physician-scientist’s career. Second, we may have misclassified some recipients with our method for sex determination. However, random misclassifications would only serve to obscure the differences between conversion rates between men and women. Similarly, our method of verifying that a woman continued to use the same name as when she received her K award may have led to some errors. For example, some Web directories may not have been up to date and may have shown women listed with their maiden name when they had in fact changed their surname. Third, although we report the detailed findings for each award-year cohort in **Table 1**, the sample sizes in these individual groups are too small to permit meaningful interpretation of small fluctuations in differences at this level of detail. Fourth, we did not have access to individual award amounts, so we cannot comment definitively on whether

differences in award amounts contribute to the observed sex differences in R01 award attainment.

Finally, it is possible that our follow-up period was too short, and many more K awardees will receive R01 funding in future years. Women, in particular, may have a longer time course to receiving an R01 award, given the exigencies they face with regard to childbearing. However, given the shape of the actuarial curves in the **Figure**, which seem to be flattening without any indication of convergence at the tail, we suspect that the sex differences we observed will persist even with further follow-up. In any case, the duration of follow-up in our study spans the period in which most medical schools require research faculty to apply for tenure. If women would eventually catch up to men because of some of the factors we describe, the up-or-out tenure system may stand in the way.

In conclusion, fewer than half of the K08 and K23 award recipients we studied achieved an R01 award by 2007, and we found a significant disparity between male and female K award recipients. Increasing attention has been devoted in recent years to the physician-scientist pipeline (28–30) and concerns that the NIH funding process may not adequately support clinical research (31, 32). The Association of Professors of Medicine's Physician-Scientist Initiative recommended that "institutions should proactively promote the advancement and minimize the attrition of women in physician-scientist careers" (33). Our study suggests that such attention and concern is merited. Success of career development award recipients, who have a demonstrated aptitude and commitment to research and in whom considerable societal resources have been invested, is critical evidence of whether the physician-scientist pipeline is functioning adequately. Our finding of sex disparities in the advancement of this highly selected group is particularly concerning. Further investigation and interventions are warranted to better address the challenges faced by junior academic investigators, both men and women.

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APPENDIX: METHODS OF INTERNET SEARCHING FOR EVIDENCE OF NEW INSTITUTIONAL AFFILIATION OR SURNAME CHANGE AMONG FEMALE K AWARDEES

As noted in the Methods section, we scrutinized all female K08 and K23 recipients whose names did not appear on the lists of R01 award recipients to account for female surname change due to marriage or divorce. If a woman's full name did not appear in the current online directory of the institution listed in her K award application, we used Google to search the Internet for evidence of a new institutional affiliation or name change.

If our search of the name revealed a new institutional affiliation, we confirmed identity by using the recipient's middle name, education and work history, research area, and picture (if available); we then confirmed the current appointment at this institution by using the same methods of directory or institutional Web page searching described in the Methods section. In some cases, our searches returned evidence of current location in private practice, government, or industry. We confirmed these appointments by using the criteria already described, and verified that individual Web pages were navigable from the main organizational Web page.

When neither of these 2 approaches confirmed continued use of the same name, we entered the NIH grant number as a search term in Google. If the results included a link to an institutional Web page or curriculum vita for a woman with the same first name but different last name (a completely different last name or a shortened, extended, or hyphenated version of the maiden name); the linked file listed the K award as a source of funding on which the woman was the principal investigator; and we found no inconsistencies among the middle initial, medical education, department, and subject area, we considered this sufficient evidence that the K awardee of interest had changed her

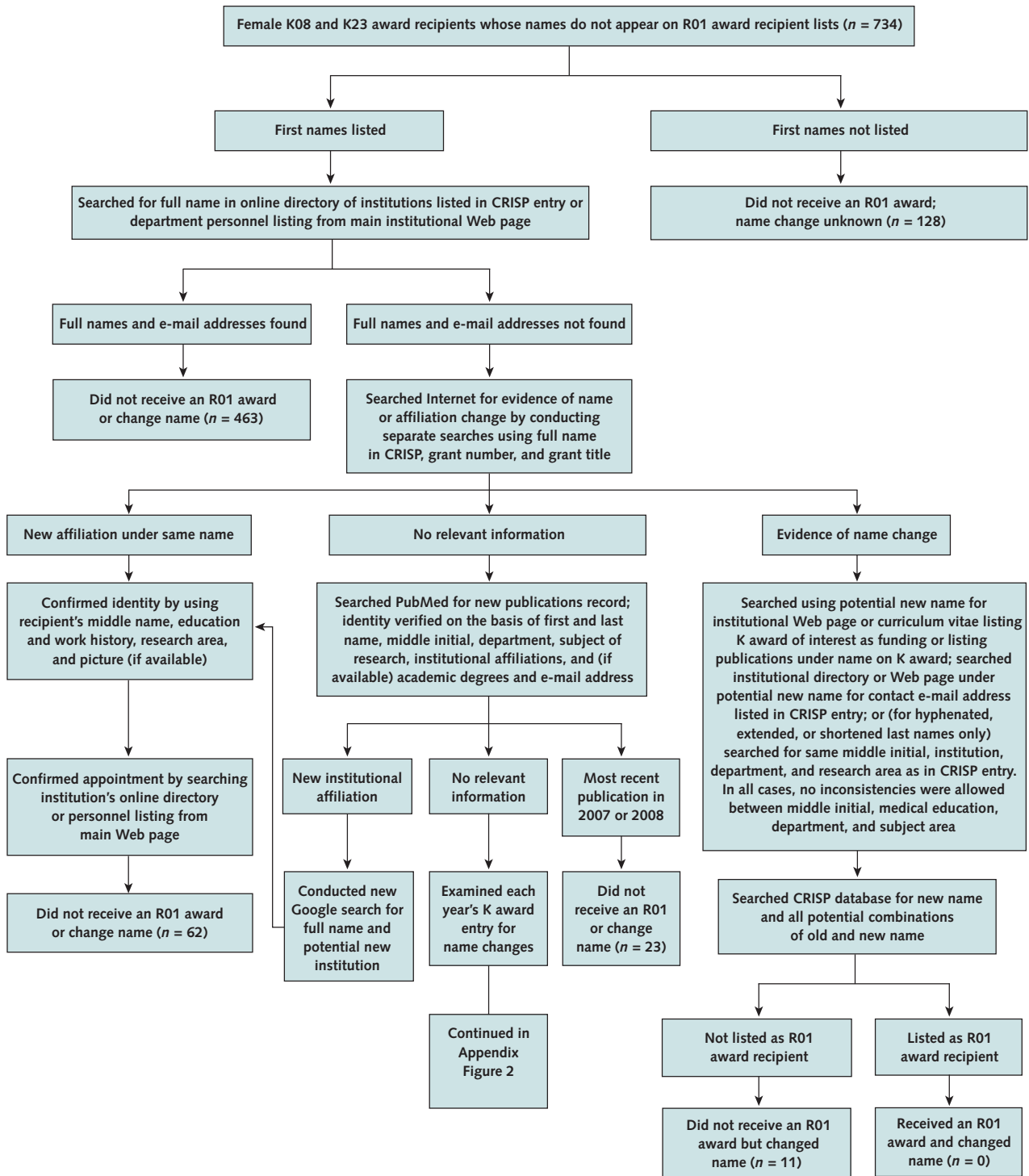
name. If no such results were returned from a search for the NIH grant number, we applied the same technique to a search for the title of the grant (enclosed in quotation marks to limit the search results).

We also looked for other potential evidence of a name change in the results of an Internet search for the K award recipient's name, provided that that name was sufficiently unusual. For example, if a search for "Reshma Jagsi" returned results for "Reshma Jagsi-Pottow," "Reshma Jagsi Pottow," or "Reshma Pottow" (the last case occurring when Web pages contained information that used both the woman's current name and her maiden name, such as a listing of previous publications), we investigated these results by further Internet searching. We considered the evidence to be sufficient that the K award name and the name returned in the Internet search belonged to the same person if we found an institutional Web page or curriculum vita under the new name that listed the specific K award of interest as a source of funding or listed publications under the name on the K award; an institutional directory or Web page under the new name that showed the contact e-mail address to be the same as the address listed on the K award CRISP entry; or (if the last name was hyphenated, extended, or shortened) a result with the same middle initial, institution, department, and research area as listed on the K award CRISP entry. In all cases, we allowed no inconsistencies in middle initial (either the previous middle initial or first letter of the previous last name), medical education, department, or subject area.

When none of these methods of Internet searching yielded conclusive information, we used PubMed to access the recipient's publication record. We identified her most recent publication (on the basis of first and last name, middle initial, department, subject of research, authors' institutional affiliations, and—if available—academic degrees and e-mail address); if the most recent publication occurred in 2007 or 2008, we considered this sufficient evidence that she was still using the same name as that under which she received her K award. If a different institutional affiliation was the sole discrepancy, we used the same methods of directory or institutional Web page searching described in the Methods section to confirm that the recipient was still using the same name and had simply changed institutions.

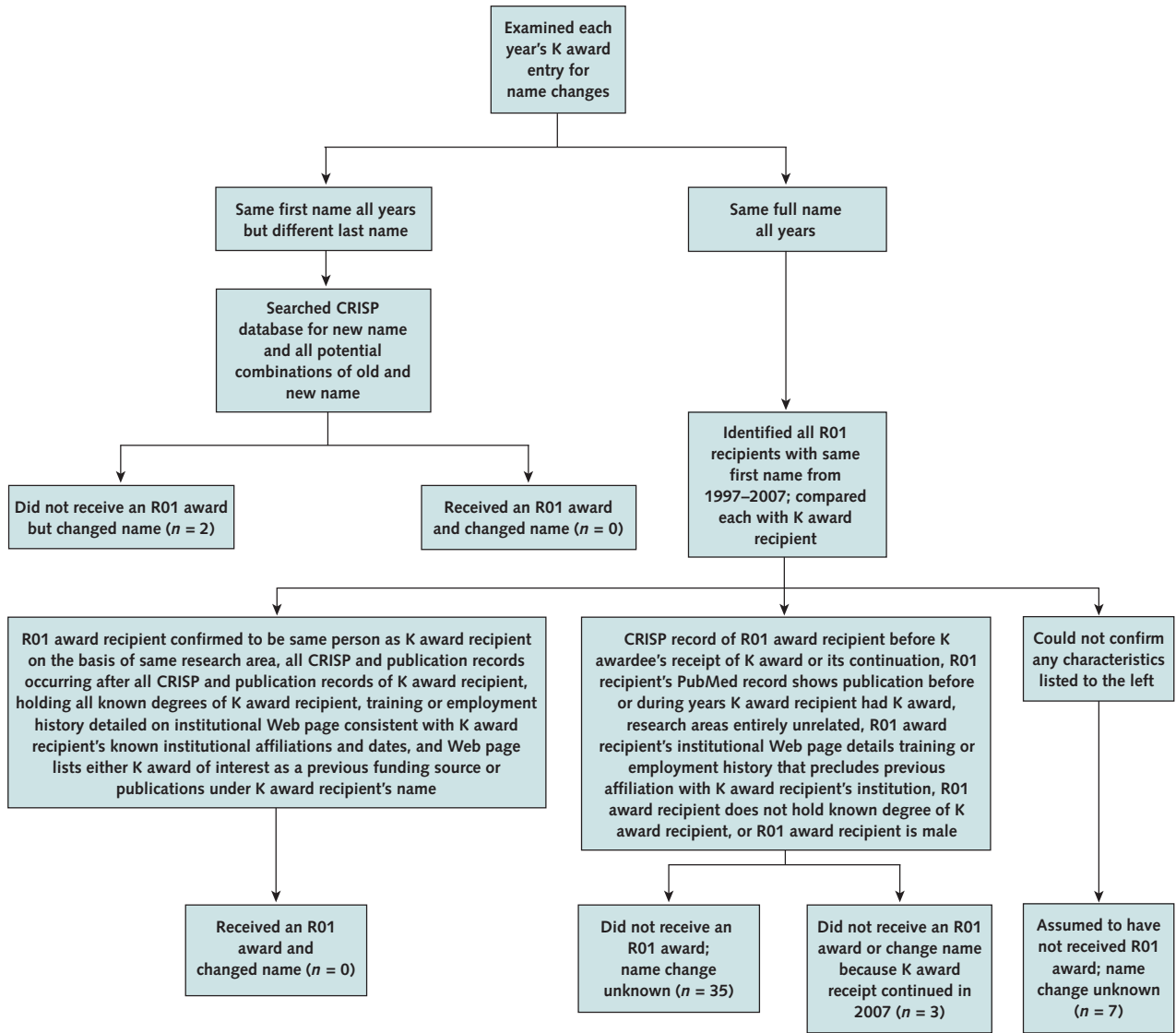
If we could not confirm the continued use of the name or name change with these methods, we made additional queries for any evidence of name change. We used the CRISP database to identify the entries for each year of the K08 or K23 award, and checked the name on each year of the grant for changes. If the principal investigator's first name remained the same but her surname changed in the CRISP entry in 1 or more of the later years of the award, we considered this to be conclusive evidence that the recipient had changed her name. Finally, if none of these mechanisms definitively indicated use of the original name or occurrence of a name change, we identified all R01 awardees with the same first name as the K awardee and individually compared them by using additional Internet searches to determine whether they could be the same person. **Appendix Figures 1 and 2** detail our search strategy.

Appendix Figure 1. Flow diagram of method of searching for new institutional affiliation or surname change among female recipients of K awards, part 1.



CRISP = Computer Retrieval of Information on Scientific Projects.

Appendix Figure 2. Flow diagram of method of searching for new institutional affiliation or surname change among female recipients of K awards, part 2.



CRISP = Computer Retrieval of Information on Scientific Projects.