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Research Productivity of Graduates from 3 Physician-Scientist Training Programs

Liselotte N. Dyrbye, MD, Keith D. Lindor, MD, Nicholas F. LaRusso, MD, David A. Cook, MD, MHPE
Department of Medicine, Mayo Clinic College of Medicine, Rochester, Minn.

Physician-scientists—physicians who spend the majority of their time conducting medical research—are essential to ongoing biomedical advances.[1-3] Yet despite decades of concerns, the number of physician-scientists continues to decrease.[4] In response to this trend, the National Institutes of Health (NIH), non-profit organizations, and medical schools have developed research training pathways to facilitate the development of physician-scientists.[5] Such pathways include MD-PhD programs, institutionally funded combined residency-fellowship programs that allot substantial time for mentored research (eg, the American Board of Internal Medicine Research Pathway[6]), and postgraduate research training programs during fellowship at medical schools and teaching hospitals.

Training physician-scientists incurs substantial personal, institutional, and national expense. Physicians starting their investigative careers via one of these pathways typically invest in 2 to 3 additional years of training. The National Research Service Award (NRSA) has invested nearly $600 million in grants[7] to support predoctoral (ie, the Medical Scientist Training Program) and postdoctoral training programs (ie, institutional training grants [T32] or, less commonly, individual postdoctoral fellowships [F32]). Medical schools and teaching hospitals invest additional resources to maintain such programs because the provided funds do not match expenditures.[5]

Understanding the outcomes of each training pathway will help individuals, institutions, and funding agencies channel resources to use and support programs likely to produce desired results. Yet, little is known about the outcomes of these programs. MD-PhD graduates often have productive research careers,[3,8,9] but it is difficult to ascertain how much of their success can be attributed to their predoctoral research training.[10] Limited research has investigated the academic productivity of physicians supported by NRSA institutional training grants during postgraduate research training.[11-14] We found no information about the academic productivity of graduates of combined residency-fellowship research training programs.

In this study, we sought to compare the MD-PhD, the research-oriented combined residency-fellowship, and the NRSA institutional training grant programs using outcomes of grants and publications.

METHODS

Training Programs

The Mayo Clinic College of Medicine offers 3 programs for the development of physician-scientists. In the MD-PhD program, students typically begin their research training after the second year of medical school. After completing a PhD thesis, students finish their medical training. The clinician investigator (CI) training program is a research-oriented combined residency-fellowship program. During the period of this study, physicians in training applied during their first year of residency or, less often, during the National

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Requests for reprints should be addressed to David A. Cook, MD, MHPE, Division of General Internal Medicine, Mayo Clinic College of Medicine, Baldwin 4A, Mayo Clinic, 200 First Street SW, Rochester, MN 55905.

E-mail address: cook.david33@mayo.edu

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Resident Match Program. Following an abbreviated residency period, accepted individuals complete a subspecialty fellowship that includes 2 years of mentored research, formal training in clinical and basic research, clinical training, and completion of a research project. The NRSA-T32 program provides stipend support for subspecialty fellows (US citizen or permanent residents only) to pursue 1-2 years of mentored research. The program relies on research mentorship, with didactic and other organizational components varying for each grant.

PERSPECTIVES VIEWPOINTS

- Physician-scientists can complete their education through several pathways: MD-PhD programs, institutionally funded combined residency-fellowship programs, and postgraduate research training programs such as those funded by National Research Service Awards.
- Greater productivity of physician-scientists can result from those programs that identify potential candidates early on, such as clinician investigator and MD-PhD programs.

Study Design and Participants

We conducted a retrospective cohort study of graduates from these research training programs. All MD-PhD graduates of the Mayo Clinic College of Medicine between 1988 and 2000 were eligible within the MD-PhD cohort. We excluded MD-PhD graduates who were still in postgraduate training. Students who obtained a PhD before enrolling in medical school were not included in this group, but could qualify for study inclusion through participation in one of the other training programs. Graduates of the Mayo CI program who finished residency between 1990 and 2000 and recipients of NRSA-T32 institutional research training grants who completed their fellowship training at Mayo between 1990 and 2000 were eligible within the corresponding cohort. The earlier inclusion date for MD-PhDs was selected to offset the time these graduates spent in postgraduate training. One CI graduate who subsequently received an NRSA-T32 grant was counted with the CI cohort. No other graduates met criteria for more than one group.

Outcomes and Data Collection

Primary outcomes for this study were number of grants, time to first grant, and number of publications. Secondary outcomes were the *h*-index of publication impact,[15] academic employment, and academic rank.

We used institutional databases to obtain demographic information on all eligible participants. We requested curricula vitae (CVs) from all eligible participants; provision of a CV constituted consent to include CV data in this study. We also included information from CVs found on Internet searches. From each CV we abstracted the number of publications, number and date of grants (NIH and non-NIH grants counted separately), role in each grant (primary or co-investigator), current employment (academic or non-academic), current academic rank (senior [associate or full professor] or junior rank), and research training in addition to the MD-PhD, CI, or NRSA-T32 program.

We also quantified publications and NIH grants using objective data ("confirmed" publications and NIH grants). We identified confirmed NIH grants by searching the federal Computer Retrieval of Information on Scientific Projects (CRISP) database. We determined confirmed publications by searching MEDLINE for each graduate's name and attributed publications to the graduate if at least one of the following criteria was met: the institutional affiliation matched the graduate's institution, the publication was listed on the graduate's CV, or the subject matter matched the graduate's specialty. We obtained the current *h*-index for each graduate using the Information Sciences Institute Web of Knowledge, which includes articles published after 1992.

The end date for inclusion of grants and publications was December 31, 2005. The Mayo Institutional Review Board approved this study.

Data Analysis

We used the Kruskal-Wallis test, followed by post hoc Wilcoxon rank sum tests as needed to compare the number of publications, the number of grants, and the *h*-index between groups. We used chi-squared or Fisher's exact test to compare the receipt of any grant, current academic position, and current academic rank between groups. Because nonparametric tests do not permit multivariate analysis, we used general linear models to compare the ranked number of publications, ranked number of grants, and ranked *h*-index between groups while simultaneously adjusting for time since medical school graduation. Similarly, we used logistic regression to compare academic rank between groups while adjusting for time since graduation.

We employed Kaplan-Meier survival curves and the Wilcoxon test to compare the time to first grant as a primary investigator between the 3 training groups. We used Cox proportional hazards models to investigate the influence of variables of interest on this model. The main analysis used the entire cohort looking at grants from any source; sub-analyses looked at grants from any source among the CVs that were available and only confirmed NIH grants. All analyses were conducted using SAS 9.1 (SAS Institute Inc., Cary, NC) and a 2-sided alpha of 0.05.

RESULTS

During the study period, 32 medical students graduated from the MD-PhD program and completed postgraduate training, 64 residents and fellows completed the CI program, and 78 fellows completed training under the NRSA-T32 program. Of these 174, 26 (15%) were women. CVs were available for 134 physicians (77%): 28 MD-PhD (88%), 57 CI (89%), and 49 NRSA-T32 (63%). Academic employment was similar across training programs (*P* = .10). Mean ± SD follow-up time from medical school graduation was 16.1 ± 5.0 years and from completion of residency/fellowship training was 7.2 ± 4.2 years. Ten physicians pursued additional research training: one MD-PhD received an NRSA fellowship grant (at another institution); one CI graduate received a master's degree between MD graduation and CI training; and 8 completed research fellowships (3 before and 5 after their research training at Mayo). Table 1 describes additional demographics.

Number of Grants and Time to First Grant

Using CRISP, we confirmed that 39 (22%) physicians had received 94 NIH grants as primary investigators. We found no significant difference between training programs in the proportion of graduates with confirmed NIH grants (*P* = .12; Table 2). Similar results were found for self-reported NIH grants. The number of NIH grants per physician did not differ between programs for either confirmed (*P* = .13) or self-reported (*P* = .10) NIH grants.

According to CVs, graduates had collectively received 289 non-NIH grants, including 13 non-NIH government grants (eg, military, state agencies), 140 industry grants, and 136 grants from other sources (eg, philanthropy, professional associations). Considering all grants regardless of funding source (either confirmed or from CV), more CI graduates (67%) had obtained at least one grant as a primary investigator than MD-PhD (38%, *P* = .006) or NRSA-T32 (41%, *P* = .002) graduates (*P* <.001 for overall comparison). MD-PhD and NRSA-T32 graduates were similar (*P* = 0.73). The number of grants also varied by group (*P* = .022), with CI physicians receiving more grants from any source than either NRSA-T32 (*P* = .039) or MD-PhD (*P* = .012) physicians. Again, NRSA-T32 and MD-PhD graduates were not significantly different (*P* = .39). Adjustment for time since medical school graduation demonstrated similar findings.

Table 1 Graduate Demographics

	Total n = 174	MD-PhD n = 32	CI n = 64	NRSA n = 78	*P* Value*
Current age (years), mean ± SD	42.7 ± 4.7	40.0 ± 3.6	42.6 ± 4.7	43.8 ± 4.7	<.001
Years since MD graduation, mean ± SD	16.1 ± 5.0	10.6 ± 3.6	16.8 ± 4.0	17.8 ± 4.7	<.001
Years since residency/fellowship training,† mean ± SD	7.2 ± 4.2	4.4 ± 3.5	7.5 ± 4.3	8.4 ± 3.8	<.001
Male sex, n (%)	148 (85)	27 (84)	58 (91)	63 (81)	.26
Academic rank‡					.021
Senior, n (%)	44 (39)	3 (15)	24 (51)	17 (38)	
Junior, n (%)	68 (61)	17 (85)	23 (49)	28 (62)	
Current practice type§					.10
Academic, n (%)	110 (67)	18 (60)	48 (77)	44 (62)	
Non-academic, n (%)	53 (33)	12 (40)	14 (23)	27 (38)	
PhD degree, n (%)	51 (29)	32 (100)	10 (16)	9 (12)	<.001
Residency					<.001
Anesthesiology, n (%)	16 (9)	2 (6)	2 (3)	12 (15)	
Internal medicine, n (%)	100 (57)	6 (19)	45 (70)	49 (63)	
Other clinical specialties,¶ n (%)	27 (16)	14 (44)	7 (11)	6 (8)	
Pathology, n (%)	7 (4)	7 (22)	0	0	
Surgery and surgical specialty,□ n (%)	21 (12)	1 (3)	10 (16)	10 (13)	
Unknown, n (%)	3 (2)	2 (6)	0	1 (1)	
Additional research training,** n (%)	10 (6)	5 (16)	4 (6)	1 (1)	.013

CI = clinician investigator; NRSA = National Research Service Award.

**P* value represents comparison across MD-PhD, CI, and NRSA; see text for selected pairwise comparisons.

†Data available for 131 graduates.

‡Data available for 114 graduates; junior ranks were assistant professor, instructor, or no rank; senior rank were associate or full professor.

§Data available for 163 graduates.

¶Other clinical specialties were: Dermatology (n = 2), Emergency Medicine (n = 2), Neurology (n = 4), Pediatrics (n = 9), Physical Medicine (n = 2), Obstetrics/Gynecology (n = 1), Psychiatry (n = 1), and Radiation Oncology (n = 6).

□Surgical specialties were: Neurosurgery (n = 1), Otorhinolaryngology (n = 1), Orthopedics (n = 3), and Urology (n = 2).

**Additional research training defined as further research training beyond the program indicated.

Table 2 Grants Following Research Training

	Total	MD-PhD	CI	NRSA	*P* Value*
Physicians with a grant as PI					
Grant any source, n = 174; n (%)	87 (50)	12 (38)	43 (67)	32 (41)	<.001
Confirmed NIH grant, n = 174; n (%)	39 (22)	10 (31)	17 (27)	12 (15)	.12
Self-reported NIH grant, n = 134; n (%)	35 (26)	5 (18)	19 (33)	11 (22)	.24
Self-reported non-NIH grant, n = 134; n (%)	67 (50)	6 (21)	38 (67)	23 (47)	<.001
Number of grants					
Grant any source, n = 174; mean ± SD (median)	3.3 ± 5.1 (0)	1.5 ± 2.6 (0)	4.9 ± 6.3 (2)	2.7 ± 4.6 (0)	.022
Confirmed NIH grant, n = 174; mean ± SD (median)	0.5 ± 1.3 (0)	0.5 ± 0.9 (0)	0.8 ± 1.6 (0)	0.4 ± 1.2 (0)	.13
Self-reported NIH grant, n = 134; mean ± SD (median)	0.6 ± 1.3 (0)	0.3 ± 0.7 (0)	0.8 ± 1.6 (0)	0.4 ± 1.0 (0)	.10
Self-reported non-NIH grant, n = 134; mean ± SD (median)	2.2 ± 3.4 (1)	0.5 ± 1.2 (0)	2.9 ± 3.2 (2)	2.2 ± 4.0 (1)	<.001
Years until first grant as PI†					
Grant any source, n = 174; mean ± SD (median)	9.4 ± 4.2 (9)	6.7 ± 2.9 (6.5)	10.3 ± 4.5 (10)	9.3 ± 3.9 (9)	‡
Confirmed NIH grant, n = 174; mean ± SD (median)	10.4 ± 4.4 (10)	6.5 ± 1.7 (6.5)	12.0 ± 4.7 (11)	11.5 ± 3.8 (11)	‡
Self-reported NIH grant, n = 134; mean ± SD (median)	10.9 ± 4.1 (11)	6.0 ± 1.4 (7)	12.1 ± 4.3 (11)	10.9 ± 2.7 (11)	‡
Self-reported non-NIH grant, n = 134; mean ± SD (median)	10.9 ± 4.9 (11)	11.3 ± 5.4 (12.5)	11.5 ± 4.4 (11.5)	9.8 ± 5.5 (10)	‡

CI = clinician investigator; NRSA = National Research Service Award; PI = primary investigator; NIH = National Institutes of Health; CRISP = Computer Retrieval of Information on Scientific Projects.

Confirmed grants were identified from CRISP database; self-reported grants were identified from graduates' curricula vitae. "Grant any source" is either confirmed from CRISP or self-reported.

**P* value represents comparison across MD-PhD, CI, and NRSA; see text for selected pairwise comparisons.

†Years from graduating medical school to first grant as primary investigator. Averages reflect only those who received at least one grant.

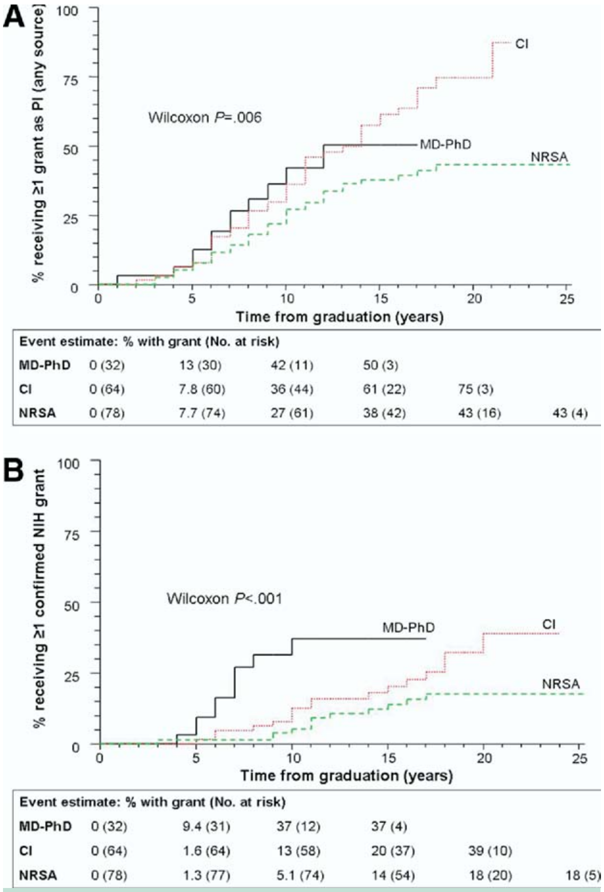
‡See survival curve analyses for comparisons across groups.

Among graduates receiving a grant (any source), the mean interval from medical school graduation to first grant was 6.7 ± 2.9, 10.3 ± 4.5, and 9.3 ± 3.9 years for graduates in the MD-PhD, CI, and NRSA-T32 programs, respectively. The interval from medical school graduation to first confirmed NIH grant (among the 39 who received them) was 6.5 ± 1.7, 12.0 ± 4.7, and 11.5 ± 3.8 years for graduates in the MD-PhD, CI, and NRSA-T32 programs, respectively. The Figure (panel A) shows the survival curve for time to first grant (any source). CI graduates obtained their first grant sooner than NRSA-T32 graduates (hazard ratio 0.49, 95% confidence interval [95% CI], 0.31-0.78, *P* = .003), while the time to first grant was similar between MD-PhD and CI and between MD-PhD and NRSA-T32 graduates. Academic employment was associated with time to first grant (hazard ratio 6.98, 95% CI, 3.33-14.61 compared with non-academic employment, *P* <.001) whereas sex and possession of a PhD were not (*P* >.23). When we repeated the analysis of time to first grant including only graduates with available CVs, we found no differences between training groups (*P* >.11; see Table 3). However, in another analysis using only confirmed NIH grants as the outcome (Figure, panel B), we found that MD-PhD graduates obtained their first grant sooner than either CI or NRSA-T32 graduates (*P* = .016 for CI vs. MD-PhD; *P* <.001 for MD-PhD vs. NRSA), while the difference between CI and NRSA-T32 graduates approached but did not reach statistical significance (*P* = .085).

Publication Productivity and Academic Rank

As shown in Table 4, CI physicians had more MEDLINE-confirmed publications (mean 26.5 ± 24.5) than either NRSA-T32 (17.9 ± 26.3, *P* = .003) or MD-PhD (18.2 ± 20.1, *P* = .03) physicians (*P* = .009 overall). After adjustment for time since medical school graduation, the overall model remained significant (*P* = .007) and the adjusted publications for CI graduates remained higher than those for NRSA-T32 graduates (*P* = .001), but MD-PhD graduates were not significantly different from either of the other groups (*P* ≥.13).

The *h*-index estimates the scientific impact of a researcher's publications.[15] A researcher with an index



Event estimate: % with grant (No. at risk)

MD-PhD	0 (32)	13 (30)	42 (11)	50 (3)		
CI	0 (64)	7.8 (60)	36 (44)	61 (22)	75 (3)	
NRSA	0 (78)	7.7 (74)	27 (61)	38 (42)	43 (16)	43 (4)

Event estimate: % with grant (No. at risk)

MD-PhD	0 (32)	9.4 (31)	37 (12)	37 (4)		
CI	0 (64)	1.6 (64)	13 (58)	20 (37)	39 (10)	
NRSA	0 (78)	1.3 (77)	5.1 (74)	14 (54)	18 (20)	18 (5)

Figure Kaplan-Meier analysis of time from medical school graduation to first grant as primary investigator. (A) Panel A shows a significant difference between groups in the time to first grant (any source) (n = 174). Pairwise analyses further found that clinician-investigator (CI) graduates received their first grant (any source) sooner than National Research Service Award institutional training grant (NRSA) graduates (see Table 3). (B) Panel B shows this analysis repeated to include only confirmed National Institutes of Health (NIH) grants (n = 174), and again there are significant differences between groups. Pairwise analyses found that MD-PhD graduates received their first NIH grant sooner than either CI or NRSA graduates (see Table 3).

of *h* has published *h* papers, each of which as been cited at least *h* times. Both before and after adjusting for time since medical school graduation, CI graduates had a higher *h*-index than NRSA-T32 graduates (adjusted $P = .003$), whereas MD-PhD graduates were similar to both CI ($P = .24$) and NRSA-T32 ($P = .37$) graduates.

Three of 20 (15%) MD-PhD graduates had senior academic rank, compared with 24 of 47 CI (51%, $P = .006$) and 17 of 45 NRSA-T32 graduates (38%; $P = .066$ compared with MD-PhD, $P = .20$ compared with CI). However, after adjusting for time since medical school graduation using logistic regression, these differences were no longer significant (odds ratio for CI vs MD-PhD, 2.1 [95% CI, 0.4-10.2], $P = .36$; CI vs NRSA-T32, 1.9 [0.8-4.6], $P = .15$; MD-PhD vs NRSA-T32, 0.6 [0.1-3.1], $P = .56$).

DISCUSSION

This study compared 3 research training programs: dual-degree MD-PhD, combined residency-fellowship research (CI) track, and NRSA-T32 fellowship training grants. We found that regardless of the research training program, the majority of graduates (≥56%) hold academic positions and rank, suggesting that they remain research-oriented. The proportion of graduates with NIH grants and mean number of NIH grants were similar between groups. However, CI graduates more often had at least one grant from any source, more grants and publications, and earlier success in obtaining research funding than NRSA-T32 graduates. CI graduates also were more likely than MD-PhD graduates to have a grant and had more grants, but time to first grant (any type) and number of publications were similar, and time to first NIH grant was shorter for MD-PhD graduates. In contrast, MD-PhD and NRSA-T32 graduates were similar in nearly all productivity measures. In summary, the productivity of graduates from CI and MD-PhD training programs appears similar, and CI graduates may be slightly more productive than NRSA-T32 graduates.

Comparison with prior literature is limited by differences between studies in duration of follow-up, outcome measures, funding opportunities, and publication venues. Nonetheless, the academic productivity of MD-PhD graduates in our study appears similar to that of a national sample from 1986-1990.[8] Previous studies of NRSA-T32 recipients reported that 22%-47% of physicians have NIH funding,[11-13] which exceeds what we found. However, our graduates had, on average, more publications than the median of 12 per graduate reported in a previous study.[11] Our NRSA-T32 graduates obtained their first grant at about the same time as previously described cohorts (6-7 years from training completion to first NIH grant) if we assume about 6 years for specialty training.[11] We found no reports describing research productivity of combined residency-fellowship research tracks.

These training programs begin at different stages in the continuum of physician-scientist development, and serve somewhat different needs. The differences in academic productivity observed in this study are likely due to both program differences and differences in physicians in training at the time of program entry. Application to both the MD-PhD and CI programs occurs relatively early and most applicants have research experience. In contrast, institutional NRSA-T32 training grants begin during fellowship, and trainees thus gain their research experience near the end of training. This distinction may disadvantage them[16] rel-

Table 3 Hazard Ratios for Time from Medical School Graduation to First Grant as Primary Investigator

Training Programs	Hazard Ratio (95% Confidence Interval), *P* Value Any Grant, Entire Cohort (n = 174)	Any Grant, Curricula Vitae Available (n = 134)	Confirmed NIH Grant (n = 39)
CI* vs MD-PhD	0.91 (0.48, 1.78), *P* = .78	0.54 (0.25, 1.16), *P* = .11	2.71 (1.20, 6.10), *P* = .016
CI* vs NRSA	0.49 (0.31, 0.78), *P* = .003	0.69 (0.43, 1.12), *P* = .13	0.52 (0.25, 1.09), *P* = .085
MD-PhD* vs NRSA	0.54 (0.27, 1.06), *P* = .075	1.27 (0.58, 2.82), *P* = .55	0.19 (0.08, 0.46), *P* <.001

NIH = National Institutes of Health; CI = clinician investigator; NRSA = National Research Service Award.

*Reference program (ratio <1 indicates earlier grant for reference program).

ative to individuals who pursue research training earlier (ie, MD-PhD or CI). Unfortunately, the influence of participant selection versus program differences could not be isolated in this study.

Because programs that identify learners earlier appear to produce more academically productive physician-scientists, students who identify a strong research interest at an early stage should consider MD-PhD or combined residency-fellowship programs. However, individuals whose research interests develop later or are unable to participate in these programs can still expect a productive academic career following NRSA-T32 training. Indeed, given the lesser investment of time and other resources, such training may be a cost-effective alternative. Furthermore, participation in one program need not preclude training in another.

Our findings have implications for funding organizations. Clinical revenue and philanthropy provide all funding for the CI program and substantial support for the MD-PhD and NRSA-T32 programs. As clinical revenues decrease, continued support for such programs may be in jeopardy. The US government has not, to date, funded combined residency-fellowship research training programs, but such support may be needed and justified given the academic productivity of CI graduates. Simultaneously, we caution that withdrawal of federal support for MD-PhD and NRSA programs would only worsen the already precarious physician-scientist pipeline.[3,4]

Our study has limitations. First, the generalizability of these results beyond our institution is unknown. However, the MD-PhD productivity outcomes and the time to first grant for NRSA-T32 graduates are similar to previous research.[8] Second, the retrospective study design limits our ability to determine causality or separate the effects of program interventions from learner

Table 4 Publication Productivity Following Research Training

	Total n = 174	MD-PhD n = 32	CI n = 64	NRSA n = 78	*P* Value*
Confirmed publications					
Author any position, mean ± SD (median)	21.1 ± 24.8 (13.5)	18.2 ± 20.1 (13.5)	26.5 ± 24.5 (22)	17.9 ± 26.3 (10)	.009
Author any position, adjusted,† mean	—	24.1	25.7	16.1	.007
First author, mean ± SD (median)	7.9 ± 7.7 (5)	7.2 ± 6.3 (6)	9.7 ± 7.8 (8)	6.7 ± 8.0 (5)	.043
First author, adjusted,† mean	—	8.3	9.5	6.4	.042
Self-reported publications					
Author any position, mean ± SD (median)	25.4 ± 24.9 (20)	19.4 ± 18.2 (17.5)	30.2 ± 23.7 (25)	23.3 ± 28.7 (18)	.017
Author any position, adjusted,† mean	—	25.4	28.7	21.5	.013
First author, mean ± SD (median)	9.1 ± 6.3 (8)	7.8 ± 4.7 (7)	11.0 ± 7.2 (12)	7.6 ± 5.3 (6)	.026
First author, adjusted,† mean	—	8.6	10.8	7.3	.025
h-index					
h-index, mean ± SD (median)	8.1 ± 6.6 (6.5)	7.5 ± 6.2 (6)	9.8 ± 6.8 (9)	6.9 ± 6.4 (5)	.013
h-index, adjusted,† mean	—	7.5	9.8	6.8	.013

Confirmed publications were identified from the MEDLINE database; self-reported publications were identified from graduates' curricula vitae.

**P* values represent comparison across MD-PhD, CI, and NRSA; see text for pairwise comparisons.

†Means following adjustment for years since medical school graduation; SD not available.

selection. Third, fewer CVs were available for NRSA-T32 graduates. This group is thus underrepresented in analyses of grants that include the entire cohort. The analyses confined to confirmed grants avoid response bias, but are limited by few events. Finally, the type of research conducted by graduates may vary between programs, and opportunities for funding and dissemination may vary by research focus. However, we relied on grants, publications, and academic rank, which are the typical means for evaluating research training outcomes.

Our study has several strengths. First, we compared research training programs in the same institution, thus controlling for organization characteristics that may influence the development of successful researchers.[17] Second, we confirmed most outcomes through independent sources. Third, this is the first study, to our knowledge, to report the research productivity of graduates of a combined residency-fellowship research training program.

Clarifying the optimal development pathway for physician-scientists will require further research. In addition to confirming our findings, such research could explore specific program characteristics such as mentoring, didactics, timing of research, or distinguishing program effects from resident and fellow attributes and selection processes.

CONCLUSIONS

To advance the biomedical sciences we must attract, train, and retain future physician-scientists.[3,9,18] MD-PhD, combined residency-fellowships, and NRSA-T32 training programs can all lead to productive academic careers, although programs that identify trainees earlier (ie, MD-PhD and CI) may facilitate greater productivity. Continuation of such programs will require ongoing financial support and institutional commitment.

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