

Impact of the National Heart, Lung, and Blood Institute's Loan Repayment Program Funding on Retention of the National Institutes of Health Biomedical Workforce

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ABSTRACT

Background: The National Institutes of Health (NIH) Loan Repayment Programs (LRPs) were established by Congress in 2000 to help attract and retain highly qualified health professionals in biomedical careers by relieving financial pressure incurred from educational loans obtained during medical school and other advanced-degree clinical training programs. In 2019, the NIH LRP Program increased the maximum repayment from \$35,000 per year to \$50,000 per year for an individual's educational debt in return for two years of research performed in an NIH mission-relevant area (<https://www.lrp.nih.gov/eligibility-programs>). In addition, in 2020, the National Heart, Lung, and Blood Institute (NHLBI) increased its participation in the LRP by adding the Health Disparities Research Program to Clinical Research and Pediatric Research Programs.

Objective: Before these substantive changes took effect, we sought to determine the impact of the NHLBI's participation in the LRP program on retention of scientists in the biomedical research workforce over the past 20 years.

Methods: NHLBI LRP applicant cohorts from 2003 and 2008 were carefully examined with a 10-year follow-up period to measure the impact of applying for and obtaining NIH LRP funding on subsequent K- and R-level application and award rates, publication number, and average relative citation ratio as metrics to assess recruitment and retention of scientists in the biomedical research workforce.

Results: Obtaining the LRP award was strongly associated with increased submission of and success in obtaining K- and RPG-grant funding and publications for both the 2003 and 2008 NHLBI LRP cohorts. An analysis of subgroups in the 2008 LRP cohort without prior F, K, or RPG funding revealed a consistently strong association between obtaining

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an LRP award and subsequent K- or RPG-award submission and success as well as potential synergy between obtaining an LRP award and participation on a T grant toward subsequent K- or RPG-award success rates.

Conclusion: The LRP award appears to enhance retention in the biomedical research workforce when measured using metrics of grant application and award rates as well as research publications over a 10-year period.

Keywords:

biomedical workforce; clinician scientists; Loan Repayment Program; NHLBI; NIH

Physician-scientists, defined by the National Institutes of Health (NIH) Physician Scientist Workforce–Working Group report, are those with professional degrees who have training in clinical care and who are engaged in biomedical research (<https://report.nih.gov/workforce/psw/index.aspx>). They have a unique clinical medicine–driven perspective believed to be critical for translating clinical observations into testable hypotheses and ultimately into clinical advances that will improve public health. Over the past several decades, however, a number of studies have documented a steady decline in the number of physician-scientists pursuing careers in academic medicine (1–3), prompting much discussion and efforts to understand root causes and strategies to reverse this trend (4).

Many potential contributors to the decline in physician-scientists have been identified and include, but are not limited to, the following: increasing debt burden compounded by longer medical education and clinical training, income disparities between privatized health care and academic teaching hospitals, the

influence of revenue-based healthcare practice models on protected research time, fluctuating pay lines and funding opportunities resulting in the inability to rely on NIH funding for research support, and the qualitative impact of how physician trainees are impacted by research mentors' struggles to maintain sufficient research funding (5–9). Cumulatively, the importance and excitement of a career in research may seem less appealing and more arduous to achieve success (10, 11).

Given the multitude of economic-based causes potentially contributing to the decline of physician-scientists, a strategy to mitigate this impact and potentially increase the physician-scientist pool was implicit in a congressional mandate for the NIH to establish a Loan Repayment Program (LRP) to repay a portion of qualified student loans for awarded applicants engaged in NIH mission-relevant research areas. The LRP is a renewable 2-year contract contingent on continued progress on their research projects and a commitment to continue to devote 20 hours per week to research.

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As a part of the NIH LRP Program, the National Heart, Lung, and Blood Institute (NHLBI) has historically participated in two of the five extramural LRPs, the LRP for Clinical Researchers and the LRP for Pediatric Research. After receipt and initial screening for Institute responsiveness by the Division of Loan Repayment, applications submitted to these two LRPs are assigned to the NHLBI for review. Reviewers with appropriate experience are recruited to review the proposals in a virtual review meeting in the NIH Internet Assisted Review system. Evaluation criteria used by external reviewers include concepts such as the applicant's potential to pursue a career in research and quality of the overall environment to prepare the applicant for a research career, and for renewal applications, progress under the previous project period. Among the review criteria, the highest relevance is given to the scientific project in relation to the goals of NHLBI as well as the candidate characteristics, including the ability to obtain funding to support the proposed research. After peer review, applications under consideration for funding with meritorious scores also undergo a financial vetting process. The full funding cycle takes about 10–11 months, similar to other participating NIH Institutes.

In 2019, the NHLBI signed on to participate in the LRP for Health Disparities Research and now provides the highest level of Institute support to the NIH LRP. Beginning in 2020, the NIH LRP has increased the maximum yearly support (from \$35,000 to \$50,000) because of increasing levels of loan burden on applicants. Before these important changes took effect in our Institute, we sought to assess the impact of the NHLBI LRP on recruitment and retention of physician-scientists in the NHLBI biomedical workforce over the past 20 years by reporting on

the 2003 and 2008 NHLBI LRP applicant cohorts over a 10-year follow-up period.

METHODS

Data Sources

Data used for this study came from the NIH database of information on extramural application and award records, known as Information for Management, Planning, Analysis, and Coordination II (IMPAC II). The NIH Query View Report and iSearch systems were used to extract the data from the IMPAC II database, PubMed XML, and UberResearch. Some PI degree data were not available in the IMPAC II system through the PI records. These degrees were extracted manually from the PI's LRP application.

Sex data were provided to the authors by the NIH Division of Loan Repayment. Sex data were not available for all applicants. Regarding use of personally identifiable PI data, we followed the NIH policy stipulating: "All analyses conducted on date of birth, citizenship, sex, race, [and] ethnicity ... data will report aggregate statistical findings only and will not identify individuals" (<https://grants.nih.gov/grants/collection-of-personal-demographic-data.htm>).

Data Definitions

Degrees

For the purposes of this analysis, the M.D. category includes the following degrees: M.D., M.B. B.S. (Foreign Bachelor of Medicine and Surgery), and D.O. (Doctor of Osteopathy). Ph.D. includes the following degrees: Ph.D. and Sc.D. (Doctor of Science). Degrees in the Other category include D.V.M. (Doctor of Veterinary Medicine), D.V.M./Ph.D., E.D.D. (Doctor of Education), P.H.M.D. (Doctor of Pharmacy), P.H.M.D./Ph.D., Psy.D.

(Doctor of Psychology), and D.N.Sc. (Doctor of Nursing Science).

K mechanisms

For the purposes of this analysis, K mechanism refers to individual career development and transition awards. Individual K activity codes consist of K01, K02, K04, K05, K07, K08, K11, K14, K15, K16, K17, K18, K20, K21, K22, K23, K24, K25, K26, K99, KL1, and KM1. Institutional K awards including the K12, KL2, and K30 activity codes were excluded from this analysis.

F mechanisms

F mechanisms refer to individual fellowships under the Ruth L. Kirschstein National Research Service Awards. The F activity codes consist of F30, F31, F32, and F33.

T mechanisms

T mechanisms refer to institutional research training grants under the Ruth L. Kirschstein National Research Service Awards. The T activity codes consist of T32, TL2, T34, and T35. For the purposes of this analysis, where T mechanisms are listed, this refers to trainees that were appointed to the institutional training grants.

Research Project Grant

Research Project Grant (RPG) activity codes consist of DP1, DP2, DP3, DP4, DP5, P01, P42, PN1, PM1, R00, R01, R03, R15, R21, R22, R23, R29, R33, R34, R35, R36, R37, R50, R55, R56, R61, RC1, RC2, RC3, RC4, RF1, RL1, RL2, RL9, RM1, UA5, UC1, UC2, UC3, UC4, UC7, UF1, UG3, UH2, UH3, UH5, UM1, UM2, U01, U19, and U34.

LRP Cohorts

Search parameters included fiscal year (FY), NHLBI administrative Institute or Center (IC), and L30 (Clinical LRP) and

L40 (Pediatric LRP) activity codes. LRP applicants submitted applications to either the Extramural LRP for Clinical Research or the Extramural LRP for Pediatric Research. The 2003 LRP cohort consists of all LRP applicants who were assigned to NHLBI in FY 2003, excluding 22 applicants who were withdrawn. Because this was the first cohort of LRP applicants, all applications were Type 1 (New) applications. Ten applicants were misclassified in IMPAC II and were actually FY 2004 applicants, so they were excluded from the study. The 2008 LRP cohort consists of all LRP applicants who were assigned to NHLBI in FY 2008, excluding 32 applicants who were withdrawn and 3 applicants who declined funding. This cohort consists of both Type 1 (New) and Type 2 (Renewal) applications. The respective FY cohorts were split into awardees and nonawardees on the basis of the funding status of the LRP. Only applications meritoriously reviewed and slated for funding were evaluated for financial qualification and represented in the awardee cohort. LRP cohort data was verified by the NIH Division of Loan Repayment, who maintain their own database. LRP cohort data were used to generate data tables that list aggregate demographic, degree, and LRP application type (clinical or pediatric) for 2003 LRP and 2008 LRP cohorts.

NIH Grant Application Data and Statistical Analysis

To study the grant application submissions of each cohort, unique Principal Investigator (PI) identification numbers (the PI profile ID) were searched in the IMPAC II database for all grant applications submitted. These applications include multi-PI applications for which the LRP applicant was not the contact PI. One LRP applicant was found to have two PI IDs, so

Table 1. NHLBI 2003 LRP applicant cohort

Characteristic	Applicants (%)	Awardees	Nonawardees
Total	212	116	96
Female	90 (42)	45	45
Male	120 (57)	71	49
M.D.	175 (83)	95	80
M.D./Ph.D.	12 (6)	9	3
Ph.D.	20 (9)	11	9
Other	4 (2)	1	4
Clinical	153 (65)	81	56
Pediatric	81 (35)	35	40
Previous F	14 (7)	6	8
Previous K	30 (14)	24	6
Previous T	43 (20)	22	21
Previous RPG	8 (4)	7	1
None of the above	135 (64)	69	66

Definition of abbreviations: LRP=Loan Repayment Program; NHLBI=National Heart, Lung, and Blood Institute; RPG=Research Project Grant.

both IDs were used in the searches. Grant mechanism definitions as described above were used to limit the search to only those mechanisms relevant to the analysis. Data extracted included all PI names, all PI profile IDs, application title, activity code, application type, award status, administrative IC, and FY. Extracted data were downloaded to Microsoft Excel and manually inspected for completeness and accuracy. For all cohorts, previous awards consist of all F, K, T (as a trainee), and RPGs awarded to the LRP applicant from 1950 through the concurrent FY of the LRP. *A priori* decisions were made to quantify grant application data each year over a 10-year period starting with the FY after LRP application. Subsequent applications for the 2003 LRP cohort included all K and RPG applications submitted from FYs 2004 to 2013. Subsequent applications

for the 2008 LRP cohorts included all K and RPG applications submitted from FYs 2009 to 2018. For subsequent awarded grants tracked over respective 10-year periods, both competing (Type 1 and 2) and noncompeting out-years (Type 5) of all awarded grants were included. For subsequent applications among LRP awardees and LRP nonawardees, only competing (Type 1 and 2) applications were included. We quantified cumulative grant application and success rates among non-LRP and LRP awardee groups using “did not apply,” “applied and didn’t receive,” and “applied and received” outcome categories. Because the main covariates of interest were described as a proportion (percentages), we used a chi-square test (Microsoft Excel 2016, “CHISQ.TEST (observed,expected)”) as a measure of statistical inference. Upon inspection of the 2008

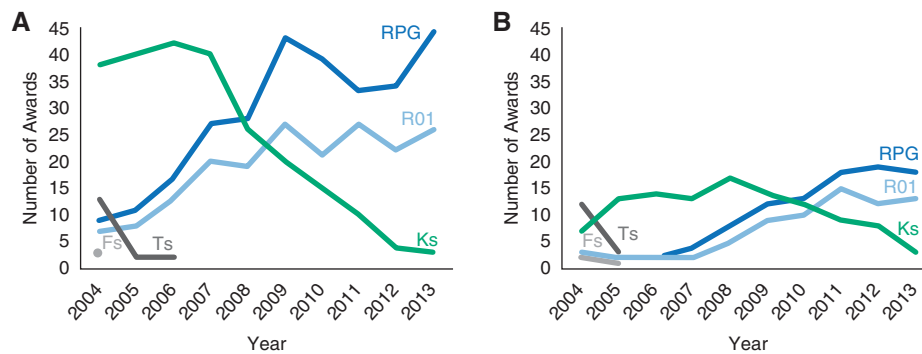


Figure 1. Number of active awards after applying to the 2003 Loan Repayment Program (LRP). (A) Number of active awards held by 2003 LRP awardees after applying to the LRP. (B) Number of active awards held by 2003 LRP nonawardees after applying to the LRP. Post-LRP application awards are categorized by Research Project Grants (RPGs), R01s, K mechanism, F mechanism, and T mechanism. T mechanism includes those who were trainees on a T. RPG includes R01. Awards listed include out-years of grants awarded before the LRP as well as those awarded after the LRP.

LRP cohort data, we observed a high percentage of LRP applicants with prior grant award participation and an unequal distribution of prior F and K grants among LRP awardees. As such, we evaluated LRP application subcohorts without prior funding or with only prior institutional T grant participation. We were unable to evaluate non-NIH grant application data, as this information is not available through the IMPAC II database.

Publication Data and Analysis

To extract publication data, all NIH grants for all LRP applicants from 1950 through 2018 (including those that do not qualify as F, K, T, or RPG for the purposes of this study to capture as many publications as possible) were identified using the LRP applicants' PI Profile IDs. Publications linked to these NIH grants were then extracted from IMPAC II via iSearch. Data extracted included digital object identifier, PMID, publication date, publication title, all author names, journal name, relative citation ratio (RCR), and associated grant numbers. Extracted data were downloaded to Microsoft Excel and manually inspected for completeness and accuracy. Only publications with an associated PMID were included.

Publications in which the LRP applicant was identified as either the first or last author were manually extracted. For the 2003 cohort, publications include all those from calendar year 2003–2013, and for the 2008 cohort, this includes all publications from calendar year 2008–2018. Average RCR values were calculated from the RCRs of each publication at the time that the data were extracted. Publications not linked to NIH grants were not identified.

Data Availability

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

RESULTS

2003 LRP Cohort

A total of 212 LRP applications were assigned to the NHLBI (Table 1), and 116 applications were awarded for an overall

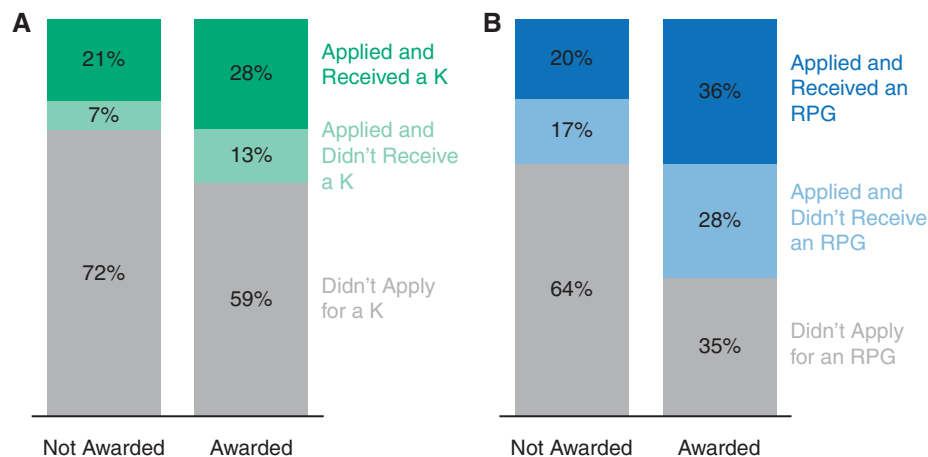


Figure 2. Subsequent applications of 2003 Loan Repayment Program (LRP) awardees and nonawardees—2004–2013. (A) Percentage of LRP nonawardees (labeled as “Not Awarded,” $n = 96$) and LRP awardees (labeled as “Awarded,” $n = 116$) who applied for and received a K award, applied for but did not receive a K award, or never applied for a K award after the LRP. Comparing the expected proportions of LRP nonawardees to LRP awardees among the applied and received a K award, applied and didn’t receive a K award, or did not apply for a K award categories, there was no significant difference from observed proportions (χ^2 test, $P = 0.15$). (B) Percentage of LRP nonawardees and LRP awardees who applied for and received an Research Project Grant (RPG), applied for but did not receive an RPG, or never applied for an RPG after the LRP. Comparing the expected proportions of LRP nonawardees to LRP awardees among the applied and received an RPG, applied and didn’t receive an RPG, or did not apply for an RPG categories, there was a significant difference from observed proportions (χ^2 test, $P = 0.00023$).

success rate of 55%. Applicants to the Clinical Researchers LRP were more successful than applicants to the Pediatric Research LRP, and LRP applicants who had a previous K or RPG had higher LRP success rates than those with a previous F or who were supported by a T (43% and 51%, respectively).

Concurrent and subsequent funding support

Next, we identified all active F, K, T, R01, and RPG support for 10 years after LRP application (Figure 1) and assessed LRP awardees (Figure 1A) and LRP nonawardees (Figure 1B) separately to assess the trajectory of subsequent grant awards over the next 10 years. Among LRP awardees, a decrease in the number of active K awards over time coincided with a continual increase in R01 awards and other RPG awards; this same trend was not evident among LRP nonawardees, for whom the data demonstrated a slower rate of increase that plateaued around 2011,

resulting in a lower peak number of R01 awards. Of note, the majority of those applicants with previous K awards stem from the LRP awardee pool as compared with the nonawardee pool (24 and 6, respectively), and in both awardee and nonawardee cohorts, very few LRP awardees or nonawardees were supported by F or T grants after their LRP application.

Subsequent applications

Because the 10-year data indicated a higher number of funded awards for LRP awardees compared with nonawardees, we sought to determine whether there were differences in application rates among LRP awardees and nonawardees as a potential explanation, focusing on K and RPG grant mechanisms. Cumulatively over a 10-year period, the percentage of LRP awardees who applied for or were awarded Ks was only slightly higher than the percentage of LRP nonawardees (Figure 2A). However, a much higher

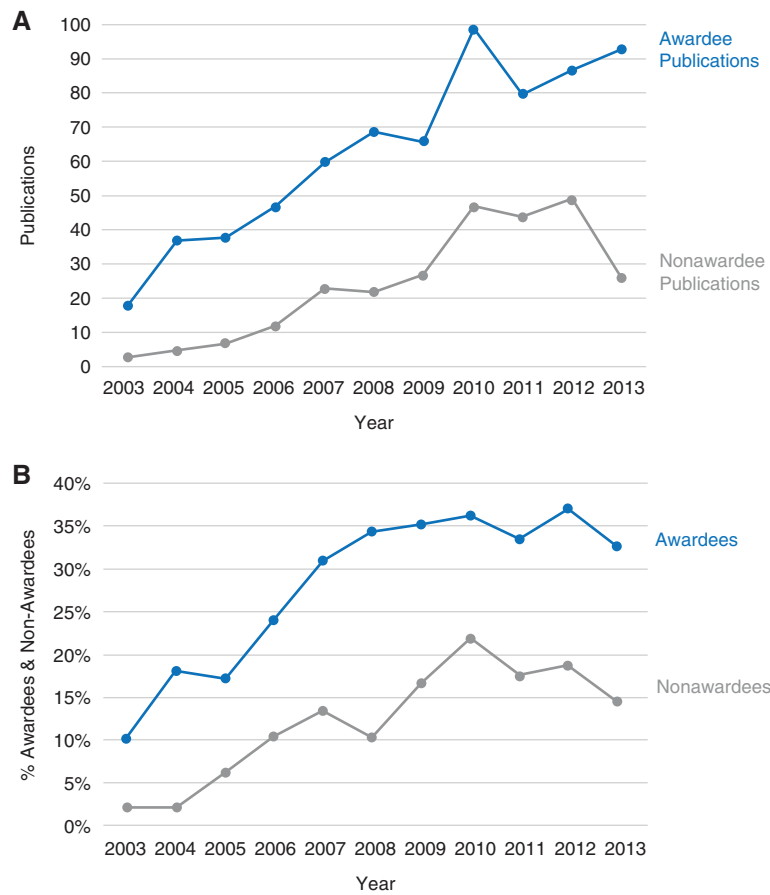


Figure 3. Publications by 2003 Loan Repayment Program (LRP) awardees and nonawardees. (A) Total number of publications per year by LRP awardees and nonawardees. (B) Percentage of LRP awardees and nonawardees who published each year.

percentage of LRP awardees (64%) applied for or received an RPG within 10 years compared with LRP nonawardees (37%) (Figure 2B). Each applicant was enumerated once, either for the “applied and received a K or RPG” category or for the “applied and didn’t receive a K or RPG” category, irrespective of the number of times they applied. LRP awardees were not more likely to apply and be awarded a K grant ($P=0.15$) but were significantly more likely to apply and be awarded an RPG as compared with LRP nonawardees ($P=0.00023$). Among LRP awardees, 72% of subsequent K grants and 64% of subsequent RPGs were awarded by the NHLBI compared with

75% and 56%, respectively, for non-LRP awardees.

Publications

As another metric of success and retention in academic research, we assessed the 2003 LRP applicant pool for subsequent scientific publications over an 11-year period from 2003 to 2013 (Figure 3). We included the LRP application year to capture additional publications that may have been associated with the LRP award. Each year, there were more publications linked to an NIH award with an LRP awardee as first or last author compared with LRP nonawardees, with an average of about 6 publications per LRP awardee and 2.8

Table 2. NHLBI 2008 LRP applicant cohort

Characteristic	Applicants (%)	Awardees	Nonawardees
Total	355	154	201
Female	140 (39)	69	71
Male	207 (58)	83	124
M.D.	268 (75)	123	145
M.D./Ph.D.	22 (6)	15	7
Ph.D.	53 (15)	14	39
Other	12 (3)	2	10
Clinical	232 (65)	109	123
Pediatric	123 (35)	45	78
Previous F	36 (10)	21	15
Previous K	48 (14)	34	14
Previous T	196 (55)	103	93
Previous RPG	3 (1)	3	0
None of the above	135 (38)	38	97

For definition of abbreviations, see Table 1.

publications per nonawardee across the 11-year period. Overall, 66% of LRP awardees published at least one peer-reviewed manuscript compared with 31%

of all nonawardees, and the average RCR among publications by LRP awardees was 2.5, whereas the average RCR for LRP nonawardees was 1.5.

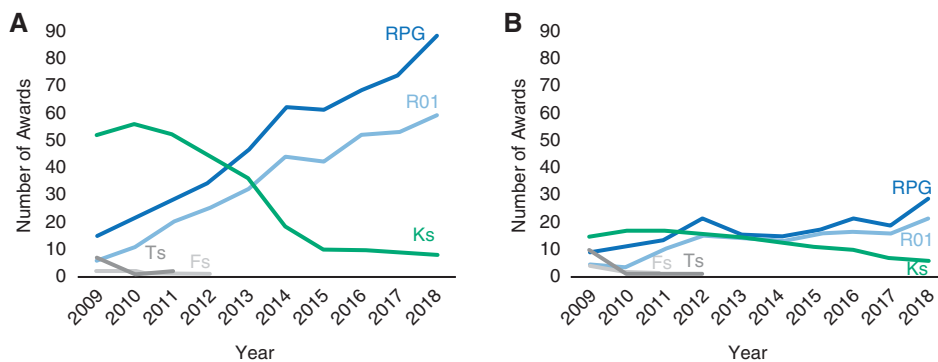


Figure 4. Number of active awards after applying to the 2008 Loan Repayment Program (LRP). (A) Number of active awards held by 2008 LRP awardees after applying to the LRP. (B) Number of active awards held by 2008 LRP nonawardees after applying to the LRP. Post-LRP application awards are categorized by Research Project Grants (RPG), R01s, K mechanism, F mechanism, and T mechanism. T mechanism includes those that were trainees on a T. Awards listed include out-years of grants awarded before the LRP as well as those awarded after the LRP. RPG = Research Project Grant.

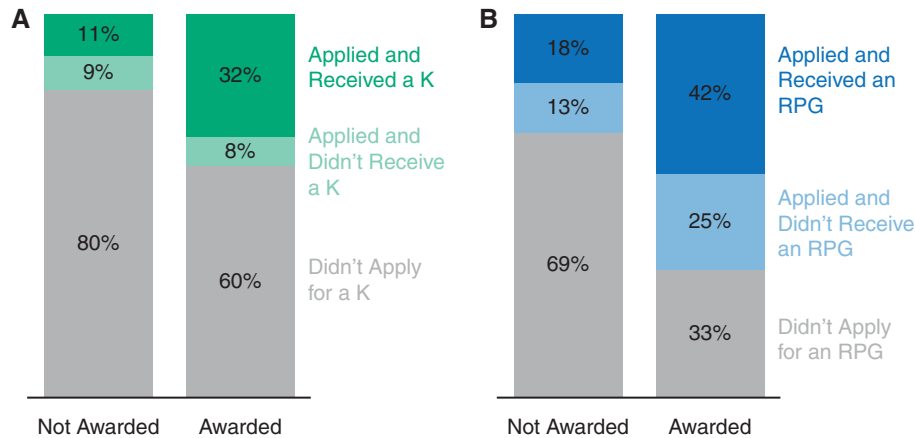


Figure 5. Subsequent applications of 2008 Loan Repayment Program (LRP) awardees and nonawardees—2009–2018. (A) Percentage of LRP nonawardees (labeled as “Not Awarded,” $n=201$) and awardees (labeled as “Awarded,” $n=154$) who applied for and received a K award, applied for but did not receive a K award, or never applied for a K award after the LRP. As compared with expected proportions for each category among LRP nonawardees to LRP awardees for subsequent K awards, there was a significant difference from observed proportions (χ^2 test, $P=6.6 \times 10^{-6}$). (B) Percentage of LRP awardees and nonawardees who applied for and received a Research Project Grant (RPG), applied for but did not receive an RPG, or never applied for an RPG after the LRP. As compared with expected proportions for each category among LRP nonawardees to LRP awardees for subsequent RPG awards, there was a significant difference from observed proportions (χ^2 test, $P=1.1 \times 10^{-10}$).

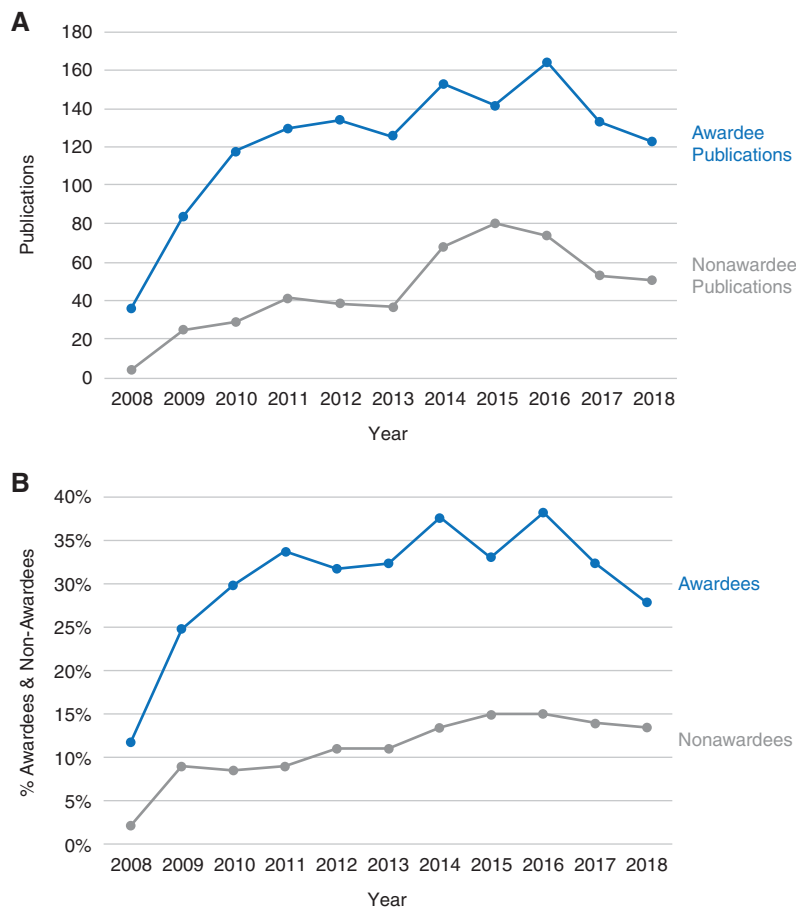


Figure 6. Publications by 2008 Loan Repayment Program (LRP) awardees and nonawardees. (A) Total number of publications per year by LRP awardees and nonawardees. (B) Percentage of LRP awardees and nonawardees who published each year.

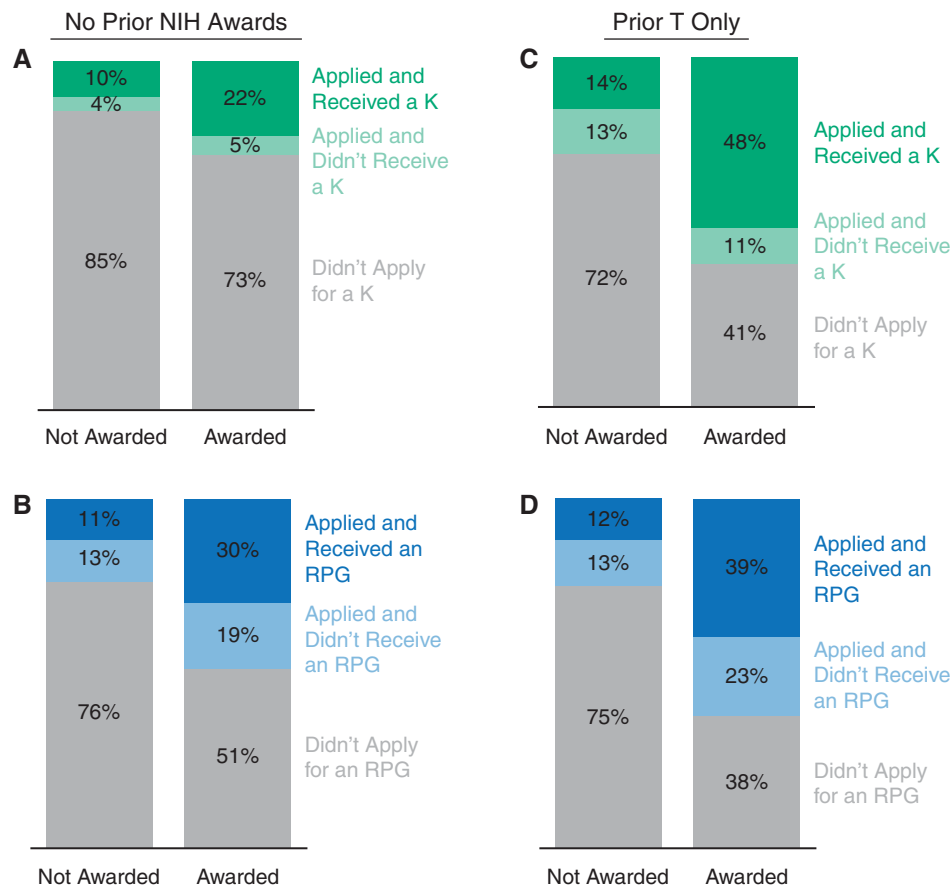


Figure 7. Subsequent applications (2009–2018) of 2008 Loan Repayment Program (LRP) awardees and nonawardees with no prior NIH grant support (A and B) or only as a T grant trainee (C and D). (A) Percentage of LRP nonawardees ($n = 96$) and awardees ($n = 37$) who received, applied for but did not receive, or never applied for a K award after the LRP. As compared with expected proportions for each category among LRP nonawardees to LRP awardees for subsequent K awards, there was no significant difference from observed proportions (χ^2 test, $P = 0.22$). (B) Percentage of LRP nonawardees ($n = 96$) and awardees ($n = 37$) who received, applied for but did not receive, or never applied for an Research Project Grant (RPG) after LRP; a significant difference was observed (χ^2 test, $P = 0.014$). (C) Percentage of LRP nonawardees ($n = 76$) and awardees ($n = 66$) who were T grant trainees; a significant difference was observed among those who received, applied for but did not receive, or never applied for a K award after the LRP (χ^2 test, $P = 5.25 \times 10^{-5}$). (D) Percentage of LRP nonawardees ($n = 76$) and awardees ($n = 66$) who were T grant trainees; a significant difference was observed among those who received, applied for but did not receive, or never applied for an RPG after LRP (χ^2 test, $P = 2.6 \times 10^{-5}$). NIH = National Institutes of Health.

2008 LRP Cohort

A total of 355 LRP applications were assigned to NHLBI (Table 2), and 154 applications were awarded for an overall success rate of 43%. In contrast to the 2003 LRP Cohort, female applicants had a higher success rate, and the majority of awardees and nearly half of nonawardees were supported by a previous T award.

Concurrent and subsequent funding support

In performing a comparable analysis to the 2003 LRP cohort, we identified all active F, K, T, R01, and RPG support for 10 years after their LRP application (Figure 4) and assessed LRP awardees (Figure 4A) and LRP nonawardees (Figure 4B) separately to help quantify the impact of the LRP on subsequent grant awards. Despite a smaller

Table 3. NHLBI 2008 LRP applicant subcohort with no prior NIH funding

Characteristic	Applicants (%)	Awardees	Nonawardees
Total	133	37	96
Female	50 (38)	15	35
Male	80 (60)	22	58
M.D.	100 (75)	29	71
M.D./Ph.D.	6 (5)	4	2
PhD	19 (14)	4	15
Other	8 (7)	0	8
Clinical	79 (59)	22	57
Pediatric	54 (41)	15	39

Definition of abbreviations: LRP=Loan Repayment Program; NHLBI=National Heart, Lung, and Blood Institute; NIH=National Institutes of Health.

pool (154 LRP awardees vs. 201 LRP nonawardees), LRP awardees received more NIH grant awards than LRP nonawardees, with an increase in active R01 or RPG awards almost every year of the 10-year period. In a trend similar to the 2003 LRP cohort, the number of active K awards decreases in the LRP awardee cohort as R01 and RPG awards increase. Among the LRP nonawardee group,

however, there is no appreciable increase in active K awards and a modest increase in R01 and RPG awards only toward the end of the 10-year period.

Subsequent applications

Next, we evaluated the percentage of LRP applicants who applied for subsequent K or RPG funding in the 10 years after the LRP application (Figure 5). Among LRP

Table 4. NHLBI 2008 LRP applicant subcohort with prior T grant participation

Characteristic	Applicants (%)	Awardees	Nonawardees
Total	142	66	76
Female	62 (44)	32	30
Male	76 (54)	32	44
M.D.	115 (81)	56	59
M.D./Ph.D.	8 (6)	6	2
PhD	17 (12)	4	13
Other	2 (2)	0	2
Clinical	99 (70)	52	47
Pediatric	43 (30)	14	29

Definition of abbreviations: LRP=Loan Repayment Program; NHLBI=National Heart, Lung, and Blood Institute.

awardees, 40% applied for or were awarded a K grant, and 67% applied for or were awarded an RPG. Comparatively, among LRP nonawardees, 20% applied for or were awarded a K grant, and 31% applied for or were awarded an RPG. The percentage of LRP awardees that secured either K or RPG funding was more than twofold that of LRP nonawardees ($P=6.6 \times 10^{-6}$ for K and $P=1.1 \times 10^{-10}$ for RPG awards). Overall, these data demonstrate in the 2008 NHLBI LRP cohort that success in obtaining LRP funding was associated with a marked increase in subsequent K or RPG application and funding rates. Among LRP awardees, 76% of subsequent K grants and 66% of subsequent RPGs were awarded by the NHLBI compared with 70% and 53%, respectively, for non-LRP awardees.

Publications

LRP awardees from the 2008 LRP cohort had more NIH grant-linked publications than LRP nonawardees, both by absolute number (Figure 6A) and by a percentage of each LRP applicant group (Figure 6B). Over the 11-year period, 68% of LRP awardees published at least one manuscript compared with 30% of the nonawardees. At the time of this analysis, 2008 LRP awardees and nonawardees did have a similar RCR average at 1.85 and 1.82, respectively.

2008 LRP Subcohort

Subcohort characteristics

As noted from Table 2, prior F and K awards were much more common among LRP awardees than LRP nonawardees, suggesting it may be a study confounder. Therefore, to further define the specific impact of the LRP award, we also looked at two 2008 LRP applicant subcohorts, one that had no prior NIH grant support (Table 3) and one that had only been supported by an institutional T award before their 2008

LRP application (Table 4). Each subcohort was fairly similar to the overall 2008 LRP cohort with a predominance of males, M.D. as a terminal degree, and applications to the clinical LRP.

Subsequent applications

We identified all NIH K and RPG applications and awards for LRP applicants who had not received any prior NIH funding support (Figures 7A and 7B). From this subcohort, the success rates were more than double for subsequent K awards and nearly triple for subsequent RPG awards among LRP awardees compared with LRP nonawardees.

In the subcohort with support on an NIH T award, the positive impact of getting an LRP award on subsequent K or RPG success rates is further magnified (Figures 7C and 7D). LRP awardees from this subcohort were three times as likely to apply for and receive NIH K and RPG awards than the LRP nonawardees. Because the subcohort with support on a T award was comparable in size to the subcohort with no prior funding, we also compared across subcohorts to assess a potential impact of T training programs on LRP applicants (Figures 7A and 7B compared with Figures 7C and 7D). Although there were no significant differences in K or RPG application and award rates for LRP nonawardees in each subcohort, LRP awardees from the subcohort with prior T funding were more than twice as likely to apply for and receive a K award and about 10% more likely to apply for and receive an RPG than LRP awardees from the subcohort with no prior NIH support.

DISCUSSION

The NIH LRPs were established by Congress to increase the number of clinically trained health professionals

engaged in biomedical research careers by providing partial relief of financial burdens from educational debts incurred during the pursuit of advanced degree clinical training. We undertook this analysis to evaluate the potential impact of LRPs on success and retention in the biomedical workforce by comparing grant application submission and success rates as well as publications between LRP awardees and LRP nonawardees over a 10-year period in two NHLBI LRP applicant cohorts. We chose to analyze the 2003 and 2008 cohorts to evaluate stability in the impact of the LRP over time and yet allow for a sufficient follow-up duration for a specified cohort in which to assess retention in the biomedical workforce. The results suggest that obtaining the LRP award was strongly associated with increased submission of and success in obtaining K- and RPG- grant funding and publications for the 2003 and 2008 NHLBI LRP cohorts. Furthermore, our analysis of subgroups in the 2008 cohort without prior F, K, or RPG funding or with only prior participation on a T grant demonstrated a persistently strong association between receiving an LRP award and subsequent K- or RPG-award submission and success. Although we cannot determine causality or necessarily understand why success in obtaining an LRP award predicted retention in the biomedical research workforce, there are a few possible explanations. One, success in obtaining grants may give an investigator protected research time as well as confidence in the grant application and evaluation process, thus increasing the likelihood of applying for and achieving success in securing future funding. Two, metrics of retention such as subsequent grant application and award rates are quantifiable. However, perhaps a more important, qualitative determinant of retention is the economic and emotional

stability derived from offsetting a significant portion of educational debt through LRP award receipt and renewal, which in turn may positively influence a choice to pursue an academic career (12) and allow an early career physician-scientist to be more focused on asking and answering relevant research questions. Other studies have also found that a strategy based on providing financial incentives was successful in improving recruitment and retention of physicians in underserved areas (13–15). Our analysis of two cohorts separated by 5 years revealed stable trends but also revealed potential differences in the LRP applicant pool that developed over time. One stable trend is that the cohorts of applicants are in the early stages of their research careers when they apply to the LRP program. Only 4% of the LRP applicants in the 2003 and 1% in the 2008 cohort had previously obtained an RPG award, and 14% of LRP applicants in each cohort year had previously received a K award. Overall, nearly two-thirds of the 2003 NHLBI LRP cohort had not received any NIH training award, including participation on an institutional T grant. In contrast, however, just over one-third of the 2008 NHLBI LRP cohort had not received any NIH training award, and this difference was largely because of an increase in the number of LRP applicants in the 2008 cohort who participated in an institutional T grant, suggesting more overlap between the LRP applicant pool and institutional T grant trainees over time. Because of this increase, and because of the discrepancy in LRP awardee and LRP nonawardee groups with respect to prior NIH funding, we analyzed the 2008 NHLBI LRP cohort for important subgroups in Tables 3 and 4 and Figure 7. Collectively, the data from subcohorts of LRP applicants without any prior NIH funding or with prior

participation only on an NIH T training grant solidify the importance of success in the LRP program as a tool to persist and thrive in biomedical research for at least a decade, and potentially longer.

Publications are generally considered to be a good measure of productivity in a research career. Based on data presented in Figures 3 and 6, LRP awardees from both 2003 and 2008 NHLBI LRP cohorts consistently published far more NIH grant-linked publications than LRP non-awardees. One caveat to this data is that LRP awardees had more NIH awards to link to their publications than LRP non-awardees, and we did not track publications that were not linked to NIH awards, so we cannot presume the same relationship exists for non-NIH-linked publications. However, over the 11-year tracking period for both cohorts, approximately two-thirds of all LRP awardees published at least once, a proportion more than double their LRP nonawardee counterparts, and, similarly, a difference in proportions between groups was present in each year of the follow-up period. Thus, if publications are an indicator of program success and researcher retention, the LRP has been extremely effective in this regard.

Our findings may be limited to the NHLBI 2003 and 2008 LRP cohorts and may not be generalizable to other NHLBI LRP cohort years or to LRP cohorts from other NIH Institutes in the same year(s). One reason for a lack of generalizability to other NIH Institute LRP cohorts is the relatively high proportion of M.D. and M.D.–Ph.D. physicians (89% in the 2008 NHLBI LRP cohort) compared with the overall 2008 NIH cohort of LRP applicants who applied to the Clinical Research or Pediatric Research LRP programs (50%) (<https://www.lrp.nih.gov/lrpdatabook/pdf/>

[FY2008_Extramural_Data_Book_Final.pdf](https://www.lrp.nih.gov/pdf/LRP_Evaluation_Report_508final06082009.pdf)). Differences in application rates by sex may be another reason for reduced generalizability. There was a higher percentage of male applicants in the 2003 (57% vs. 50%) and 2008 (58% vs. 50%) NHLBI LRP cohorts compared with overall NIH LRP cohorts in those respective years (for 2003: https://www.lrp.nih.gov/pdf/LRP_Evaluation_Report_508final06082009.pdf, Figure 2; for 2008: https://www.lrp.nih.gov/lrpdatabook/pdf/FY2008_Extramural_Data_Book_Final.pdf); however, success rates by sex were not consistent across cohort years, with a higher success rate among males in the 2003 NHLBI LRP cohort and a lower success rate among males in the 2008 NHLBI cohort compared with the NIH LRP cohort in those respective years. Another potential limitation to our study relates to the somewhat arbitrary time period of 10 years over which we assessed for biomedical research retention. However, based on the slope of the grant award curve in Figures 1 and 4, 10 years of follow-up may have actually underestimated the difference between LRP awardees and LRP nonawardees for this metric of academic success and retention, particularly for RPGs. Finally, our analysis may have been limited by lumping all LRP awardees into one group and all LRP nonawardees into another group rather than only comparing awarded and not awarded LRP applicants who all received a priority score within a “bubble” range, as was done by the NIH LRP Program Evaluation Working Group (https://www.lrp.nih.gov/pdf/LRP_Evaluation_Report_508final06082009.pdf); however, it is likely that the size of a cohort defined by a score range among NHLBI applicants would have been too small to draw any meaningful conclusions.

CONCLUSION

The NIH LRP Program, set forth by a congressional mandate in 2000 to help recruit and retain physician-scientists in biomedical research, is approaching 20 years in existence, with some important changes to IC support that have been recently implemented. In anticipation of these changes, the NHLBI extramural program staff analyzed two cohorts of LRP applicants to determine if lowering the financial burden created by educational loans and if success in the LRP program would increase

retention of physician-scientists in biomedical research. The data support this hypothesis and suggest that an LRP award is strongly associated with subsequent K- and RPG-award success. A longer follow up of the 2003 and 2008 NHLBI cohorts and a comparison to LRP cohorts established following changes in the NIH LRP Program occurring in 2019 and 2020 may be worthwhile.

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