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An Institutional Post-doctoral Research Training Program: Predictors of Publication Rate and Federal Funding Success of Its Graduates

Abstract

Objective—The National Institute of Mental Health funds institutional National Research Service Awards (NRSA) to provide post-doctoral research training. While peer reviewed publications are the most common outcome measure utilized, there has been little discussion of either how publications should be counted (are all publications equal) or of what factors impact the long term publication rates of trainees in these programs.

Method—Current curricula vitas from 92 graduates of an institutional NRSA and from the faculty mentors of that program were reviewed to assess publications through 2005. Publications were weighted based on peer versus non-peer reviewed and authorship position. Trainee and mentor factors were assessed for their impact on publication rates and on becoming principal investigators of larger scale federal grants such as an NIH R01.

Results—Weighted publication scores correlate with total publication rates at such a high rate ($r=0.99$, $p<.001$) that the two scores can be used interchangeably. Forty-three percent of graduates average at least one publication per year after completing the post-doctoral program; twenty percent were listed as an independent investigator on a larger federal grant. The number of publications published during post-doctoral training and additional funded training beyond that provided by the institutional NRSA are correlated with increased post-training program publication rates; other factors including gender, terminal degree, number of publications prior to post-doctoral training, and mentor variables had no significant impact. Additional funded training, male gender, and increased time since completion of the training are associated with increased likelihood of larger grant federal funding.

Conclusions—Weighting publications by whether they were peer-reviewed and by authorship position appears to have little benefit over a simple counting of the number of publications. Publication during research training and the pursuit of funding for additional individual research training may be appropriate short-term goals within an institutional research training program.

Keywords

training; post-doctoral; research

A post-doctoral training experience is often considered a critical step in the career development of an independent researcher. The National Institutes of Mental Health supports both individual and institutional post-doctoral training programs (F32 Individual National Research Service Awards and T32 Institutional National Research Service Awards). In 2005, the National Institute of Mental Health (NIMH) supported training for 585 post-doctoral positions at a cost of over \$38.3 million dollars (1;2). The majority of the support was provided via 135 Institutional Awards; 87% of the NIMH-supported post-doctoral slots were via institutional awards. Despite this heavy investment in using institutional National Research Service Awards to fund post-doctoral research training positions, there is little literature on the effectiveness of this usage of federal research dollars.

One of the difficulties in assessing the effectiveness of post-doctoral training programs is a lack of consensus on how to define a successful outcome. One option would be to focus on the scientific impact of a program's graduates. Hirsch (3) has suggested a method for assessing an individual's scientific contributions. Often termed the h-index, this method attempts to quantify the impact of an individual scientist's work. The h-index is calculated by determining the number of times each article is cited, and then determining the highest number of articles with an equivalent number of citations. For example, an h-index of 7 indicates that an author has 7 or more publications and at least 7 of those publications have been cited 7 or more times; an h-index of 12 indicates that an author has 12 or more total publications and at least 12 of those publications have been cited 12 or more times. One of the limitations to this approach is that the h-index is a summary score and will increase as an individual progresses in their career (4), making the h-index of limited value when comparing individuals at different career stages. Hirsch also explored the idea of using "m," which is equal to the h-index divided by the number of years since an individual's first published paper. However, because the h-index does not increase linearly over the course of a career, m is not useful either early or late in a career and thus is also not well suited to compare individuals at different career stages. Despite several attempts to improve on the h-index (5–9), there as of yet is no satisfactory method to control for stage of career, especially for individuals early in their career (4).

An alternative, and more common, approach to assess a training program's success is to focus on the number of scientific publications of its graduates. This approach has the advantage that the number of publications can be divided by the number of years since program completion to compute a "number of publications per year" variable which may allow comparison across various stages of careers. One of the limitations to this approach is that it is unclear if all publications should be counted equally. For example, should a first author publication be considered equal to an article where the graduate is a more distal author? Or should a peer-reviewed article be considered equal to a book chapter or monograph?

The University of Colorado institutional NRSA is in its 29th year of continuous funding. While the institutional NRSA is administratively centered within the Department of Psychiatry at the University of Colorado Health Sciences Center, it has always been conceptualized as a multi-specialty, multi-departmental, multi-institutional program, drawing faculty mentors from nine departments across four major teaching institutions. Criterion for faculty recruitment has included a primary goal of diversity of methodological approaches; other factors considered include faculty who (a) are senior faculty and have a history of (b) consistent external funding including R01s, (c) consistent peer-reviewed publication record, (d) sufficient resources to allow the post-doctoral fellow to develop his/her own career rather than working exclusively in the mentor's area of expertise, and (e) some evidence of successful mentoring. As a starting point to address the issue of whether publications should be weighted when measuring trainee outcome, as well as to explore what factors predict publication rates after completion of post-doctoral training, we utilize results from this single long-standing institutional NRSA.

Method

Subjects

The sample consists of 92 individuals who completed post-doctoral training as part of the University of Colorado's Institutional NRSA "Development of Maladaptive Behavior" (T32 MH15442) from 1979 to 2004. The sample includes 24 MDs, 67 PhDs, and 1 MD-PhD; is 68% female; and, as of 2005, had completed the post-doctoral training program an average of 12±7 years earlier (range 1–26 years). Additional demographic information is provided in Table 1.

Data collection—former post-doctoral fellows

Current curricula vitas were requested from all 92 individuals and received from 89 (97%); publication and funding histories for the remaining 3 former participants were extrapolated from public databases. Each curriculum vitae was reviewed and all publications were classified as peer-reviewed or non-peer-reviewed (books, book chapters, monographs, etc) and, based on the former post-doctoral trainee's position in the author list as first author, second author, senior author, or other author. Senior author was defined as the former post-doctoral trainee being cited as the last author on a publication where the first author was identified on the former post-doctoral trainee's curriculum vitae as a current or former trainee of this individual.

Data collection—faculty mentors

In order to explore what mentor qualities may influence outcome, information was also requested from faculty mentors for this Institutional NRSA. By the end of 2005, 35 faculty members have been listed as a potential mentor for at least 2 years of the program (15 with a terminal MD degree and 20 with a terminal PhD degree; 16 female, 19 male); the faculty consists of approximately 20 members at any given time. Male and female mentors did not significantly differ on length of time as a mentor, funding history, publication rate, or the impact of their work (h-index). Twenty-nine (83%) of the faculty have acted as the primary mentor for a post-doctoral trainee. Mentor attrition has occurred for natural career reasons (death, retirement, moving out-of-state); no mentor has been asked to leave the program. Mentors have remained on the post-doctoral faculty for an average of 12 ± 8 years (range 3–27 years). Six of the faculty members are former trainees of this Institutional NRSA. An h-index was calculated for each faculty mentor based on a search of citations in June 2007. To match the trainee data, only publications published prior to the end of 2005 were included in calculating the h-index. However, since dates of citation are not easily identifiable, the calculation of the h-index may include situations where a mentor's article was cited between January 2006 and June 2007. Thus, the h-indexes may be slightly elevated above what they would have been at the end of 2005. Mentors had an average h-index (3) of 17.8 ± 11.0 (range 5–50); 86% of the mentors have an h-index of 10 or greater. Mentors with the lowest h-index are engaged in fields with historically lower peer-reviewed publishing rates (e.g. nursing and physical therapy). Curricula vitas from all 35 (100%) of the faculty were examined. Publication records were classified in a manner identical to that described for the former trainees, except that to determine number of publications per year, only manuscripts published during the period that the individual was a faculty member were included. Table 1 summarizes information from the faculty.

Analysis—defining outcomes

The number of publications per year is one of the more common measures of an individual's ability to conceptualize, design, implement, collect data, analyze, interpret, and disseminate research results (10–12). However, there has been little discussion as to whether research output is better determined by counting all publications equally or by weighting publications based on the individual's contribution; for example, when an individual is listed as the first author, second author, etc. To address this question, we surveyed the 21 current faculty of this institutional NRSA on the relative weighting that should be applied to each publication; Twenty (95%) of the faculty responded with results summarized in Table 2. Each publication in each CV was given a weighted score, summed, and then divided by the number of years since completion of the post-doctoral training program to produce a weighted publication score for each individual. The correlation between publications per year and the weighted publication score is a reflection of the variation in publication values across individuals. Publication rates may vary across individuals; however a high correlation between the number of publications and the weighted publication score would suggest that the percentage of publications that are first-author publications would be similar across individuals.

As a secondary outcome measure, CVs were dichotomized as whether the former post-doctoral fellow had obtained, as a principal investigator, an R01 or similar larger federally funded grant (e.g. an NIH R38 or Veterans Administration Merit Review grant).

Analysis—Factors that influence outcomes

Factors that may influence outcome, including factors related to the trainee (age at entry into the post-doctoral program, gender, race/ethnicity (Non-Hispanic Caucasian versus other), terminal degree, successful funding of an individual training grant, year of graduation from the program, number of publications prior to entering the post-doctoral program, and number of publications during the post-doctoral program) and factors related to the mentor (gender, terminal degree, publications per year, h-index, and funding status) were collected for each trainee and their primary mentor. The number of publications published after completion of the post-doctoral program per year was either correlated to the factors (for continuous variables) or compared with a student's t-test (for categorical variables). All variables that suggested a relationship with number of trainee publications per year ($p < .10$) were added into a step-wise multiple regression model.

One common question is whether there are cohort effects on long-term research success, effects that may be due to national issues such as variance in federal funding levels. As an initial examination of this issue, we classified graduates into 5-year graduation blocks (1979–1984, 1985–1989, 1990–1994, 1995–1999, and 2000–2004). Publication rates were then compared across these groups.

Results

As of the end of 2005, these 92 participants have published 1721 publications; this includes 1493 peer-reviewed articles (660 of which are first-authored by one of the participants) and 328 other publications such as books, book chapters, or monographs.

Table 2 summarizes the weighting given to each publication classification. Figure 1 displays, for trainees, the correlation between number of publications per year and the weighted publication score ($r = .99$, $p < .001$). A single outlier averaged 11 publications per year. With that trainee removed, the correlation between number of publications per year and the weighted publication score remained unchanged ($r = .99$, $p < .001$). The high correlation suggests that the two scores are interchangeable. To be consistent with previous literature, total number of publications is used as the outcome variable for the present analysis.

Table 3 summarizes the impact of individual and mentor variables on trainee publication rate. Additional funded training, such as an individual NRSA or career development award (e.g. NIH-funded K-Award), age at entry into the program, ethnicity, and the number of papers published while enrolled in the T32 program were the only significant predictors of post-training publication rate; there was a trend for gender to also have an impact. Using a step-wise linear multiple regression with a probability of $< .05$ to enter and $< .10$ to remove, only additional funded training and number of papers published while enrolled in the T32 program are included in the model ($R^2 = .22$, $P < 0.001$). There was a trend for age at entry into the post-doctoral program to be a significant addition to the model ($p = .06$; younger age associated with increased post-program publication rate).

Twenty percent of graduates have received at least one larger federally-funded grant (an NIH R01 or equivalent). Male gender, having received an individual training grant, and more years since graduation from the program are associated with increased likelihood of having received an NIH R01. There was a trend for a younger age at entry into the post-doctoral program and race/ethnicity something other than non-Hispanic Caucasian to have an impact. Using a step-

wise linear multiple regression with a probability of $<.05$ to enter and $<.10$ to remove, only additional funded training, male gender, and an increased number of years since graduation from the T32 program are included in the model ($R^2 = .35$, $P < 0.001$).

Using approximately 5-year cohorts, there is no difference between cohorts either in the post-program publication rates ($F=0.62$; $p = .65$) or in the percentage of graduates who average at least 1 publication per year ($\chi^2 = 2.6$, $p = .63$).

Discussion

The most common outcome measure for training programs is trainee publication rate. However, there has been little discussion of how to weight publications, including the relative value of peer-reviewed versus non-peer reviewed publications and 1st-author versus other-author publications. A survey of current program research faculty provides an initial examination into this issue. Faculty provided weighted values for several different publication types (Table 2) with a peer-reviewed first-author publication standardized to 1.0 and other publications ranging downward to a value of 0.33 for third or more distal author on a non-peer reviewed publication. On average, weighted publication rates were 76% of the total number of publications, with most individuals having a spread of peer-reviewed and non-peer reviewed articles with an associated spread of authorship position. Notably, the correlation between the weighted and non-weighted publication rates was extremely high ($r=0.99$), suggesting that the spread of publication type and authorship position was consistent across individuals. In other words, while the rate of publications may differ across individuals, the percentage of publications that were first author versus other author or peer-reviewed versus non peer-reviewed was similar across former trainees and the two scores can be used almost interchangeably.

The 92 graduates from this postdoctoral program have 1717 scientific publications with an average of 1.2 publications per graduate per year. Consistent with what is found in Family Medicine for individuals with at least 1 year of post-doctoral research training (10), forty-three percent of the former trainees have averaged at least one published paper per year since graduation. However, in contrast to what has been found in Family Medicine faculty (13), a cross-sectional analysis found no correlation between the publication rate and the number of years since graduation. For individuals who received additional research training beyond the institutional NRSA, such as an individual NRSA or a federally funded career development award, the percent of former trainees who average at least one publication per year increases to 85%. Improved outcome in individuals who receive independent research support is consistent with what has been reported in other specialties (14); however, it is unclear whether the individual training award contributes to a positive outcome or whether successfully competing for an individual training award reflects the same processes which are associated with increased productivity.

In a similar vein, successfully competing for an individual training award is the single greatest predictor of acting as a principal investigator on an NIH-funded R01 or similar grant; 41% of individuals who received an individual training award have later received an R01 as compared to 7% of those without a history of individual training awards. The relationship between longer durations since graduation and increased likelihood of successful principal investigator funding is explainable mostly from the lack of larger grant principal investigator funding for any graduate less than 6 years removed from the post-doctoral program. This delay in funding is presumably because of the standard recommendation to follow research training with lower budget grant mechanisms prior to attempting a larger grant application.

While the current program provides structured classes in grant writing and ethics, the program is primarily based on an apprenticeship model. Post-doctoral fellows with a PhD did not

significantly differ from those with an MD in either publication rate, in the percentage of graduates that authored 1 or more publications per year, or in the likelihood of eventually being the principal investigator on a successful larger federal grant. In other words, individuals who came to the program with a history of participation in a degree-granting research-training program (PhD or MD-PhD) had no greater success than those that didn't. This does not directly answer the question of whether degree-granting pathways should be a component of physician research training, but suggests that they may be of less importance. Interestingly, the number of publications prior to entering the post-doctoral program also had no correlation with post training program productivity. Earlier research exposure, as might occur in undergraduate or medical school programs, may influence who enters a research career, but appears to have less effect on the long-term success of that career.

There was no significant effect for any mentor variables—including funding, publication rate, and impact score (h-index)—on trainee publication rate or success at becoming a principal investigator on a larger federally-funded grant. No mentor had universally good or bad outcomes; for the eight mentors with 5 or more trainees over the life of the program, success rates (defined as the percentage of past trainees averaging one or more publications per year) ranged from 14–63%. Steiner and colleagues (11) have suggested that a mentor with a “national or international reputation” increases the likelihood of trainee success. The requirements for inclusion as faculty mentors in this post-doctoral program include a focus on senior faculty who have already demonstrated a history of a consistently high peer-reviewed publication rate and a history of external funding; thus, all of the faculty mentors in this program would meet the criteria of a national or international reputation. There may have been insufficient variability in the current sample to judge the effects of many mentor variables such as publication or funding histories.

A limitation of this analysis is the focus on outcomes of trainees from a single post-doctoral program. Several program variables have remained consistent over the duration of the program including (a) the administrative structure—the director of this specific program (M.R.) has been constant over this period; the faculty is multi-specialty, multi-departmental, and multi-institutional faculty; and the program has maintained its independence from departmental administration (minimizing outside pressure to promote non-research academic development or fill service needs); (b) the training model—the program uses an apprenticeship model, utilizes an ombudsman; includes both physician and non-physician trainees and mentors; and centers its common training around a twice monthly seminar where more junior researchers, including the post-doctoral fellows, present their research questions and planned methods and analyses for feedback from senior faculty; and (c) the focus of the program—the use of developmental psychobiology to study developmental psychopathology. While holding these variables constant improves the ability to assess individual differences, a limitation of this approach is an inability to assess the impact of these program variables on trainee outcome. Future work comparing this program to similar programs is necessary to address program variables.

Conclusions

This post-doctoral program has a 43% success rate at producing productive researchers, a productive researcher defined as an individual who published one or more articles per year after completing the post-doctoral program. The ability to obtain independent career development funding and the number of publications during the post-doctoral fellowship correlate with after post-doctoral publication rates; other factors such as gender, trainee terminal degree, and mentor publication rate (at least when it is above a minimal rate) appear to have less effect. Similar examination of additional post-doctoral programs will be necessary to examine the role of program variables on outcome.

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Figure 1.

Weighted versus non-weighted publication rates. Each publication by each former trainee was classified based on where in the authorship list the trainee presented (e.g. first-author, second author, etc) and whether the publication was peer-reviewed. Each publication was then weighted based on its classification, ranging from a weight of 1 (for peer-reviewed 1st-author publications) to 0.33 (for 3rd or more distal authorship and not being peer-reviewed). Weighted publication scores correlate strongly with unweighted publication rates ($r=.99$).

Table 1
Demographic information of trainees and faculty mentors

	Trainees	Mentors
Mean number of years since completion of the training program (trainees) or as a mentor (mentors)	12±7	12±8
# of publications per year *	1.2±1.4	4.5±2.5
Age at program entry (years)	34±6 (range 26–54)	
Percentage averaging 1 or more publications per year	43%	100%
Listed as a PI on a larger federally-funded grant (e.g. an NIH R01 or equivalent)	20%	60%
Listed as Key personnel on an R01 or equivalent	60%	94%
PI on any federal grant (including career development awards and NRSAs)	45%	80%
PI on any peer-reviewed competitive grant	53%	89%
Received an individual NRSA or career developmental award	37%	

* For trainees, number of publications per year is measured for years after completion of the post-doctoral program. For mentors, publication rates are computed only for the period that they are potential mentors within the institutional post-doctoral program.

Table 2

Average Relative Weight of publications by type (peer-reviewed, non-peer-reviewed) and authorship based on input from 20 faculty mentors of the institutional NRSA. Twenty post-doctoral faculty were asked to respond to the following, “Your department is considering hiring a new faculty member. You have been asked to comment on the research capabilities of the applicant. Based on the individual’s CV, how important would you say each of the following is in determining the applicant’s research capabilities?” Each of the categories was rated on a scale of 1 to 9; the respondents were asked to “Assume the scale is linear (that is if you think one item is twice as important and a second item, then the score should be twice as high).” For each respondent, the responses were normalized such that a first-author peer-reviewed paper was given a score of 1. The responses were then averaged across all the respondents to determine a weighting for each type of published manuscript.

Publication Category	Relative weight ^a	Range
Peer-reviewed, 1 st author	1.0	
Peer-reviewed, senior author	.78	.44–1.0
Editor of a book or special edition of a Journal	.78	.33–1.13
Peer-reviewed, 2 nd author	.70	.33–1.0
Non-peer-reviewed, 1 st author	.59	.22–1.0
Non-peer-reviewed, senior author	.51	.22–1.0
Peer-reviewed, other author	.47	.17–.78
Non-peer-reviewed, 2 nd author	.42	.11–1.0
Non-peer-reviewed, other author	.33	.11–.78

Table 3

Impact of Trainee and Mentor Variables on Trainee Lifetime Publication Rates. For continuous variables, the reported statistic is a Pearson correlation between the variable and the trainee's lifetime publication rate. For categorical variables, means and standard deviations are reported; the statistic is a student's t-test.

	Mean $\pm$ S.D.	Mean $\pm$ S.D.	Statistic
Individual variables			
Year of graduation			$r = 0.08$, $p = .44$
Age at entry into the program			$r = -.22$, $p = .03$
Number of publications prior to entering the post-doctoral program			$r = 0.11$, $p = .29$
Number of publication concurrent with post-doctoral training			$r = 0.30$, $p = .003$
Gender	Female (n=63) 1.1 $\pm$ 1.3	Male (n=29) 1.6 $\pm$ 1.5	$t = 1.7$; $p = .09$
Race/Ethnicity	Caucasian Non-Hispanic (n=85) 1.2 $\pm$ 1.4	Other (n=7) 2.1 $\pm$ 1.6	$T = 1.6$; $p = .11$
Terminal degree	PhD (n=68) 1.3 $\pm$ 1.4	Not a PhD (n=24) 1.2 $\pm$ 1.5	$t = 0.3$; $p = .76$
Received a funded Individual NRSA	Yes (n=28) 1.9 $\pm$ 1.7	No (n=64) 0.9 $\pm$ 0.2	$t = 2.7$; $p = .010$
Received a federally funded career development award (e.g. a K-Award)	Yes (n=13) 2.4 $\pm$ 1.5	No (n=79) 1.08 $\pm$ 1.30	$t = 3.5$; $p = .001$
Received a funded NRSA and/or career development award (e.g. a K-Award)	Yes (n=34) 2.0 $\pm$ 1.7	No (n=58) 0.8 $\pm$ 1.0	$t = 4.0$; $p < .001$
Mentor Variables			
Gender	Female (n=28) 1.2 $\pm$ 1.4	Male (n=64) 1.3 $\pm$ 1.4	$t = 0.45$; $p = .72$
Sponsor PhD?	Yes (n=39) 1.4 $\pm$ 1.5	No (n=53) 1.1 $\pm$ 1.3	$t = 1.0$; $p = .30$
Sponsor with a funded R01	No (n=20) 1.1 $\pm$ 1.0	Yes (n=72) 1.4 $\pm$ 1.6	$t = 0.5$; $p = .61$
Sponsor publication rate (number of publications per year)			$r = 0.08$; $p = .45$
Sponsor h-index			$r = -0.05$, $p = .64$